National Environmental Guidelines for Indoor Piggeries
Management (NEGIP-M)

Australian Pork Limited

2026

AUSTRALIAN Pork®

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Foreword

The Australian pork industry utilises many different production systems, with pigs housed in conventional sheds, deep litter systems, or outdoors. These systems operate under site-specific conditions. All environmental risks must be assessed and managed by producers regardless of the type or size of the piggery.

The Australian pork industry supports and encourages all piggeries to operate in a sustainable manner while meeting their regulatory requirements.

This first edition of the *National Environmental Guidelines for Indoor Piggeries – Management* (NEGIP-M) provides a national approach for the day-to-day environmental management of indoor piggeries, consolidating a range of existing materials into one single guide. The NEGIP-M are science-based guidelines, incorporating the latest research outcomes and regulatory changes.

The NEGIP-M can be read as a companion guide to the *National Environmental Guidelines for Indoor Piggeries – Siting and Design* (NEGIP-SD), which provide advice to help businesses to build well designed sites. Together, these two documents provide guidance across the lifespan of a piggery operation.

These guidelines highlight the industry's commitment to ensuring all piggeries operate in an environmentally sustainable manner. The NEGIP-M provide a clear framework for all stakeholders to help the pork industry comply with their general environmental duties, manage and mitigate environmental risks, and to achieve best practice environmental outcomes.

The realisation of the pork industry's environmental goals would not be possible without the support of all relevant stakeholders, and Australian Pork Limited (APL) has received considerable stakeholder support for the development of the NEGIP-M.

Margo Andrae
Chief Executive Officer
Australian Pork Limited

Abbreviations

ACCU	Australian Carbon Credit Unit
APL	Australian Pork Limited
APIQ✓®	Australian Pig Industry Quality Assurance Program
B0	biochemical methane potential
BMP	best management practices
BOD	biochemical oxygen demand
CAP	covered anaerobic pond
CEC	cation exchange capacity
CER	Clean Energy Regulator
CHMP	cultural heritage management plan
CHP	combined heat and power
C:N	carbon to nitrogen ratio
DB	dry basis
DM	dry matter
dS/m	deciSiemens per metre
EC	electrical conductivity
ECse	electrical conductivity of a saturated soil extract
EMP	environmental management plan
ERF	Emissions Reduction Fund
ESP	exchangeable sodium percentage
FS	fixed solids
GHG	greenhouse gases
GSF	gestation stall free
HDPE	high density polyethylene
HLA pond	heavily loaded anaerobic pond
HRT	hydraulic retention time
K	potassium
LDPE	low density polyethylene
m/s	metre(s) per second
m3	cubic metre
ML	megalitre
MSDS	material safety data sheet
NATA	National Association of Testing Authorities
N	nitrogen
N2O	nitrous oxide
NEGIP	*National Environmental Guidelines for Indoor Piggeries*
NEGROP	*National Environmental Guidelines for Rotational Outdoor Piggeries*

Abbreviations

NH_3	ammonia
NH_4 or NH_4^+	ammonium (an ionic chemical variant of NH_3)
NO_3 or NO_3^-	nitrate
NPI	National Pollutant Inventory
OU	odour unit
P	phosphorus
PBI	phosphorus buffering index
PIRMP	pollution incident response management plan
PO_4 or PO_4^{-3}	phosphate
PP	polypropylene
RAM	restricted animal material
RDS	rational design standard
SAR	sodium adsorption ratio
SEPS	sedimentation and evaporation pond system
SPU	standard pig unit
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TKP	total Kjeldahl phosphorus
TP	total phosphorus
TS	total solids
TWL	top water level
UPSS	underground petroleum storage system
UPVC	unplasticised polyvinyl chloride
VFS	vegetated filter strip
VS	volatile solids
yr	year

Scope

The NEGIP-M provide producers with information to manage environmental risks and optimise resource use. The guidelines are designed to assist producers to meet their general environmental duty (GED). The GED is a duty for a person to minimise so far as reasonably practicable risks of harm to human health and the environment. It requires the person to eliminate risks where practical, or reduce those risks as much as possible.

The NEGIP-M complement the NEGIP-SD, which are primarily for people planning new piggeries or expansions. The NEGIP-M addresses key aspects of everyday environmental management for conventional and deep litter piggeries.

They do not apply to rotational outdoor piggeries or other outdoor piggeries of any type.

These guidelines provide state of knowledge guidance for Australian indoor piggeries. However, legislative requirements override industry guidelines. Specific requirements pertaining to workplace health and safety, biosecurity, chemical storage and use and animal welfare are outside the scope of these guidelines, although producers will need to understand and observe their obligations in relation to these matters.

Overview

APL worked with industry, the community and government to develop the first edition of the *National Environmental Guidelines for Piggeries* released in 2004. These guidelines provided a general framework for managing environmental aspects associated with piggeries and were tailored to the circumstances and conditions most commonly encountered. The second edition was released in 2010. The third edition was released in 2018 and differed from previous editions in that it provided guidance only for indoor piggeries and was thus termed the *National Environmental Guidelines for Indoor Piggeries* (NEGIP). Its counterpart provided similar guidance for the outdoor sector.

This first edition of the NEGIP-M deals specifically with best-practice day-to-day environmental management of indoor piggeries to minimise the risk of harm to the environment and public health. It includes updates based on the latest research findings and changes in acceptable design, and incorporates recent regulatory developments and changes in approvals processes.

The NEGIP-M are made up of nine parts:

SECTIONS 1-20

National guidelines – advice on management of piggeries to minimise the risk of harm to the environment and human health

Appendix A

Pond & pad permeability specifications

Appendix B

Piggery manure and effluent reuse glovebox guide – methods for the safe reuse of piggery effluent and manure

Appendix C

Duty of care statement: manure and compost

Appendix D

Manure valuation pro-forma

Appendix E

Environmental risk assessment – methods for assessing the likelihood that the piggery will have an impact on the environment, allowing for preventative and mitigative acts to be taken

Appendix F

Complaints register – example of a complaints register that can be used to record and manage complaints

Appendix G

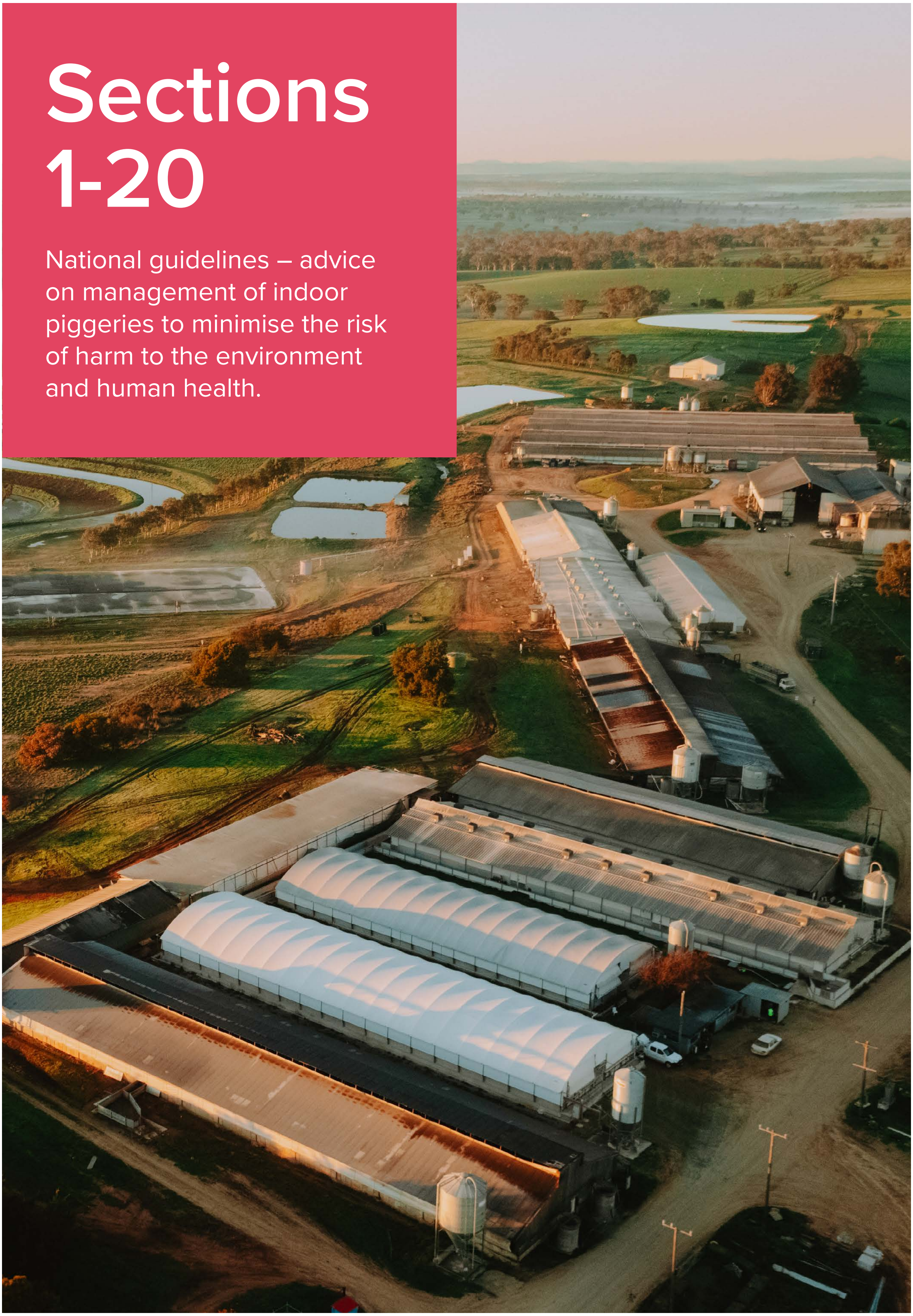
Sample collection – methods for collecting samples (e.g. water, soil, manure, compost, effluent and biogas) for analysis

Glossary

Definitions used in the NEGIP-M

Sections 1-20

National guidelines – advice on management of indoor piggeries to minimise the risk of harm to the environment and human health.



1 Introduction

The Australian pork industry is committed to continuously improving the sustainability of pork, while fostering a competitive industry. Over the last four decades, the industry has achieved significant gains in environmental performance and productivity, driven by improvements in feed efficiency and herd productivity, changes in housing and manure management practices, and improved water and energy efficiency. This has resulted in a 73% reduction in greenhouse gas (GHG) emissions intensity, a 58% reduction in fossil fuel use, and an 80% reduction in water consumption by the industry, which continues to work towards ongoing improvements in environmental performance.

The NEGIP-M are designed to support producers with day-to-day farm management. The NEGIP-M can also assist producers in demonstrating that they are meeting their GED. Decisions on which management practices will most effectively reduce risk in a given situation will depend on site characteristics, farm design, economics, and management practicalities. The NEGIP-M include a risk assessment methodology and different management strategies that could be adopted depending on circumstances. Many of the environmental issues encountered at piggeries are interlinked, and all aspects must be considered together to achieve the best overall environmental outcomes. The guidelines provide flexible operating guidance, allowing producers to select options that will address the environmental risks at their site.

The NEGIP-M address the circumstances most commonly encountered at piggeries. While they provide comprehensive management recommendations, alternative approaches may also assist producers to minimise their environmental risk and comply with their GED.

These guidelines represent the state of knowledge for the management of piggeries to minimise environmental risk. All producers should meet the environmental objectives and outcomes they contain.

2 Environmental risks

In Australia, all individuals and businesses are subject to a GED to prevent environmental harm. Good site selection and design reduces the inherent risk. However, all piggery operators must also operate their farms in a way that reduces the risk of harm to the environment and human health as far as reasonably practicable. Farms that are already managing their environmental risk may not need to make any changes to how they operate. However, piggery operators should endeavour to continuously improve, adopting relevant new techniques and technologies that reduce environmental risk and improve profitability.

The main aspects of the environment that may be affected by the operation of a piggery include:

- amenity including odour, dust, noise, light spill, flies and pests
- public health
- surface water quality and availability
- groundwater quality and availability
- native vegetation and habitat
- soils quality
- GHG emissions.

These guidelines cover each component of a piggery system and consider the potential risks posed to each aspect of the environment. Table 2.1 provides a summary of the most common potential environmental risks.

Table 2.1 Environmental risks for piggeries

Source	Community amenity	Public health	Surface water & groundwater	Soils
Feed	Feed processing and delivery → noise, dust Waste feed → odour if left	Waste feed → pests and vermin if left	Unlikely	Unlikely
Sheds	Unclean sheds → odour, dust Poor ventilation → odour, dust	Pests and vermin if unclean	Poor concrete integrity → **leaching** Earthen bases on deep litter shelters → leaching	Unlikely
Effluent system	Poor pond management → odour Unnecessary agitation of effluent → odour	Undersized, poor pond management or spills → **contamination** of water	Undersized or poorly managed sumps and ponds → surface water contamination Poorly lined sumps and ponds → groundwater contamination	Uncontrolled effluent (e.g. frequent spills) → soils contamination
Biogas system	Poor management (e.g. excessive loading rate) → odour	Poor design and maintenance → explosion or fire risk	As above	Unlikely

Source	Community amenity	Public health	Surface water & groundwater	Soils
Manure & compost	Wet manure → odour Dry manure → odour and dust Turning manure → odour and dust Poor management → fire and smoke	Handling or turning of dry manure → risk of **pathogen** transfer in aerosols Poor management → fire and smoke Increased pests and disease vectors	Poorly lined or un-**bunded** storage pads → groundwater or surface contamination	Uncontrolled **runoff** → soils contamination
Reuse	Irrigating effluent or spreading manure → risk of odour and dust, nuisance if spread under unsuitable conditions	Irrigating effluent or spreading manure → risk of pathogen transfer in aerosols if spread under unsuitable conditions	Poor practices may result in nutrient transfers to surface water and groundwater → reduction in water quality, and risks to ecosystems	Overapplication → excessive nutrients or nutrient imbalance in soil, sodicity, salinisation, acidification
Mortalities	Uncovered mortalities → odour Poorly managed composting → dust	Uncovered mortalities → increased pests and disease vectors Poorly managed composting → risk of pathogen transfer in aerosols	Poor practices resulting in nutrient transfers to surface water and groundwater → reduction in water quality and risks to ecosystems	Uncontrolled runoff → soils contamination
Traffic	Truck movements → Noise, dust and light spill	N/A	N/A	N/A

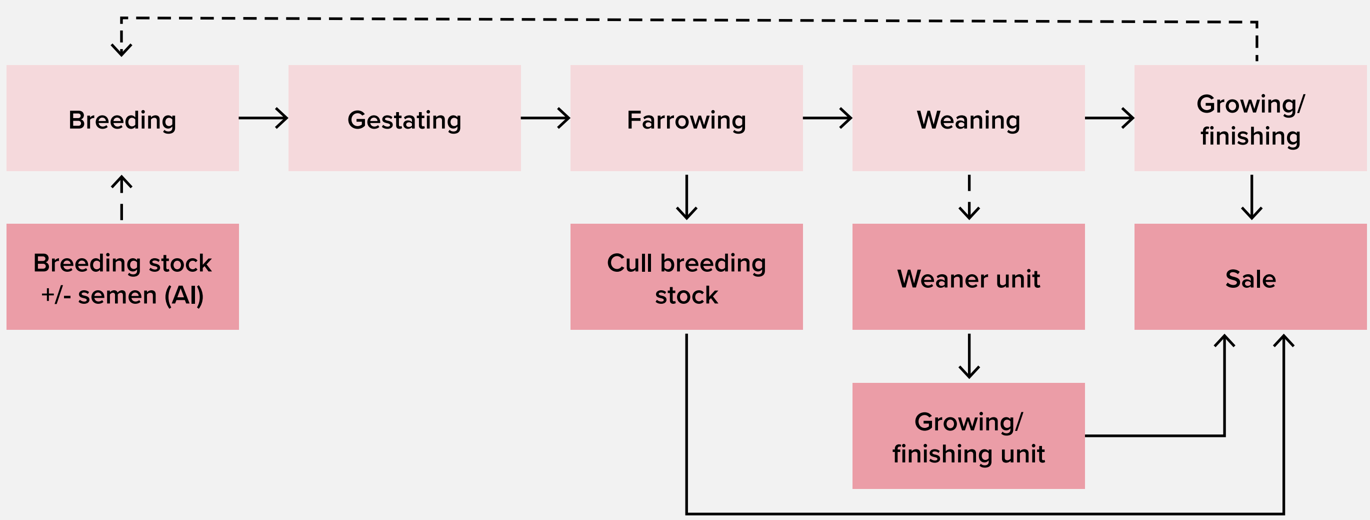


Figure 4.1 Summary of the most common pig production systems.

3 Environmental objectives

It is increasingly important for the pork industry to demonstrate environmental sustainability to ensure long-term consumer confidence in pork products.

Piggeries should be managed to:

- minimise the risk of amenity nuisance
- protect public health
- use water resources efficiently
- protect groundwater and surface waters from nutrient, biological or salt contamination
- protect or enhance native vegetation and habitats
- utilise inputs and resources efficiently and minimise wastes
- limit GHG emissions
- maintain or improve the quality of soils in reuse areas with beneficial reuse of effluent and manure
- maintain all buildings and facilities to meet current standards
- strive for continuous improvement in environmental performance.

Emerging technologies and management practices will provide producers with opportunities to continuously improve their environmental performance and enhance the reputation of the industry.

4 Indoor piggery systems

This section describes pig production and the different types of indoor systems. In an indoor piggery, the pigs are accommodated indoors in either conventional or deep litter housing.

4.1 Pig production

Pig production can be divided into three main production stages:

- **breeding**
- **weaning**
- **growing/finishing.**

The breeding stage includes the **boars**, **gilts**, gestating or dry sows, farrowing sows, **lactating sows** and **sucker pigs**.

The **dry sows** are between litters and awaiting either mating or confirmation of pregnancy and **gestation**. Sows are kept in **loose housing** from five days after mating until one week before they are ready to give birth. This can be in individual **pens** or **group housing,** providing each sow has freedom of movement, meaning she can turn around and extend her limbs. In some cases, bedding may be provided. Generally, boars are housed individually.

The **farrowing sows** are those that are due to farrow (give birth) within one week, and lactating sows with their **piglets** from farrowing to weaning. Generally, each sow and litter are kept in an individual **farrowing crate** with a **creep area** that is separated from the sow area by side rails. The creep area is needed to protect piglets from being crushed by their mother, and to provide the piglets with creep feed and additional heating.

Piglets are typically weaned at 3-4 weeks of age. **Weaner** pigs are generally aged up to 8-12 weeks. Newly weaned pigs must be housed in a warm, dry, draft-free environment.

Grower and **finisher** pigs are usually aged from 8-12 weeks up to 19-22 weeks of age but sometimes finisher pigs are older, depending on market requirements. These pigs are typically group-housed.

Individual production units can include one or more of the above pig life cycle stages, but generally fall into one of the following categories:

- **farrow-to-finish**: includes all stages
- **breeder**: breeding herd and suckers
- weaner
- grower/finisher.

Multi-site piggery systems geographically separate different production stages to improve biosecurity.

4.2 Conventional piggeries

Conventional sheds suit all classes of pigs since the shed environment, nutrition and husbandry can be tightly controlled. **Conventional piggeries** typically house pigs within steel or timber framed sheds. These are long sheds with solid roofing and walls. Sheds may be naturally ventilated using ridge vents, shutters or curtains, or mechanically ventilated with fans.

A fully environmentally controlled shed has enclosed walls with extraction fans and cooling pads, providing ventilation and climate control. Conventional sheds have a concrete base, usually with under-floor effluent collection pits or channels. The flooring is usually partly or fully slatted or perforated tiles, although old sheds may have solid flooring. Spilt feed, water and manure fall through the flooring into the underfloor channels or pits. These are regularly flushed or drained to remove effluent from the sheds.

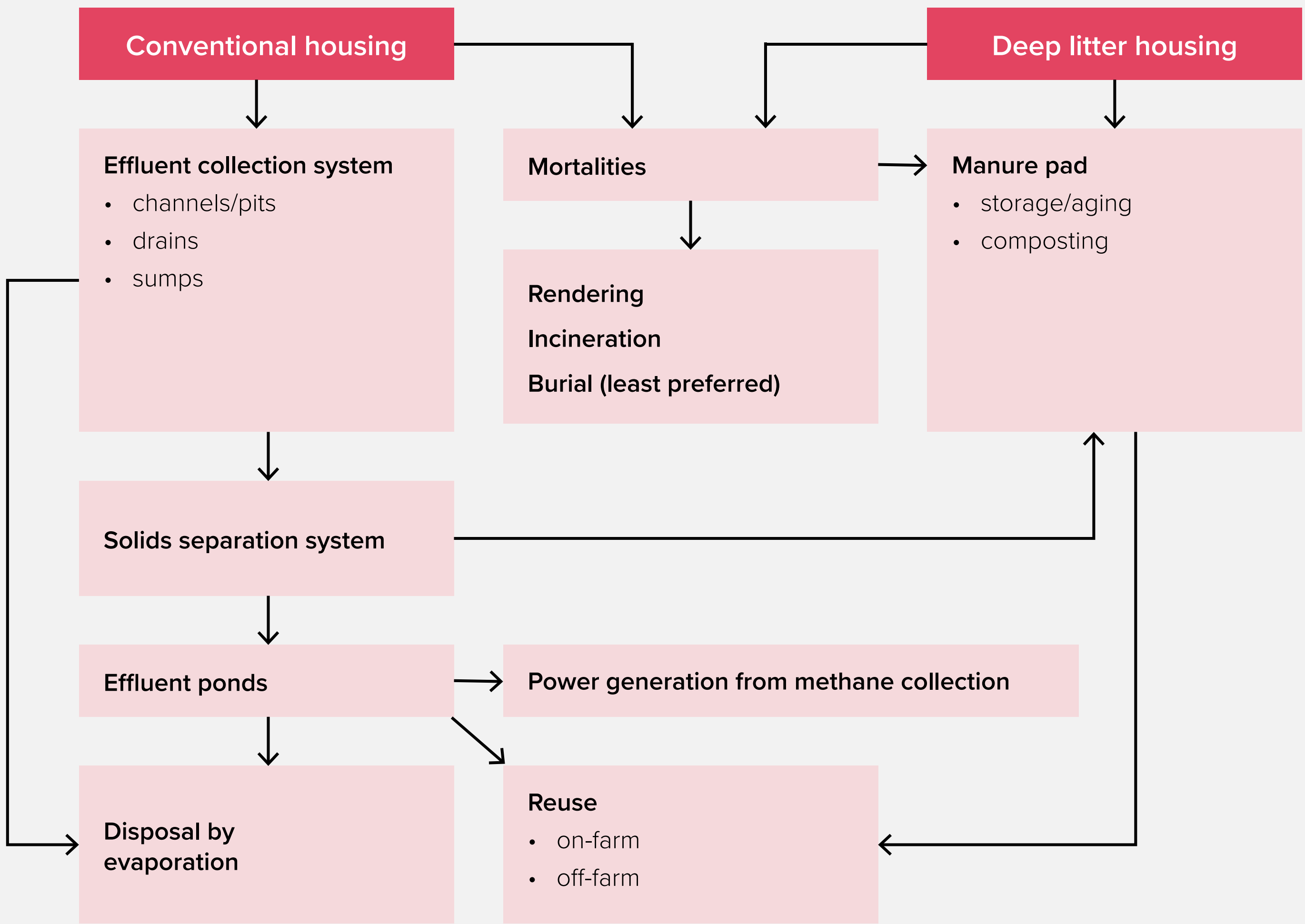
In some cases, solids are separated from the effluent stream after it exits the sheds. Most piggeries then use effluent ponds to treat the liquid component before the effluent is irrigated or evaporated. Some piggeries also collect biogas from effluent systems and use it for power generation. Solids separated from the liquid effluent anmay be immediately provided to off-site reusers or dried and either aged or composted on-site.

4.3 Deep litter piggeries

Deep litter shelters have a low capital cost compared with conventional sheds. They also use less energy and water, generally have a low carbon footprint and usually produce less odour than conventional sheds with effluent ponds. However, there is less control over the environment for the pigs. Deep litter shelters best suit weaners, growers/finishers and dry sows. Weaners and growers/finishers generally move through these sheds in batches (all-in, all-out).

Deep litter piggeries typically accommodate pigs in shelters made up of hooped metal frames covered in a waterproof fabric. However, skillion-roof sheds and converted conventional housing may also be used. The bases of the shelters are concrete or compacted earth. Straw, sawdust, rice hulls or similar loose material covers the floor, absorbing manure. The bedding is topped up as needed to ensure pigs have a dry area to lie on. The bedding is generally removed and replaced when the current batch of pigs is removed, or ideally at least once every seven weeks. **Spent bedding** may be immediately provided to off-site reusers or stored, aged or composted on-site. Figure 4.2 provides a summary of spent bedding management options.

Figure 4.2 Summary of manure management options



4.4 Standard pig units

Piggery approvals usually specify maximum operating capacity by pig numbers or **standard pig units** (SPU). SPU is a unit for defining piggery capacity by manure production. SPU multipliers for various pig classes are provided in the NEGIP-SD.

5 Resource efficiency

Using resources more efficiently, reducing the amount of effluent and manure generated, and carefully reusing effluent, manure and compost can reduce costs and minimise the risk of environmental impacts. Resource efficiency involves continuously applying an integrated, preventative strategy to all processes to ensure long-term sustainability, increase overall efficiency and reduce risks to the environment (including to humans).

Environmental outcome: Efficient use of resources, reducing manure and effluent production, and reuse and recycling of manure and effluent where appropriate.

The pork industry is continually working towards being a low emissions protein. Improving resource efficiency on-farm will support piggeries reduce their GHG emissions. The industry has already made significant improvements in this regard.

The following sections are based on APL research, including *Low Carbon Emission Roadmap for the Australian Pork Industry Manual* (Wiedemann et al. 2021), *Closing the Loop to Reduce Waste Roadmap for the Australian Pork Industry 2025 Manual* (McCormack et al. 2022), *Solar Tools and Self Auditing Checklists* (Barnes 2021) and *Understanding Energy in Pig Production* (APL 2018).

5.1 Herd productivity

Improving herd productivity reduces costs and improves economic performance by producing pigs more efficiently. This may also reduce the amount of manure for management and emissions to the environment per unit of pork produced. Improving herd productivity involves:

- increasing the number of pigs born alive, weaned and slaughtered per sow to optimise the number of pigs turned off per sow place
- increasing genetic improvements
- improving feed digestibility which reduces total feed usage and manure and nutrient excretion
- minimising feed wastage (feed is the largest input and expense for a piggery operation. Feed waste also contributes significantly to manure production and may influence GHG emissions. There is potential to reduce feed wastage in some systems by up to 50%)
- reducing feed conversion rates, (increasing the average daily gain in **growing pigs** and increasing turnoff weight at slaughter to use feed more efficiently. Additionally, for every 1% improvement in herd feed efficiency, a reduction in GHG emissions intensity by ~1% can be expected [Wiedemann et al. 2021])

In recent years, both the number of pigs slaughtered in Australia and sale weights have increased substantially despite sow numbers remaining relatively stable.

5.2 Energy

At many piggeries, energy is a significant production cost, particularly where heating, ventilation or feed milling occurs. Energy usage contributes to the GHG emissions of pork production.

To optimise energy efficiency, it is important to first understand a site's energy requirements and current usage. A site-specific energy audit is the best way to collect this data. APL's *Energy self-assessment checklist* (APL 2022) is designed to assist producers in assessing their power use and identifying ways to reduce it. If site usage exceeds expected requirements there is scope to reduce energy usage. This may necessitate monitoring power usage of various equipment to identify and rectify inefficiencies. Older equipment or technologies may be less efficient than newer or improved models.

The following are strategies with the potential to reduce energy use for heating:

- Consider the heating method used in farrowing crates. For example, a 250 W radiant bar uses 2.7 kWh/day for two crates, whereas a 175 W heat lamp uses 4.0 kWh/day for one crate.
- If using heat lamps, use the optimal heat lamp wattage to meet heating needs For example, swapping from a 175 W lamp to a 100 W lamp changes winter usage from 3.0 kWh/day to 1.9 kWh/day (no creep).
- Install creep covers to minimise heat loss and allow the use of low wattage heat lamps insulating and excluding drafts in sheds where possible to reduce heat loss, particularly during winter.
- Install thermostats in sheds to prevent excessive heating or cooling.
- Consider the power source and whether it is the most efficient for heating.

Ventilation is a significant source of energy use. To optimise efficiency:

- Select energy efficient equipment for the design air flow.
- Use automated ventilation on tunnel ventilated sheds, as these continuously adjust ventilation to match shed conditions.
- Minimise air leaks in sheds. Leaks can result in up to 20-25% more energy usage by ventilation systems and result in compromised temperature control. In sheds with leaks, warm air can leak from the shed in winter and be drawn in during summer. Measuring air pressure within the shed can assist in identifying ventilation issues.
- Regularly check, maintain and clean equipment, including fan belts and pulleys. Dirty shutters and fan blades can reduce fan efficiency by up to 30%, resulting in higher energy usage.

Pumping of water and effluent averages about 10% of the total energy requirement of pig farms but can be a much higher percentage at some farms. If pumping is important, consider:

- seeking advice on pump and pipeline selection and how to best set these up to optimise efficiency
- how well the pump performance matches the requirement (referring to the pump curve provided by the manufacturer)
- regularly servicing and maintaining pumps and filters to ensure optimal efficiency
- regularly checking for pipeline leaks (visually or by using a flow meter), as this can reduce pumping requirements and associated energy use.

Lighting is a relatively low contributor to site energy usage. However, it is usually also cheap and simple to address by replacing existing lighting with more energy efficient options.

Improving a site's power factor and managing peak loads can reduce power usage and cost. This can be done by:

- installing power factor correction capacitor equipment if the power factor is below 0.8 (requested from retailer or divide kW/KVA)
- considering voltage optimisation equipment if the voltage on site exceeds requirements
- making system modifications if the kW or kVA demand charge is a significant portion of your bill or largest motors are the direct on-line starter type:
  - swapping motor starters to star-delta or variable speed drives if motors run unloaded or variable (e.g. fans, water pumps and augers)
  - turning off equipment automatically (load shedding)
  - using embedded generation and load shedding together
  - installing energy management systems (automated energy control system).

Alternative energy sources may reduce reliance on primary mains power, reducing GHG emissions and sometimes costs. Consider:

- solar PV systems to reduce power costs and reliance on grid-based electricity
- biogas generation to reduce power and heating costs through energy generation and hot water recovery
- the use of co-digestion products to increase biogas production and energy replacement, and reduce materials going into landfill
- wind turbines
- solar thermal for warming water for use in heat pads
- batteries to store energy generated from renewable sources.

5.3 Water

Water is an increasingly scarce and expensive, resource. A water audit can identify opportunities to use water more efficiently without compromising production or cleanliness. Water usage can be reduced by:

- choosing water efficient equipment such as low wastage drinkers and high-pressure low-water use washers
- regularly inspecting and maintaining water supply systems (e.g. promptly repairing leaks)
- maintaining sheds for ease of cleaning
- positioning drinkers to minimise wastage from pigs rubbing against or playing with the drinker
- using recycled water where possible to reduce freshwater use (e.g. for shed cleaning).

Collecting roof runoff and keeping it separate from effluent may also provide an alternative source to pumped water.

5.4 Nutrients

Most nutrients entering a piggery come in as feed and bedding (where used). Feed nutrients not retained by the pigs are excreted in manure and require management and usually reuse. Good nutrient management involves:

- using feed nutrients efficiently, reducing costs and the amount of manure nutrients for management and has implications for GHG emissions
- preventing nutrients from entering waterways through spills from effluent ponds or poor reuse practices
- using nutrients beneficially as inputs to cropping or forage systems in place of synthetic fertilisers.

5.5 Waste

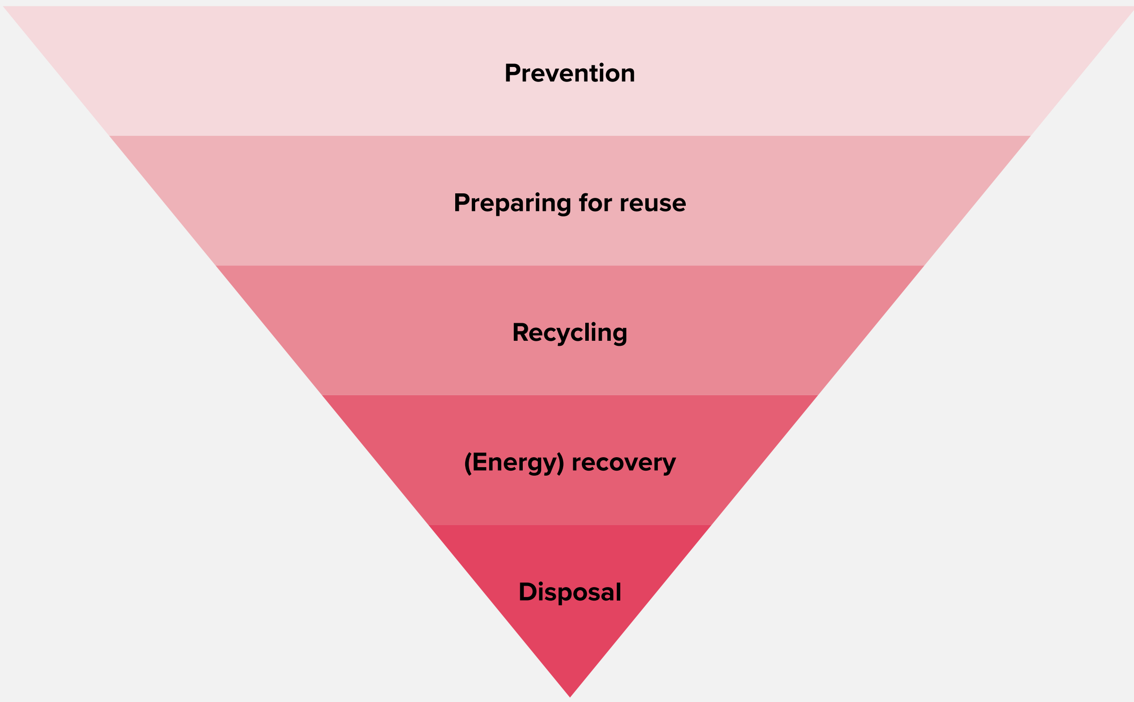
Avoiding, reducing, reusing and recycling wastes can help to reduce the carbon footprint, GHG emissions and cost of production for piggeries. The waste hierarchy provided in Figure 5.1 summarises the preferred order for managing wastes. This can be achieved by:

- using local ingredients to reduce emissions associated with transport
- using by-product feeds and human food waste in diets, utilising feeds that might otherwise go to landfill.

However, when evaluating opportunities to use alternative feedstuffs, it is important to note that some by-product feeds have particular usage, de-packaging, storage and shelf-life constraints.

It is illegal to feed **swill** to pigs. Refer to the APL fact sheet on **Swill Feeding** (APL 2022).

Figure 5.1 Waste hierarchy



Source: European Commission

Strategies for waste and resource reduction:

- Buy only what is needed and considering reuse and recycle opportunities for packaging, along with disposal costs for those materials.
- Use alternative feeds or food waste as part of the diet to reduce waste to landfill (swill must not be fed to pigs).
- Return containers and packaging to retailers where they can be reused.
- Separate recyclable materials (plastics, cardboard) into appropriate collection bins or storage areas (e.g. wire, scrap metal, concrete) until they can be recycled. It may be possible to recycle baling twine and pallet wrap if bundled. Plastics, including AI straws, may need to be bundled or packaged by plastic type for recycling.
- Eliminate single use eskies for transport of veterinary supplies or environmental samples by using thick cardboard boxes or leak-proof hard plastic tubs that can be returned at each collection time.
- Use effluent, manure and compost to replace synthetic fertiliser. On-site reuse can avoid waste associated with inputs (e.g. packaging) and minimise GHG emissions associated with production and transport of inorganic fertiliser.
- Use electronic data recording where practical to transition to paperless processes.

6 Feed management

Feed is the most expensive input for pig production and feed waste can also be a significant cost. It may also cause amenity nuisance and increase manure production and GHG emissions. Feed wastage in some systems can be reduced by up to 50% if appropriate strategies are employed. Feed milling and feed need to be properly managed to maintain quality, prevent spoilage and avoid attracting vermin.

6.1 Commodity and feed storage

Good storage of commodities and feed involves:

- storage that prevents access by vermin and pests that may cause feed losses and disease transfer risks, including covered bunkers, silos or bags
- appropriate storage of feedstuffs that may become odorous
- using impervious pits or tanks to store liquid and high moisture feedstuffs
- ensuring grain has a suitable moisture content for storage
- keeping feed dry to prevent spoilage as spoilt feed may require disposal and be odorous
- using liquid and high moisture feedstuffs while fresh. As these feedstuffs generally have a limited shelf-life, they may spoil quickly and create odour
- minimising wastage and promptly cleaning up spills that may become odorous and attract flies and vermin.

6.2 Feed milling and mixing

Managing feed milling and mixing involves:

- matching the nutritional requirements and feed particle size of each pig phase to optimise performance and minimise manure production
- optimising feed presentation. For example, changing from mash to either pellets or liquid feed significantly reduces wastage and dust
- ensuring use of local ingredients, by-product feeds, human food waste and synthetic amino acids (in place of protein meals in diets) where possible. This will both reduce waste and GHG emissions from manure
- minimising dust releases from milling and handling dry materials. Select and maintain equipment so that excessive fines are not produced. Enclosing equipment and using dust extraction equipment help to minimises dust releases
- preventing noise nuisance from milling and mixing by selecting and maintaining equipment and by managing the timing of noisy equipment. Consider operating noise levels when selecting equipment. Use suitable noise attenuation such as mufflers on machinery and insulation or enclosure to minimises noise
- minimising spills through careful selection and operation of equipment. Any spills should be promptly cleaned up so they don’t attract pests and vermin and cause odour.

6.3 Feeding systems

It is important to manage and monitor feeding infrastructure and feeding practices to minimise feed wastage and subsequent risks to the environment and amenity. Noise nuisance from pig squealing at feeding may also need to be managed.

Effects of feed wastage:

- Odour: undigested feed may spoil and become odorous, particularly when wet.
- GHG emissions: waste feed can significantly increase total GHG emissions.
- Vermin and pests: waste feed may attract rodents, birds, flies and other pests. These may be vectors for disease and may compromise health and biosecurity.
- Effluent pond performance: waste feed in effluent needs to be may add significantly to the load on the effluent system. If the pond system becomes overloaded as a result, this may compromise performance, increase sludge deposition and increase odour emissions.
- Nutrients for reuse: the greater the feed wastage percentage, the greater the amount of nutrients in the effluent or manure for reuse.

Examples of good management of feeders and feeding to reduce reduce wastage:

- Choose suitable feeders and use ad libitum or continuous feeding systems including liquid feeding, wet-dry feeders, or electronic systems that individually identify an animal and feed accordingly.
- Locate feeders away from waterers to avoid wetting of feed that may make it unpalatable.
- Optimise feeder gap adjustment by matching the opening to pig growth rate or sow needs. For example, for grower pigs, feed should cover just over half the pan but this should be reduced to one-quarter to one-third of the feeder pan for pigs >70 kg.
- Feed pigs in accordance with planned pig movements to avoid having feed left in an empty pen.
- Remove caked or spoilt feed from feeders on a regular basis.
- Put lids on feeders to exclude rodents. An adult rat will eat 15 g/day so if there is an average of 100 rats in a piggery, they will eat 0.5 t/yr (McCormack et al. 2022).
- Perform daily checks of feeding equipment (e.g. augers for over-run) and feeders to allow problems to be identified and rectified quickly.
- Present feed in a way that minimises wastage.

To minimise the risk of noise nuisance:

- Automatic feeding systems should present feed to all animals simultaneously to minimise squealing.
- Feeding should be scheduled to occur at times that are less likely to cause nuisance for neighbours.

7 Sheds

This section provides guidance for managing conventional sheds and deep litter housing.

7.1 Conventional sheds

Conventional sheds need to be managed to:

- maintain clean, low odour conditions
- maintain low dust conditions
- prevent uncontrolled effluent releases
- provide good ventilation to maintain air quality
- optimise water usage
- optimise energy usage
- minimise rodents and pests.

To maintain clean, low odour conditions within sheds:

- Maintain suitable stocking densities, as this affects manure deposition rates. Refer to the most recent edition of the *Model Code of Practice for the Welfare of Animals Pigs* (Primary Industries Standing Committee 2008) for guidance.
- Regularly remove spilt or waste feed.
- Manage manipulable or rootable material and bedding, where used, to prevent blockage of slatted or perforated flooring, pits or pipes.
- Clean floors regularly using a high-pressure, low-volume washer to optimise water efficiency.
- Consider using detergents and disinfectants in the cleaning process, using products that will not harm microorganisms in effluent ponds.
- Empty underfloor pits regularly to minimise odour and prevent uncontrolled effluent releases through the shed flooring.
- Consider recharging pits after emptying, by cleaning flooring, to cover new manure and prevent sticking to the pit base.
- Clean **flushing channels** by releasing a large volume of water (from a tank or tipping bucket) through the channel, usually at least daily. Clean water reduces odour but uses more water. Treated recycled effluent conserves fresh water but may increase odour.
- Clean **pull plug pits** by releasing the effluent every one to two weeks.
- Clean **static pits** by releasing the effluent every four to six weeks.

For both pull plugs and static pit systems, it is important to provide a regular flow of effluent into the pond system to provide food for the treatment microorganisms. This can be achieved by releasing some plugs every day to provide a relatively even flow. For biogas systems, releasing effluent more frequently will minimise methane losses and help to maximise biogas production.

Dusty piggeries are more odorous. To maintain low dust conditions within sheds:

- keep the sheds clean, including cooling pads and fans
- ensure adequate ventilation
- eliminate floor feeding
- use automated feeding equipment.

To prevent uncontrolled effluent releases:

- monitor effluent levels in pits
- ensure effluent pits are managed to prevent overflows by emptying at suitable intervals
- inspect emptied pits for any integrity issues.

Good natural or mechanical shed ventilation will help to:

- reduce odour and dust levels
- control air temperature and relative humidity
- remove excess heat and moisture
- dilute and remove airborne microorganisms
- maintain fresh air.

To maintain good air quality, manage shed ventilation by:

- opening the shutters or curtains on sheds to avoid large odour releases
- opening curtains gradually or by opening the curtains of different sheds in series
- using a thermostat to control shutter or curtain opening and fan usage
- managing tree growth as this may impede natural airflow
- regularly servicing and cleaning fans and thermostat sensors
- maintaining the shed walls, doors and curtains.

Water is used for pig drinking, shed cleaning and sometimes drip, spray or evaporative cooling. To optimise water use:

- inspect water lines, drinkers and cooling systems daily to ensure supply to the pigs, but also to detect and address leakage
- consider installing water monitoring equipment to help identify leaks or inefficiencies
- select water efficient equipment such as low wastage drinkers and high pressure-low water use washers
- maintain shed flooring and fixtures for ease of cleaning
- position drinkers to minimise wastage from pigs rubbing against or playing with the drinker
- consider using recycled water for effluent channel flushing
- use collected roof runoff as an alternative source to pumped water
- conduct a water audit to identify opportunities to reduce water use without compromising production or cleanliness.

Within sheds, energy may be used for:

- ventilation (mechanical)
- heating and cooling
- lighting
- feed delivery
- water distribution.

For detailed guidance on optimising energy efficiency, refer to Section 5.2.

To minimise rodents and pests:

- keep the sheds clean, particularly by promptly cleaning up feed spills and wastage
- regularly inspect sheds to identify and remove entry points and hiding places for vermin and birds
- use target-specific, environmentally safe baits around exterior walls and doors (pigs must not have access to baits because this can result in a breach of chemical residue limits affecting future market access. The ***Australian Pork Industry Rodenticide Stewardship Plan*** [APL 2021] provides further information)
- develop a pest monitoring program to assess pest levels and initiate controls if these become an issue.

7.2 Deep litter housing

Deep litter housing needs to be managed to:

- maintain clean, low odour conditions
- provide good ventilation
- optimise water usage
- minimise rodent and pests.

To minimise odour, it is important to:

- ensure suitable stocking densities are maintained, as this affects manure deposition rates (refer to the most recent edition of the *Model Code of Practice for the Welfare of Animals Pigs* [Primary Industries Standing Committee 2008] for guidance)
- use sufficient quantities of bedding (0.5-1 kg/SPU/day on average)
- change the bedding regularly
- top up bedding in dunging areas as needed to maintain dry, low odour conditions
- promptly address any water leaks as these will wet the bedding
- maintain good ventilation.

Good ventilation helps to maintain air quality and dry bedding. To promote good ventilation:

- open side curtains or blinds
- managing tree growth as this may impede natural airflow.

Water is used for pig drinking, sometimes for shed cleaning and sometimes drip or spray cooling.

To optimise water use:

- inspect water lines, drinkers and any spray or drip cooling systems daily to ensure supply to the pigs but also to detect and address leakages
- consider installing water monitoring equipment which helps to identify leaks or inefficiencies
- select water efficient equipment such as low wastage drinkers and high pressure-low water use washers (if used)
- position drinkers to minimise wastage from pigs rubbing against or playing with the drinker
- use collected roof runoff as an alternative source to pumped water
- conduct a water audit to identify opportunities to reduce water use without compromising production or cleanliness.

To minimise rodents and pests:

- keep the sheds clean, particularly by promptly cleaning up feed spills and wastage
- regularly inspect sheds to identify and remove entry points and hiding places for vermin and birds
- use target-specific, environmentally safe baits around exterior walls and doors. Pigs must not have access to baits because this can result in a breach of chemical residue limits affecting future market access. The *Australian Pork Industry Rodenticide Stewardship Plan* (APL 2021) provides further information
- develop a pest monitoring program to assess pest levels and initiate controls if these become an issue.

8 Purpose of effluent and manure management

Effluent and manure need to be regularly removed from sheds to maintain hygienic, low odour conditions. Once effluent and manure are removed from the shed, they require management and storage before they are reused in farming systems.

Effluent management usually involves treatment in a pond system and may include a solids stage beforehand. Manure management usually involves aging or composting.

The purpose of effluent management and storage is to:

- handle the effluent and manure steams to prevent amenity nuisance and uncontrolled releases to the environment
- stabilise the effluent and manure to reduce odour and manage nutrients for reuse
- remove moisture from wet manure which may reduce transport and spreading costs
- improve handling properties of manure for reuse
- store effluent or manure to enable reuse at practical and beneficial times for crops
- avoid the need to spread effluent or manure at times when nutrient losses to the environment are likely.

Some producers may also be able to collect biogas as a by-product of effluent treatment using a covered anaerobic pond (CAPs) or biodigesters. These systems reduce GHG emissions, can be used to generate heat and power and may be able to provide an alternative income stream through carbon crediting programs such as the Emissions Reduction Fund (ERF) or Large-scale Generation Certificate (LGC).

Under management and storage:

- the organic matter and nitrogen content of the effluent or manure generally reduce
- moisture is usually removed from solid manure
- effluent may be partitioned into separated solids, liquid and sludge, which all require different reuse strategies.

9 Managing liquid effluent

The effluent from conventional pig sheds can contain:

- manure
- waste feed
- water used for cleaning and spilt by pigs
- detergents and disinfectants
- traces of veterinary chemicals.

The manure and waste feed contribute the organic matter, most of the nutrients and some salts. Water can contribute a significant salt load.

Management of effluent involves:

- collection and conveyance
- solids separation (sometimes)
- treatment, usually in a pond-based system but sometimes in a biodigester
- storage
- reuse by land-irrigation (see Section 11) or evaporation with no reuse.

9.1 Effluent collection and conveyance

Effluent needs to be regularly removed from sheds to maintain hygienic, low odour conditions.

Effluent removal from the sheds usually involves:

- flushing channels
- pull plug pits
- static pits
- a combination.

Scraper systems are used by a small number of piggeries. Some very old piggeries have solid flooring that is hosed out.

Table 9.1 Effluent collection options

Type	Description	Cleaning frequency	Water volume	Effectiveness
Flushing channels	Concrete channels beneath slatted flooring*, cleaned by quickly releasing large volume of water from tank or tipping buckets	Daily to three times a day	High but recycled, treated effluent can make up part or all flush volume Produce relatively large volume of effluent	Good if system is well designed
Pull plugs	Pits beneath slatted flooring*, effluent drains through central gravity release pipe when plugs removed	Typically every 1-2 weeks but can be longer	Relatively low, mostly hosing washdown water#	Good if system is well designed
Static pits	Concrete pits (often with 1% slope) beneath slatted flooring*, effluent released by opening sluice gate	Up to 6 times per week	Relatively low, mostly hosing washdown water#	Reasonable if is system well designed
Solid flooring, open drains (old sheds)	Manure is hosed into open drains to sumps or ponds	Varies but daily recommended	Low	Poor – floors and pigs are often dirty
Manure scrapers	Concrete pits beneath slatted flooring*, metal scraper removes manure from channel	Varies but recommended daily	Low	Fair – some residual manure in pits that may increase shed odour. Ongoing cable maintenance

* Manure, waste feed, spilt drinking water and shed hosing and pressure washing water falls through the slatted flooring into the channels or pits.

after emptying, the pit may be partly refilled (e.g. 5 cm) to prevent manure from sticking to the floor.

A regular manure inflow to the primary pond or biodigester is necessary maintain the treatment micro-organisms. Large or irregular inflows can upset the balance of microorganisms, causing excessive acid production and incomplete anaerobic digestion.

Managing large flow volumes can also be challenging, with a risk of spills from drains and sumps if too much effluent needs to be managed at once. Channels are usually emptied at least once a day which provides for a consistent inflow, particularly if they are flushed in series throughout the day. Pits are generally emptied less frequently but emptying these in series at regular intervals will help to keep the flow of manure into the primary pond uniform.

Manure breakdown occurs when effluent is stored in pits. For biogas systems, minimising the time the effluent is stored in pits maximises methane production. Effluent should be released from pits at least weekly for these systems.

Effluent collection infrastructure should be regularly inspected for signs of deterioration or maintenance requirements. Any problems should be promptly repaired.

9.1.1 Pipes or drains ex-sheds

Impervious pipes or drains convey effluent from sheds to sumps or effluent ponds. Pipes at least 150 mm in diameter are recommended. Pipes should be regularly inspected during flushing and pit emptying to identify blockages. These can be cleared using an air compressor. Drains should be regularly checked for accumulated solids that may compromise capacity. These need to be promptly removed.

Pipes and drains need to be regularly inspected during use and when empty to identify any leaks or damage for repair.

9.1.2 Sumps

At some piggeries, effluent is directed from the flush channels or pits into a sump, allowing the flow rate to a mechanical solids separator to be managed. It also allows the effluent to be pumped up to an elevated solids separator or effluent pond.

Generally, the sump is an in-ground tank sized to store at least one day's effluent production. A screen on the inlet channel removes large materials that could block pumps. A stirrer or agitator in the sump keeps solids in solution so that they are pumped into the pond rather than settling in the sump. As this agitation may increase odour, aggressive agitation should be avoided. Stormwater runoff from surrounding areas must be excluded from sumps.

The positioning of inlets to sumps is important. Dropping effluent into sumps from above the water level can increase odour. Inlets should be at or under water level.

9.1.3 Separating solids from effluent

Solids may be separated from the effluent before it is directed into a pond or biogas system, reducing the solids load for treatment. The benefits of solids separation may include:

- a reduction in in the organic load to the pond, reducing the required treatment and sludge storage capacity so less frequent desludging is required. However, it may also affect methane production, a consideration for biogas systems
- enabling smaller pond surface areas and potentially reducing odour emissions
- improving biological degradation in the pond by removing solids that are difficult to break down (e.g. barley husks)
- removal of large particles that may block irrigation equipment or form a crust in a covered anaerobic pond (CAP) that will be difficult to remove
- a smaller effluent reuse area, although the nutrients in the removed solids will still need to be sustainably reused.

Simple screens, presses and settling devices are the most common solids separation mechanisms used in Australian piggeries. More advanced and effective solids separation systems are available, but these are more expensive and require specialist operating expertise. Table 9.2 presents data on the performance and relative capital and operating cost range, while Figure 9.1 provides a summary of the properties of solids removal systems. Management of separated solids is detailed in Section 10.1.1.

9.1.4 Screens

Screens separate solids from liquid on the basis of particle size and shape. The screen catches the larger solids while the liquid passes through the screen and is directed to a sump, effluent pond or biodigester. Screen efficiency depends upon:

- mesh size
- area of the screen
- flow rate
- solids percentage of the effluent.

The stationary run-down screen is the most common screen, sometimes called a stationary incline screen or static screen.

A vibrating screen is similar to a **run-down screen** except that the screen vibrates rapidly. Because of the moving parts, these screens have higher maintenance and power requirements than stationary run-down screens. Although the vibrating helps to prevent blocking, regular cleaning is still needed.

A rotating or centrifugal screen is a spinning cylindrical screen. The effluent is applied to the inner surface of the screen, which resembles the inside of a clothes drier. The solids slide down the inside surface of the screen.

With all screens, a biomass film will rapidly develop across the surface of the screen with use, blinding or blocking the screen. This significantly reduces its usefulness. While relatively fine screens (e.g. 1 mm) generally remove more solids, they also block more quickly, reducing effectiveness. Regular and frequent cleaning, usually with a steel brush is needed.

9.1.5 Presses

Most presses used in Australian piggeries are **screw presses**. Belt and rotating screen presses are also alternatives. A screw press consists of a cylindrical screen with a screw-conveyor in the centre. The conveyor presses the solids against a screen to remove moisture. The conveyor also moves the solids through the press to a collection area.

Screw press separators remove a greater proportion of solids and produce drier, more manageable material than screens.

Screw presses should be regularly inspected and maintained. The screen should be cleaned frequently by pressure washing.

9.1.6 Settling basins and SEPS

A settling basin or **sedimentation and evaporation pond system (SEPS)** separates solids from effluent using the density differences between the solids and the liquid, and gravity. Settling can remove a greater proportion of solids than screens and presses, but requires more management. There is potential for significant odours if settling devices are not regularly cleaned. Multiple sedimentation basins or trafficable facilities that can be used in series are recommended.

9.1.7 Settling basins

Settling basins should be shallow, long, wide and free draining. They should be designed and managed to detain the effluent for at least 20-30 minutes. The base and sides need to be impermeable. Concreting the floor and walls makes these trafficable and easy to clean, but adds to the cost. Stormwater needs to be excluded from settling basins.

9.1.8 Sedimentation and evaporation pond systems

SEPS typically consist of two or three parallel earthen channels with an associated effluent pond. The channels are long, narrow, shallow and trafficable, and each is used independently. When one is filling, the others are drying.

Effluent moves slowly through the active channel, allowing solids to drop out while the liquid drains into the pond. When a channel fills, the effluent is redirected to a different channel to allow the solids in the filled channel to dry. Although the shallow depth promotes quick drying, a surface crust often forms and inhibits evaporation. Breaking this crust, for example by dragging tyres attached to chains with a tractor, improves drying.

When the sludge becomes sufficiently dry, it can be removed using a blade, front-end loader and truck.

9.1.9 Other solids separators

Other solids separators that have been used or demonstrated at Australian piggeries include:

- baleen filters
- cyclones
- centrifuges
- dissolved air flotation (DAF)
- tangential flow separators (TFS)
- Z filters.

Table 9.2 Summary of performance of a range of solids separation systems

Separation system	Indicative capital cost range	Indicative operating cost range	Solids dryness	Maintenance and supervision	Degree of operator training	Pre-treatment/ chemicals needed	Removal efficiency (% of total solids [TS])	
							1.2% TS	3.1% TS
Sedimentation basin	Low-medium	Medium to high	Low	Medium	Low	Nil	50	50
Sedimentation and evaporation ponds	Low	Low	Low	Low	Low	Nil	60	60
Static rundown screen	Medium	Low-medium	Low	Medium	Low	Nil	20	20
Vibrating screen	Medium	Low-medium	Medium	Medium	Low	Nil	10	20
Rotating screen	Medium	Low-medium	Medium	Medium	Low	Nil	10	15
Baleen filter screen	Medium-high	Low-medium to medium	Very low	Low	Low	Nil	30	30
Screw press separators	Medium-high	Low	High	Low	Low	Nil	10	20
Belt presses	Medium-high	Medium	High	High	High	Nil	10	20
Hydrocyclones	Medium	Low	Low	Low	Low	Coarse screen	25	25
Centrifuge/ decanters	High	Medium to high	High	Low	Medium	Coarse screen	20	30
Dissolved air flotation	High	Medium to high	Low	Medium-high	Medium-high	Screen and polymer	70	70
Tangential flow Separators	High	High	Low-medium	Medium	Medium	Screw press	50	50
Z filter*	High	High	High	Medium	Medium	Polymer	58*	58*

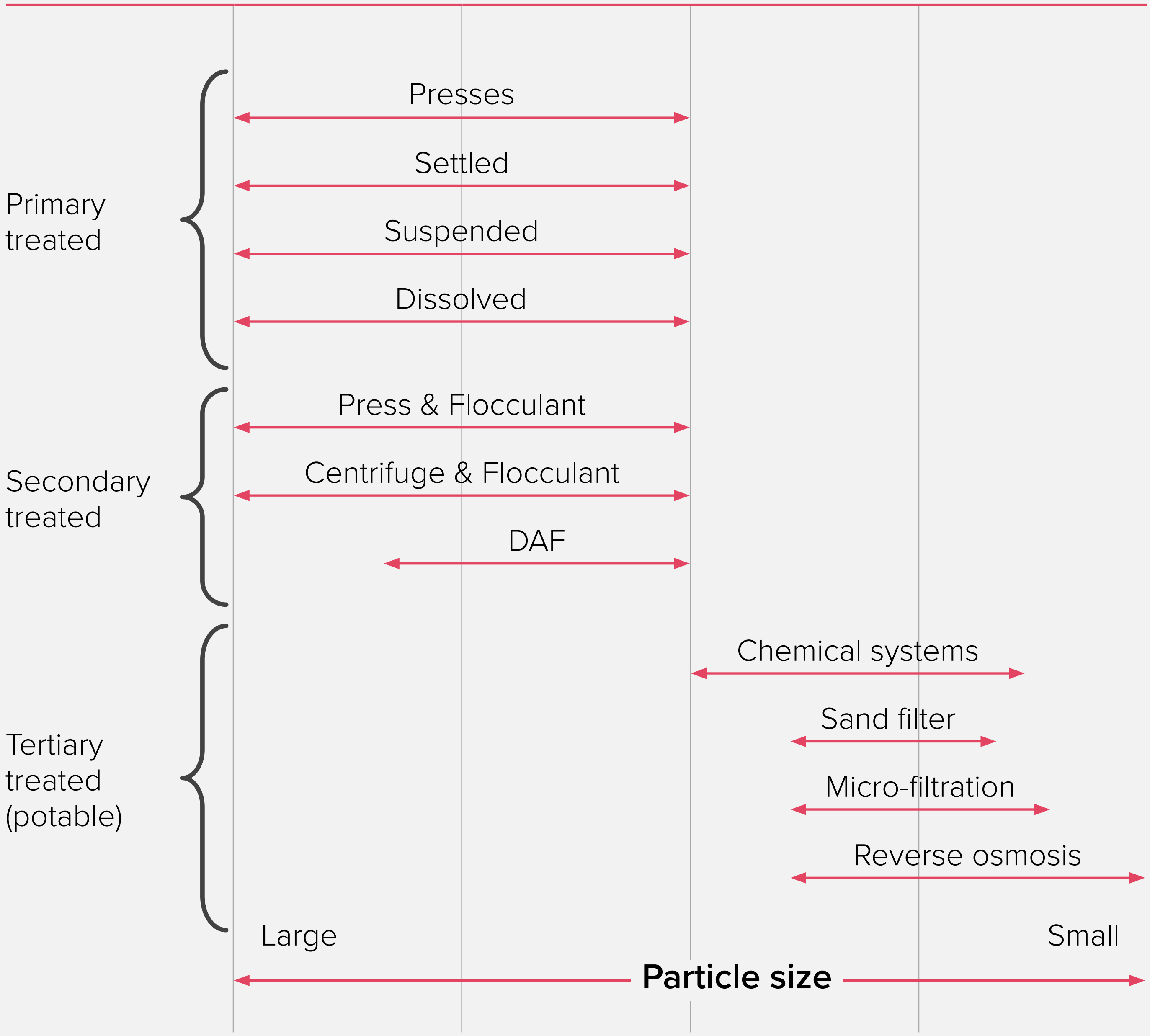
Note: A TS content of 3.1% is quite high for piggery effluent and represents a scenario where low flushing water volumes are used. A TS content of 1.2% is fairly typical for piggery effluent where high flushing water volumes are used. Generally, a larger amount of solids leads to a lower operating cost/ML of effluent.

Based on Watts et al. (2002b), except Z filter.

*Data for Z filter is from Payne (2014) and found an average TS removal rate of 58% for effluent with a TS concentration of 1.3-2.4%.

Figure 9.1 Summary of piggery solids removal systems (Watts et al. 2002b)

Piggery Effluent	Floating	Settled	Suspended	Dissolved
N	1-10%	15-30%	10-20%	50-70%
P	1-10%	50-70%	20-30%	10-20%
VS	1-10%	55-75%	5-15%	10-20%
TS	1-10%	55-75%	5-15%	15-25%



9.2 Effluent ponds

9.2.1 How effluent ponds work

At most piggeries, effluent is treated in a primary anaerobic pond, where most sludge accumulates. Secondary treatment ponds may follow. The final pond will either be a holding pond from which effluent is drawn for irrigation or an evaporation basin. **PigBal** is the industry tool for estimating the treatment capacity of effluent ponds. **WatBal** is the industry tool for sizing the wet weather capacity of effluent ponds.

In effluent ponds, organic matter in effluent is broken down by microorganisms including bacteria, enzymes, and fungi. There is a vast range of microorganisms that can survive in very different environments.

Primary groupings of microorganisms:

- Anaerobic: thrive in conditions where there is no oxygen
- Aerobic: need oxygen to survive
- Facultative: can function in the presence or absence of oxygen

Primary effluent ponds at piggeries are anaerobic due to the high organic matter loading content of the effluent. Anaerobic decomposition is a three-stage process, involving different microbial groups in each stage:

1. Enzymes break large particles down into soluble molecules.
2. These molecules are digested to yield acetate, hydrogen and carbon dioxide.
3. Methanogens convert these products into low odour methane. The methane formers are sensitive to pH levels below 6.8. They also grow very slowly, meaning they are unable to quickly respond to sudden changes in organic matter load that result in acidic conditions.

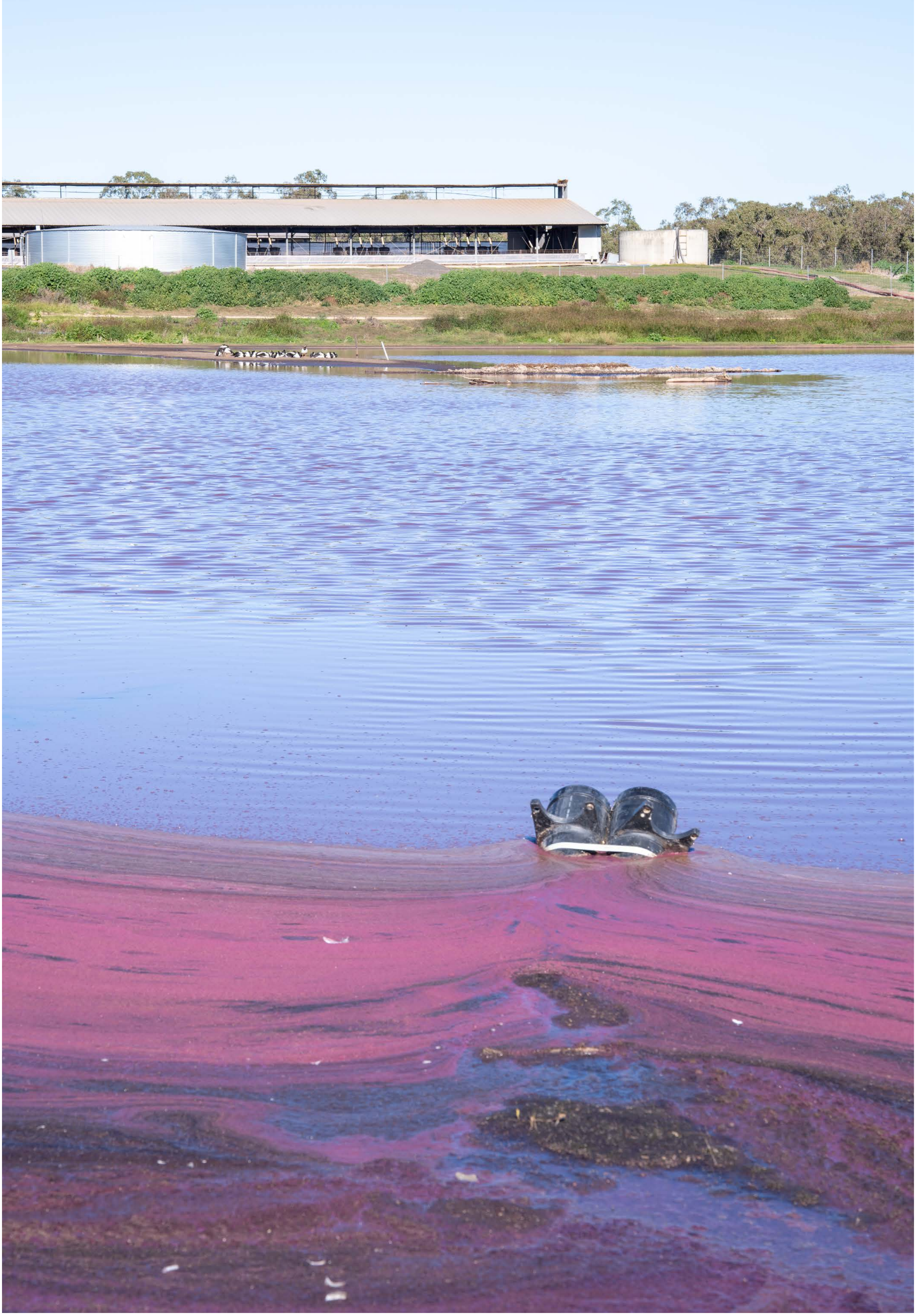
If organic matter is fully broken down anaerobically, the end products are mainly low odour methane (CH4) and carbon dioxide (CO^2) along with smaller amounts of other (sometimes odorous) gases. If the third stage does not proceed, the acidic odorous volatile compounds produced in the second stage are released. For this reason, it is important to design and manage ponds to ensure complete anaerobic digestion occurs.

Most anaerobic ponds at piggeries are uncovered, allowing the gases produced during organic matter digestion to escape into the atmosphere. However, methane is both a potential energy source and a GHG. Methane has about 28 times the global warming potential (GWP) of carbon dioxide.

Covered anaerobic ponds (CAPs) and flaring the released gases significantly reduces both odour and GHGs. Biogas systems that use the gases as a source of heat or energy are addressed in Section 9.3.

Secondary ponds may be anaerobic or facultative.

Scraper systems are used by a small number of piggeries. Some very old piggeries have solid flooring that is hosed out.



9.2.2 Anaerobic ponds

Anaerobic ponds have very low dissolved oxygen levels due to their high VS loading rate. These ponds vary in depth depending on site constraints (e.g. water depth of 2 m+). Deeper ponds are preferred as they have a smaller surface area (odour emissions) for the same volume. Anaerobic ponds are effective in reducing the organic matter content of effluent, separating some 60-90% of organic matter from the liquid. Some of the organic matter leaves as gases and some is deposited in the sludge.

Most conventional piggeries in Australia use uncovered anaerobic ponds to reduce the organic strength of effluent. They are relatively cheap to build, can manage high strength effluent and have some tolerance of variations in the quality and composition of effluent streams. However, they can be odorous, particularly if poorly managed.

Anaerobic ponds can be conventional in design (large and relatively lightly loaded) or heavily loaded. In both cases their purpose is to:

- contain and store effluent
- remove organic matter from the effluent
- allocate enough space for sludge storage between desludging
- ensure that effluent and sludge can be removed from the pond for reuse as needed.

The positioning of inlets to ponds is important. Dropping effluent into ponds from above the water level can increase odour. Inlets should be at or under water level.

9.2.2.1 Conventional anaerobic ponds

Traditionally, Australian piggery anaerobic ponds are large, with the treatment capacity sized according to the rational design standard (RDS) proposed by Barth (1985). Conventional anaerobic ponds:

- usually function effectively providing sludge is not encroaching on the treatment capacity
- can take up a significant land area
- may release nuisance odours, particularly if poorly managed
- may be expensive to build, line and cover (if this becomes necessary)
- generally require infrequent desludging (once every 5-10 years)
- can be difficult to de-sludge because of their dimensions and depth.

9.2.2.2 Heavily loaded anaerobic ponds

Heavily loaded anaerobic ponds use a significantly higher organic matter loading rate for the treatment capacity. They offer the following benefits over conventional anaerobic ponds:

- lower construction costs
- they may be easier and cheaper to de-sludge
- less odour due to reduced surface area and higher likelihood of a crust forming over the pond surface
- they are easier and cheaper to cover if this becomes necessary or desirable.

9.2.2.3 Covering anaerobic ponds for odour and GHG emissions

Since most odour comes from the anaerobic pond, an impermeable pond cover is an effective way to reduce overall piggery odour. This would usually be made from an impermeable membrane such as low-density polyethylene or polypropylene. A flare must be fitted to burn the gases released by manure breakdown. For covered anaerobic ponds (CAPs) with biogas collection, refer to Section 9.3.

Effluent management is the biggest source of GHG emissions from a piggery. Permeable pond covers may reduce GHG emissions from anaerobic ponds by 50-90%. These covers typically consist of supported straw and synthetic geofabric. They can be quickly, cheaply and easily installed. Permeable pond covers have not been widely adopted in Australian piggeries due to the maintenance needed to maintain an effective cover (due to pond cover break-down). There are government programs that support the installation of permeable pond covers, including through the Emissions Reduction Fund (EMF), and these can reduce the cost considerably.

Figure 9.2 Unheated and unmixed covered anaerobic pond

9.2.2.4 Secondary ponds

Secondary ponds are either anaerobic (see Section 9.2.2) or facultative. **Facultative ponds**:

- combine the features of both anaerobic and aerobic lagoons
- function aerobically on the surface layer while the bottom works anaerobically
- are relatively lightly loaded and quite shallow (typically up to 2.5-3 m deep)
- provide further treatment after the anaerobic process.

Aerators can be used to add oxygen to the surface although these may increase odour emissions, are expensive to run and are rarely necessary.

Aerobic ponds are commonly used in sewage treatment. These are very lightly loaded and shallow (1-1.5 m deep) to allow for light penetration and oxygen transfer. Even after going through anaerobic and facultative processes, piggery effluent is too strong to maintain an aerobic environment throughout the pond. Even mechanically aerated “aerobic” ponds are likely to be facultative due to the loading rate.

Aggressive agitation of ponds should be avoided. This may increase odour emissions by increasing the odour-emitting surface area and aerosol creation.

9.2.2.5 Holding ponds

Holding ponds provide wet weather storage and hold treated effluent ahead of reuse. They must to be managed to have sufficient spare capacity to store rainfall from wet weather events. Holding ponds should be managed to spill less than once every 10 years (on average).

9.2.2.6 Evaporative basins

Evaporation basins can provide for effluent disposal in dry regions where evaporation rates greatly exceed rainfall. Ideally some water should be retained in the base of clay-lined evaporation ponds to avoid drying out and cracking.

9.2.3 Maintaining effluent ponds

9.2.3.1 Managing anaerobic ponds

Anaerobic ponds need careful management to establish and maintain a healthy population of the microorganisms used to degrade the manure. Consistent conditions within the pond helps to sustain the desirable microbial populations. This helps to ensure complete anaerobic digestion, avoiding the odorous conditions that result from incomplete break-down (see Section 9.2.1). This can be achieved by:

- helping to establish a suitable microbial population in new ponds more quickly by partially filling these with effluent or a small amount of fresh sludge from a nearby pond or another piggery with the same health status (this may not always be practical)
- ensuring frequent and regular effluent inflows that provide a constant food supply for the microorganisms
- selecting cleaning products and pharmaceuticals that won't inhibit microbial activity
- maintaining a generous liquid volume in the pond to help buffer against uneven effluent loads or accidental entry of chemicals that might harm the microorganisms
- maintaining sufficient treatment capacity in the pond by regularly desludging (see Section 9.2.3.4).

A pond that is generating excessive odour may not be functioning correctly and the reasons need to be investigated. As a starting point, some basic testing is recommended, including:

- **total solids** (TS) of raw effluent and treated effluent
- **volatile solids** (VS) of raw effluent and treated effluent
- pH
- **salinity** (measured as **total dissolved solids** [TDS] or electrical conductivity [EC]).

A **composite sample** (at least 20 sub-samples) of the effluent entering the pond and the treated effluent at the pond exit point should be collected. To prevent sample deterioration, the samples need to be kept cool and transported promptly to the laboratory.

If the pond is removing less than half the VS from the raw effluent (determined by testing the raw effluent and the treated effluent) or the VS concentration of the treated effluent exceeds 1% (Skerman et al. 2008), this is an indication that there is an issue.

This may be due to:

- excessive sludge accumulation and the need for desludging
- disruption to the pond bacteria by chemicals or a pH imbalance
- difficulties in obtaining representative effluent samples for testing, which introduces error.

The ideal pH range is 6.8-8.0. A low pH may indicate incomplete anaerobic digestion. This could be due to inadequate treatment capacity (overloading may be needed to desludge or expand primary pond capacity) or irregular effluent inflow.

Salinity may also impede pond performance. In some cases, ponds may need to be diluted with fresh water to keep the salinity at an acceptable level.

If necessary, a more detailed investigation of the situation could include:

- collecting and analysing more samples to confirm results
- measuring the sludge depth by plunging a 0.3 m wide "T" into various sites with the pond. This may indicate a need for desludging.

A purple colour in large anaerobic ponds indicates the presence of a group of bacteria that reduce hydrogen sulphide to elemental sulphur, thereby reducing odour. They are an indicator of a well-functioning anaerobic pond.

9.2.3.2 Wet weather storage

Spills from effluent ponds can contaminate waterways and land. To prevent spills:

- manage the ponds to ensure there is sufficient spare capacity to contain the rainfall from storm events or extended wet periods
- irrigate effluent as opportunities arise to provide this storage.

9.2.3.3 Freeboard

Freeboard is the distance between the maximum water depth of a pond and the top of the bank. Freeboard:

- protects against spills from wave action or imperfections in crest height
- can be maintained by locating the tops of weirs or pipes between ponds at a depth of 0.6 m or more below crest height to provide suitable freeboard
- should not be used for storing effluent, as the effluent level in the whole pond system needs to be managed to maintain freeboard.

9.2.3.4 Desludging

Sludge accumulates continuously in effluent ponds; mainly in the primary pond. Periodic desludging is necessary to maintain the treatment capacity of the effluent pond. Care needs to be taken during the desludging process to protect the integrity of the pond lining (clay or synthetic).

The need for desludging should be investigated if:

- VS reduction in the anaerobic pond falls below 50%
- the VS concentration of the treated effluent exceeds 1%.

See Section 9.2.3.1 for investigation of these issues.

The options for pond desludging depend on:

- the physical properties of the sludge
- pond design and accessibility
- equipment availability
- the land area available for sludge management.

Sludge removal frequency affects the quantities and properties of the sludge. Removing sludge annually is the best treatment option because it:

- provides flexibility in removal options
- keeps the mass of nutrients to a manageable level
- can be timed to fit in with cropping cycles.

Removing sludge:

- more frequently results in a greater amount of sludge for removal overall, as frequent removal encourages more frequent buildup
- too infrequently (e.g. several years or more) may result in sludge that is too thick to pump
- at intervals of less than six months may compromise pond treatment and yield sludge that is only partially broken-down and may be more odorous
- annually:
  - provides flexibility in removal options
  - keeps the mass of nutrients to a manageable level
  - can be timed to fit in with cropping cycles.

Options for sludge removal from primary ponds include:

- pumping if effluent contains up to 5% solids
- use of positive displacement pumps or vacuum tankers slurries with a TS concentration of 5-15%
- bulk mechanical methods (e.g. excavators) if the sludge will have a TS content exceeding 15% as this will be too thick to pump

The TS content of sludge from a number of Australian piggeries sampled had wide variation, from 3.2% to 16.4%.

There are a range of options for sludge removal. These are outlined in Table 9.3.

Table 9.3 Methods for sludge removal

Method	Advantages	Limitations/risks	Notes
Rotary positive displacement pump	• Cost-effective, does not need continual supervision • Agitates sludge, keeping solids in suspension (enhances removal)	• Requires frequent suction hose repositioning • May increase odour • Prone to pipe blockages from large solids • Less effective when pumping clear effluent if holes form in sludge layer	• Suitable for regular sludge with manageable solids size
Vacuum tanker	• Good for small piggeries that spread sludge directly • Useful where dewatering basins are close by	• Labour intensive • Less suitable if sludge must be moved a long distance	• Suitable and practical for small-scale farms
Desludging ports	• Minimises disruption to pond function • Reduces risk of damage to liners and covers • Enables desludging to drying bay	• For covered anaerobic ponds, requires frequent removal of recently settled sludge (<3% TS) rather than infrequent removal of dense sludge	• Works with pumps or vacuum tankers
Dredging	• Pump can access all parts of pond • Suitable for large ponds • Does not need continual supervision	• Inefficient in ponds with variable sludge depths • Susceptible to pump blockages	• Mobile and scalable option
Long reach excavator	• Can remove very old or thick sludge • Handles higher TS content than pumped methods	• Labour and time intensive • High risk of damaging clay or plastic liners	• Typically used for older ponds with heavy accumulation
Agitation (stirrers)	• Keeps solids in suspension, allowing other methods to remove sludge	• May significantly increase odour in downstream ponds due to use of stirrers	• Often used in combination with other methods

Additional management considerations:

- At small farms, sludge may be spread directly onto reuse areas after extraction.
- For larger volumes or distant reuse sites, sludge must be dewatered (e.g. in drying bays).
- Sludge storage must be on low-permeability surfaces with leachate/runoff capture, and stormwater excluded.

Table 9.4 Methods for dewatering sludge

Method	Details
Long-term storage	• Sludge is dried in a large, bunded area or basin. • Sludge takes a long time (many months to years) to dry. • When the sludge crusts over, evaporation is limited. • Breaking the crust can enhance drying.
Short-term drying bays	• Purpose-built, shallow evaporation bays. • Clay-lined evaporation bays are cheap to build and properly constructed bays offer good groundwater protection. • Dewatering rate can be improved by laying down a gravel base over the clay liner, adding slotted pipes across the bay, then covering these with fine graded sand. However, this adds cost and there is a risk of pipe damage by machinery when the sludge is removed. • Geofabric walls and sand over a clay liner allow for drainage through the walls and the base, further enhancing drying. • Bays about 0.6-0.7 m deep can be filled to a depth of 0.3-0.4 m and provide 0.3 m of wet weather storage. • Sludge can be removed from the bays and stored in windrows when it is partly dry. If the sludge can be formed into a stable pile about 1.5 m high it is dry enough for windrow composting or storage.
Sedimentation and evaportation pond systems (SEPS)	• SEPS were originally developed to avoid the difficult problem of removing sludge from large, deep conventional ponds. • SEPS are continually loaded with fresh effluent that moves slowly through the SEPS channel and then into the pond system. Because of the slow movement through the channel, some solids settle out before the effluent drains into the subsequent pond. Information on SEPS is provided in Section 9.1.6.
Geotextile tubes	• Long permeable bags filter liquid from solids, sometimes in conjunction with coagulants or flocculants. • The tubes need to be located on a low-permeability base, with drainage and runoff captured. • They may suit sites with limited land. • They are relatively expensive, particularly if coagulants or flocculants are used. • Pond desludging and drying is often a slow and challenging process. Before desludging, there are important factors to consider.
Potential odour impacts	• Prevailing winds in relation to sensitive receptors – avoid desludging when winds are more likely to be towards neighbours. • Time – avoid desludging when receptors are more likely to be home (e.g. Christmas/New Year period, school holidays). • Sludge removal options based on the pond dimensions and the expected physical properties of the sludge for removal (e.g. semi-liquid, solid). • The quantity of sludge for removal, management and reuse. • Whether the pond will be taken off-line for desludging – decanting most of the liquid before desludging will reduce dewatering and transfer or transport costs. However, suitable alternative effluent management will be needed. It may be possible to divert effluent to the secondary pond for a short amount of time. Because total pond capacity will be reduced during that time, good management will be needed to avoid pond spills in the event of rain. • Sludge dewatering method, including where and how long the extracted sludge will be stored. • Where the sludge will be stored (if it is not spread immediately). • Where and how the sludge will be reused.

9.2.3.5 Digestate

Biogas digesters discharge digestate when the process is completed. This consists of a mixture of liquid and solid material. The solids are usually separated from the liquid using a screw press, rotating screen, centrifuge or similar (see Section 9.1.3) and then managed like other manure (see Section 10). The liquid is directed to an effluent pond system or at least a holding pond (see Section 9.2) prior to reuse on land.

9.2.3.6 Maintaining banks, bases and liners

To maintain banks of effluent ponds:

- grass the outer banks of effluent ponds to prevent weed infestation, cracking and erosion
- keep the grass on the outer bank short to allow for regular inspections to detect bank deterioration and reduce snake habitats
- remove trees, shrubs and woody weeds which can damage the bank
- remove vegetation that is growing into the pond as it can impede access and clog pipes and weirs
- regularly inspect and maintain bank integrity.

Pond liners:

- must be constructed and maintained to have low permeability
- need regular inspection to ensure they are in good condition
- constructed from clay liners may crack if they are allowed to dry out fully (ponds should be filled as soon as practical after construction and retain some liquid)
- constructed from synthetic materials need to be protected to avoid damage. They should be fenced to protect them from damage by livestock and wildlife trampling or digging. Extra care needs to be taken during desludging to maintain liner integrity. Options for desludging ponds are detailed in Section 9.2.3.4
- should be inspected when conditions allow, with maintenance undertaken as required.

Ponds with covers should be:

- fenced to protect them from livestock or wildlife damage
- regularly inspected to ensure they are in good condition with repairs made as needed, including flares
  Anyone working with pond covers and flares must be suitably trained and qualified.

9.2.3.7 Contingency plans

Contingency plans are needed to manage emergency situations that could include:

- pump breakdowns
- power outages
- pipeline blockages
- entry of foreign substances to the ponds
- spills.

9.3 Biogas systems

Biogas systems are an alternative to primary anaerobic ponds. During anaerobic digestion of effluent, a large amount of biogas consisting mostly of methane and carbon dioxide is released. Methane is both a potent greenhouse gas and also the main constituent of natural gas. Capturing the biogas enables its use as an energy source or for heat generation. The heat can be used to warm water for heat pads or for radiators. The power generated from biogas systems can reduce or eliminate energy costs and may also generate income by feeding back into the grid.

The use of biogas systems also significantly reduces the GHG emissions of the piggery. Emissions abated may also have a market value through schemes like the Emissions Reduction Fund (ERF) and Large Renewable Energy Certificates (LREC). Refer to the NEGIP-SD.

9.3.1 Types of biogas systems

Biogas systems used in Australian piggeries:

- Unmixed-unheated covered anaerobic ponds (CAPs) (sometimes called covered **anaerobic lagoons** or CALs):
  - In these systems the pond cover inflates to store biogas that is then available for on-farm heat or energy.
  - Microbial activity and biogas production is higher during warmer months, and lower during cooler months resulting in variable biogas production.
- Digesters, including mixed-heated CAPs, or tank digesters (engineered digesters):
  - Mix and with heat effluent to optimise biogas production, keeping production consistent throughout the year.
  - These systems are more complex and require more management and maintenance.
  - Maintaining a constant temperature of 34-38°C is ideal.
  - Sludge and digestate will need management.

9.3.2 Biogas system commissioning

Because piggery biogas is flammable and contains highly toxic gases, it is very important to confirm the system is safe to use prior to start-up.

Commissioning considerations:

- Thorough pre-commissioning testing should always be carried out before filling an unmixed-unheated CAP or digester for the first time.
- Qualified installers (e.g. licensed electrical workers and qualified gas fitters) should always check and warrant all components and ensure the equipment is safe and ready to use.
- The system should only be filled with effluent once it is deemed safe.
- Seeding a CAP with effluent or sludge from another piggery pond may help the pond reach its full potential more quickly. This should ideally be done gradually. Consider biosecurity risks when selecting an effluent or sludge source.
- It typically typically takes 6-18 months for a new system to reach full operation and biogas production.

For further safety guideance during pre-commissioning and purging, refer to the most recent edition of the APL *Code of Practice for On-Farm Biogas Production and Use (Piggeries)* (APL 2015).

9.3.3 Biogas system management

The performance of biogas systems depends on:

- their type
- their design and management
- the health of the microorganisms within them
- the methane potential of the material they are digesting (Tait et al. 2017).

Optimising the health of the microbial population within a biogas system relies on:

- providing optimal nutrition
- avoiding the introduction or accumulation of substances that are toxic or inhibitory
- providing an optimal temperature range.

From a practical perspective, piggery effluent contains ample organic matter and nutrients for a biogas system, so the following tips will help maintain your system:

- A regular flow of organic matter into the system will keep the microorganisms fed.
- Flushing or emptying pits regularly helps to maintain an even flow of nutrition to the microbes.
- Frequent flushing or emptying of pits (at least weekly) reduces manure breakdown in pits, optimising biogas production.
- Shock loads (larger amounts of material being added in one go) should be avoided.
- Co-digestion (addition of wastes with the effluent) should be carefully managed to ensure the system is not overloaded.
- Co-digestion materials should be preferentially selected. Piggery effluent is relatively high in nitrogen, so adding too much nitrogen may result in high ammonia levels that inhibit biogas production.
- Avoid cleaning chemicals and pharmaceuticals that may be toxic or inhibitory to treatment microorganisms. Consider what chemicals are being used within the piggery and what effect these might have on the effluent system microorganisms.
- Maintain a temperature range of 34-38°C in heated CAPs.

9.3.4 Co-digestion

Biogas system performance may be enhanced by co-digesting other materials with the effluent. There may also be scope to provide an additional income stream by charging to receive waste from others, although it is important to consider biosecurity risks and regulatory or licencing requirements. A reasonable level of co-digestion performance is likely if:

- adequate amounts of nutrients are available
- inhibition thresholds for ammonia are not exceeded
- loading limits are not exceeded by adding too much organic matter (Tait et al. 2018).

The selection of mixtures is very important to ensure stable digestion. Co-substrates should be selected based on:

- compatibility with the piggery effluent:
  - Select wastes that are readily biodegradable and concentrated, making excellent methane boosters (Tait et al. 2017).
  - As piggery effluent is a high nitrogen material, it will ideally be paired with a high carbon waste to lower the risk of ammonia inhibition of methane formation. Glycerol and fat, oil and grease are substrates that provide for high loading rates and produce good biological performance.
  - Macerated food waste and food industry waste can be a good option. They usually rapidly digest, have a low impact on residual solids and have a low inhibition risk. Often these wastes are dilute and the volumetric rate may limit use (Tait et al. 2018).
- availability and reliability of supply
- economic viability. Income or cost offset could include:
  - increased biogas production
  - fertiliser value of digestate or effluent
  - any payments received in exchange for the waste.

Costs might include:

- disposal of additional digestate or effluent
- transport
- receival facility charges, and sometimes the cost of materials for co-digestion (Tait et al. 2018)
- Cost of updating licences and regulatory requirements.

Co-digestion may also introduce new risks, including:

- biosecurity risks from the waste itself or vehicles transporting it to the site
- inclusion of chemicals that may kill the digester microorganisms
- elevating the organic load beyond the design capability of the CAP or digester. It is necessary to control the loading rate to avoid process failure
- increased sludge accumulation rate and the need for more frequent desludging
- environmental impacts associated with poor storage of co-digestion substrates for example runoff to land or surface waters, leaching to groundwater, and increased odour emissions
- increased nutrients or salts in effluent, sludge and digestate that need to be considered from a reuse perspective
- the possibility that digestate may contain contaminants such as heavy metals or chemicals that may be unsuitable for reuse, resulting in transport and disposal costs.

9.3.5 Biogas system maintenance

To maintain a biogas system:

- Always operate the system in accordance with the manufacturer's specifications.
- Regularly visually check the integrity of above-ground biogas infrastructure for cracks, tears or damage and ensure that they are repaired by the installer or another appropriately qualified contractor.
- Conduct preventative maintenance of equipment in accordance with manufacturer's specifications, including installation of a Type B gas fitter if required.
- Purge the system of biogas prior to access for major maintenance. It needs to be below the lower explosive limit (LEL) and have safe hydrogen sulphide levels prior to decommissioning or major maintenance that could result in risk exposure.
- Regularly check condensate pH levels in iron sponge scrubbers as acidic condensate may reduce hydrogen sulphide removal efficiency.
- Check biofilm growth in biogas conditioning systems, particularly those using biological scrubbing.
- Ensure proper recycling or disposal of all used oil, filters, spent scrubbing media, condensate from scrubbers and decommissioning waste (e.g. removed pond covers and metal parts).
- Desludge CAPs regularly. Removing sludge every one to two years ensures good conversion of organic matter to methane (see Section 9.2.3.4).
- Manage digestate discharged from biogas digestors (see Section 9.2.3.5)
- Undertake regular monitoring (see Section 9.3.6).
- Record all details of maintenance checks.

Operating a biogas system introduces a range of safety risks, including:

- exposure to electrical and mechanical systems
- noise
- slips and falls
- drowning
- toxic gases.

It is important to train all staff in the risks and for the piggery to manage the biogas system to minimise, eliminate or minimise risk. Some of the things you can do to reduce or manage risks include:

- Never allow staff to enter manure pits, digesters or other confined spaces (unless they appropriate accreditation).
- Ensure staff and contractors are aware that the hydrogen sulphide in biogas may be lethal.
- Ensure a hydrogen sulphide or flammable gas detector is worn or carried when working around biogas equipment.
- Never allow a staff member to undertake electrical work unless they are a licensed electrical worker.
- Only allow a qualified gas fitter to undertake work with Type A or B pipework and Type B appliances).

The APL *Code of Practice for On-Farm Biogas Production and Use (Piggeries)* (APL 2015) provides further details to minimise risks.

9.3.6 Biogas system monitoring

Monitoring for biogas projects includes the following performance measurements:

- Effluent pH: a pH range of 6.8-7.8 indicates typical operation for a biogas system, whereas a pH falling outside of this range could indicate that the anaerobic digestion system is not performing optimally or is under stress.
- TS and VS content in the effluent: The VS to TS ratio in the effluent varies between systems and may require expert interpretation. Generally, values less than 0.65 indicate that manure organic matter is being efficiently converted into biogas.
- Volumetric production of biogas or amount of electricity generated.
- Measurements required of an ERF project where relevant. These could include:
  - the proportion of methane in the biogas produced
  - measurement records that indicate whether biogas use equipment was operational during a particular monitoring time period
  - biogas composition measurements at the frequency required for ERF reporting.

Note: it typically takes 6-18 months for a new system to reach full operation depending on whether pond seeding was successful and whether or not any issues arise.

The methane content in biogas can vary depending on inputs (e.g. by-products) but should be at least 50% volume and should generally be between 60% and 75%. Values of less than 50% could indicate a significant leak, or stressed digestion microbiology. Values exceeding 75%, while atypical do not necessarily represent a process concern, but may indicate that meter calibration is required.

9.3.7 Biogas system emergency response

An emergency response plan must be in place for managing emergency situations pertaining to biogas. Refer to the APL *Code of Practice for On-Farm Biogas Production and Use (Piggeries)* (APL 2015) for guidance on developing this plan.

10 Managing manure

Manure can take the form of:

- separated solids
- spent bedding
- pond sludge (if dried).

Options for managing manure removed from pig housing range from storage in static piles (stockpiling or aging) through to active composting. During this time, the manure will break down and moisture, dry matter and nitrogen losses will occur. Generally, the longer or more intensively manure is managed, the greater the losses.

Table 10.1 Manure management options

Type of manure	Management options
Seperated solids and spent bedding	Stockpiling, aging or composting
Wet solids	Typically require dewatering, drying or the addition of dry material to make them stackable for stockpiling, aging or composting
Liquid pond sludge	Include spreading directly after removal from the pond using a vacuum tanker or dewatering, drying for spreading as a solid

More information on each type of waste listed in Table 10.1 is provided in the sections below.

10.1 Production and properties of manure

The quantity of manure produced affects the required size of management and storage areas and the type of handling equipment required. The moisture content and form of manure varies and this affects management.

10.1.1 Solids separated from liquid effluent

Solid separators:

- Remove a proportion of the solid manure from the effluent stream, reducing the strength of the effluent for treatment (see Table 10.2).
- Provide increased nutrient reuse flexibility by splitting the nutrients between effluent and the separated solids. The amount of TS and the particle size distribution of solids removed by different solids separators varies widely.

The PigBal model can be used to estimate the quantity of TS and macro-nutrients (nitrogen, phosphorus and potassium) removed by different types of solids separators.

Table 10.2 Typical solids and nutrient removal rates for different types of solids separators

Technology	Removal rate (%)				
	Total solids	Volatile solids	Nitrogen	Phosphorus	Potassium
Screw press[a]	32	37	37	41	8
Rundown screen[a]	20	25	8	11	0
Vibrating screen[a]	20	25	8	11	0
Rotating screen[a]	15	20	5	10	0
Baleen filter[a]	30	37	12	17	0
SEPS[a]	77	82	36	89	4
Settling basin[a]	55	70	20	40	3
Z filter[a]	58	73	35	50	10

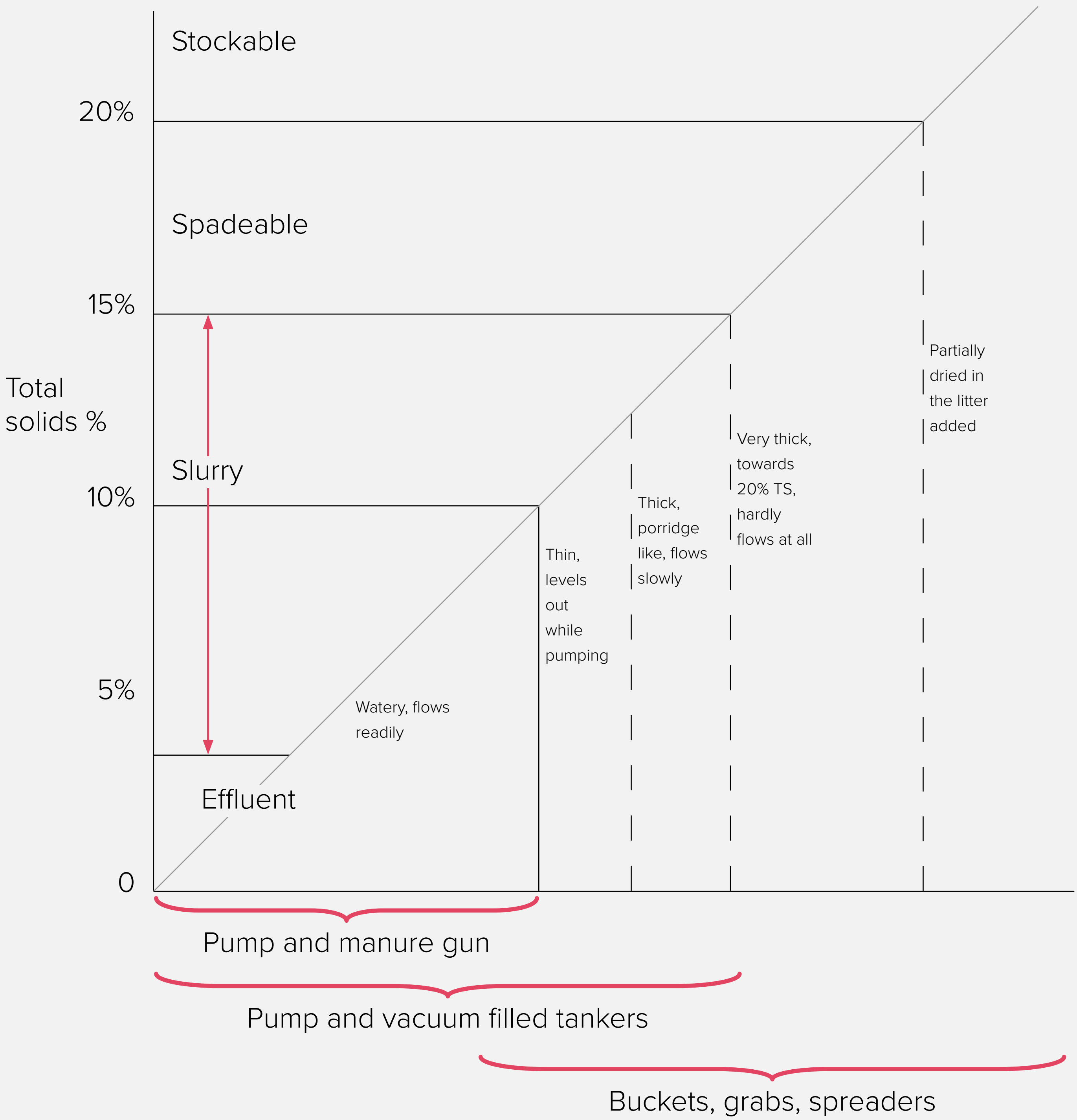
a McGahan et al. (2010)/Pigbal default values b Payne (2014)

Figure 10.1 summarises the handling properties of solids at different moisture contents. the following information can be used as a guide:

- Screens remove coarser material that has a low TS content (5-10%).
- Screw press solids are also fairly coarse but contain less moisture (20-30% TS) and are easily managed being stackable with little seepage or slumping.
- Sedimentation basins and sedimentation and evaporation pond systems (SEPS) yield large amounts of wet solids with a high proportion of fines.

Wet separated solids can be blended with dry bulky materials like sawdust, woodchips or straw to reduce moisture content, increase carbon and improve porosity. alternatively, they can be dried in a shallow basin.

Figure 10.1 Handling characteristics of solids at different moisture contents (Watts el al. 2002a)



10.1.2 Spent bedding

Spent bedding has good handling properties. It is a moist material (45-60% TS) with a relatively low bulk density that is easy to stack, load and transport. However, the moisture content is usually quite variable within a single batch. It should be mixed so that the moisture content is more evenly distributed before storage, composting or spreading.

Chemical analysis results for spent bedding are provided in Table 11.7.

The quantity of spent bedding produced depends on the bedding usage rate and the type and number of pigs. Pigbal should be used to estimate spent bedding production. However, for bedding usage of 0.75 kg/SPU/day, decomposition losses of 20%, a final moisture of 50% and bulk density of 700, approximate spent bedding production might be:

- 265 kg/hd/yr or 0.38 m^3/hd/yr for weaners
- 530 kg/hd/yr or 0.76 m^3/hd/yr for growers
- 865 kg/hd/yr or 1.2 m^3/hd/yr for finishers and dry sows.

10.1.3 Pond sludge

The physical properties of sludge depend on its age and how it was removed from the pond. For example, if the effluent has been agitated to suspend the sludge, it may be a liquid containing 5-15% TS that can be pumped or suctioned. It will have a higher TS content if it has been removed using a long reach excavator. Unless sludge will be spread or irrigated directly after removal, it needs to be partly dewatered to improve its handling properties.

Once the moisture content drops to about 50% it is much easier to handle and can be stockpiled or composted with a carbon source or spread with a manure spreader.

Sludge accumulates in ponds at a rate of approximately 0.17 m^3/SPU/yr (less if a solids separator is used). However, the quantity removed will vary widely depending on the sludge removal method (particularly the amount of effluent removed with the sludge) and the removal efficiency.

10.1.4 Manure stockpiling and composting areas

An area is needed to store or manage manure until it can be removed for spreading (usually in conjunction with cropping cycles) or further processing. Materials kept in this area can be either stockpiled or actively composted. Space will be needed for:

- managing or composting manure
- composting mortalities
- storing any carbon sources or amendments that will be co-composted with the manure or mortalities
- equipment manoeuvring: space will be required between and at the end of windrows and piles for equipment to move and turn. Usually a width of 4-5 m will be needed between pairs of windrows, although this can be reduced for self-propelled equipment.

Manure and mortalities should always be stored or composted on a bunded, impervious area (often this will be the same area). Refer to Appendix A for a pond pad permeability specification. For further details of mortalities management see Section 12.

Ruminant animals must not have access to manure or compost management and storage areas as the manure is classed as restricted animal material (RAM).

10.2 Equipment for aging and composting manure

Equipment that could be used for aging or composting manure includes:

- front-end loaders
- tractor-drawn PTO-driven compost turners
- tractor-drawn self-powered compost turners
- self-propelled straddle turners
- water tankers.

Factors to consider when assessing equipment:

- Windrow dimensions: tractor-drawn PTO-driven units; tractor-drawn self-powered units and self-propelled straddle turners are better for large windrows and can handle larger amounts of compost. Tractor-drawn models are generally limited to piles less than 3 m high, while self-propelled models can turn 4 m high windrows. (Note: higher windrows are more likely to reach temperatures that cause fires). Consider space needed between windrows for different types of turners.
- Turning rates:
  - Three-point linkage models: 200–400 m^3/hour
  - Tractor-drawn units: 400–800 m^3/hour
  - Self-propelled turners: 1,200–6,500 m^3/hour
- Power requirements: required tractor power depends on the turner size. Three-point linkage turners typically need 35–45 kW, while PTO-driven units require 60–100 kW. Tractors must have a creeper gear or hydraulic assist on the turner for slow-speed operation.
- Mode of turning:
  - Straddle turners process windrows in a single pass and must match the windrow width to the drum length.
  - Auger turners move compost to one side using paddles and are well suited to confined sites as they require less tractor space alongside the windrow.
- Watering: turners with trailing hose systems can add water during turning, improving efficiency for medium to large operations. Some turners can tow a water tanker, which may be more suitable for small farms without fixed watering infrastructure.
- Amount of manure:
  - Front-end loaders suit small operations and are commonly available on-farm, but they are too slow for large volumes and may not mix material thoroughly.
  - Three-point linkage units are suitable for small to medium-scale composting.
  - Purpose-built compost turners with augers, rotary drums.

10.3 Aging (or stockpiling) manure

Aging or stockpiling manure is the simplest and most cost-effective storage method. It involves storing manure in static piles or windrows with minimal or no active management until it is spread on land, typically when nutrients are required for the next cropping cycle. Manure may be stockpiled for up to 12 months. However, it must not be stored indefinitely and there should be a plan in place for its ongoing use or sale.

10.3.1 Benefits of aging manure

The benefits of aging manure include:

- removal of solids and moisture, which increases the concentration of some nutrients (e.g. phosphorus)
- improving the handling properties of the manure
- potentially lower dust and odour emissions compared with composting if left in static piles that are not turned
- minimal capital and labour inputs compared with composting
- reducing the number of pathogens and weed seeds, although the lack of turning means that not all material will be exposed to the high core temperatures needed to destroy all pathogens and weed seeds.

However, because the manure aging process is less actively managed than composting, the product may be less consistent and contain some pathogens and weed seeds.

10.3.2 Managing the manure aging process

The manure aging process should be managed to maintain low odour, aerobic conditions within the pile. Drier manure decomposes aerobically, which is a low odour process.

Considerations when managing manure aging:

- Space needed for storage of manure and any carbon sources to be added, along with equipment manoeuvring space.
- Pile height:
  - Forming wet solids into low piles or windrows and turning these promotes drying without excessive heat production.
  - Piles that are too low will not heat up, a process which assists decomposition, pathogen deactivation and weed seed destruction.
  - Piles that are too high may self-combust due to excessive internal heating. While stockpile fires only smoulder rather than having flames, they can continue to burn slowly for weeks or longer, causing odour and smoke.
  - Piles up to 2 m in height are recommended.
- Pile shape:
  - Sloping sides on piles shed water to facilitate drying.
  - Windrows with a triangular cross-section, a base width of 3-4 m and a height of 1.5-2 m generally work well.
- Mixing material prior to forming into piles:
  - The moisture and nutrient content of spent bedding can be very uneven and mixing helps to combine bedding from the dunging area into the drier material.
  - Blending wet solids with a dry, bulky, high carbon material (e.g. straw, sawdust, rice hulls) is also an option for reducing the moisture content and introducing oxygen.
- If and when to turn piles. Manure that is very dry will produce dust and odour when turned.
- How to manage waste grain and other high energy materials. Including large amounts of waste grain in piles can trigger increased temperatures within piles and ignition risk.
- Windrow/pile consolidation:
  - When the solids have dried and completed several months of aging, they can be consolidated into larger piles before being spread or taken off-site.
  - These piles should be located within the designated management and storage area.
- How much material will be produced:
  - The amount of finished aged material will depend on the amount of material at the start of the process, how fresh the material is and the change in moisture content.
  - Losses of 50-60% of the initial volume could be expected due to losses of water and VS. Nitrogen losses of about 20% can also be expected.
- Additional odour controls if necessary. Windrows and piles should be left uncovered to promote drying. In rare cases, where odour is a significant issue, capping newer piles with fully aged manure or fresh straw may be helpful. This may also be appropriate in very wet locations.

10.4 Composting manure

Composting involves the active management of manure or spent bedding, sometimes with the addition of water, effluent or other co-composting materials. Active management involves turning the windrow after the core temperature is maintained at 55-65°C for three consecutive days and repeating at least four times. Most pathogens and weed seeds are inactivated at these temperatures.

Permission requirements vary across states and territories. In most cases, approval is not required to compost manure (with or without co-composting material) if it is produced and used on-farm. However, using co-composting materials from off-site may require separate environmental approval. Similarly, if compost is taken off-farm, additional approvals and requirements may apply. Check state regulations. *AS 4454-2012 - Composts, Soil Conditioners and Mulches* (Standards Australia 2012) is a voluntary standard that is widely used by large-scale, commercial composters. It defines composting as: "The process whereby organic materials are microbiologically transformed under (generally) aerobic conditions to achieve pasteurisation and a specified level of maturity".

Manure compost needs to be "fit for purpose" depending on the planned end-use. Some composters use AS4454-2012 to confirm that their compost meets the standards as pasteurised or matured product (Standards Australia 2012). Some state and territory environmental agencies have their own standards for pasteurised and matured compost that are usually based on AS4454-2012. A product that does not meet the requirements of the AS4454-2012 standard may be suitable for a range of end-uses. There may be specific requirements for some uses, for example the FreshCare standards for horticulture.

10.4.1 Benefits of composting manure

Benefits of composting manure may include:

- reduced bulk and moisture content in the product
- more friable and consistent material which is more easily handled and spread
- possibility of value-adding on- or off-farm
- reduced viable weed seeds and pathogens
- nutrients stabilised into slow-release form, which needs to be considered when planning fertiliser programs
- reduced nitrogen losses on spreading (although nitrogen is lost during composting)
- increased phosphorus concentration compared with raw manure (due to dry matter and moisture losses during composting)
- low odour method of managing manure if managed well
- emission of carbon dioxide rather than methane which may lower GHG emissions if managed well.

Reusing compost on-farm adds carbon and nutrients to the soil. The carbon helps to improve aeration, water holding capacity and structure, while the nutrients can replace inorganic fertilisers.

While composting usually produces a more consistent, stable product than aging, it:

- involves considerably more management and equipment
- is more expensive due to the time and equipment involved
- may result in higher nitrogen losses due to turning, particularly if the carbon to nitrogen ratio is below 20-25:1
- may release more odour and dust if the material is being turned when too dry.

10.4.2 Windrow composting

Composting involves an active stage and a curing stage. Table 10.3 outlines what happens during both stages of the process.

Table 10.3 Active and curing stages of composting process

Stage	Process	Management
Active stage		
Early in stage	Readily digestible sugars and starches are initially rapidly broken down and the temperature within the pile rises, typically to 55-65°C.	Turning helps to incorporate fresh material into the centre of the pile. Watering may be necessary to optimise the process. Pasteurised compost will usually require five turns of the windrow, with each turn occurring after the pile has reached and maintained a temperature of >55°C for three consecutive days.
	The temperature remains elevated for several weeks providing there is sufficient nitrogen, carbon, moisture and air.	
Later in stage	More resistant materials like lignin are broken down and most pathogens and weed seeds destroyed.	
End of stage	The decomposed material is converted into humus. When the temperature within the pile no longer rises significantly after turning, the compost is ready for curing.	Active stage requires a minimum of three to four weeks with intensive management or turning. However, it typically takes at least six to eight weeks.
Curing stage	Occurs at lower temperatures.	Can use larger windrows or piles than active phase, providing window remains aerobic (low odour). This stage usually takes at least four to eight weeks.
	Curing continues the breakdown of resistant components, reducing organic acid levels, carbon-to-nitrogen ratio and other properties that may be detrimental to crops.	

The composting process produces little odour and is unlikely to cause any nuisance if conducted well. This includes:

- beginning with a suitable carbon-to-nitrogen ratio (C:N)
- maintaining a suitable moisture content that optimises the process and avoids dust production
- considering atmospheric conditions when turning.

Manure is most commonly composted in windrows. Material composted in long, low windrows:

- dries more quickly
- is easily turned
- tends to break down aerobically (low odour).

Steps in windrow composting:

1. Blend the materials for composting to achieve a suitable carbon to nitrogen (C:N) ratio and moisture content.

- The C:N should be at least 20-40:1 but ideally 25-40:1. The moisture content should ideally be 50-60%. The material should feel moist but it should be difficult to squeeze water from it.
- Adding high-carbon, bulky materials can improve wet or fine solids and pond sludge by increasing airflow and carbon availability. Sawdust and wood shavings (C:N of 200–500:1) are ideal. Straw, rice hulls and spent bedding are also suitable. Shredding straw increases surface area.
- Ensure co-composting materials are free from contaminants (e.g. residual chemicals, glass, plastics). Test ingredients for carbon and nitrogen content to develop a suitable recipe. Online calculators, such as Cornell Compost Calculator, can assist.
- If material is too dry, water it until adequately moist. Some compost turners apply water during turning. Alternatively, use a soaker hose or micro-sprinklers along the windrow apex. Monitor to avoid runoff or leaching. As a guide:

  - Adding 200 L of water increases the moisture content of 1 tonne of material from 40% to 50%.
  - Adding 500 L increases moisture from 50% to 60%.
  - Effluent can be used for the initial watering only. Avoid using it later, as it may introduce pathogens.
  - If material is too wet, dry it by turning every few days or add dry co-composting material.

2. Form the materials into windrows with a triangular cross-section so they shed water. Windrows 3-4 m wide at the base and 1.5-2 m high work well. Higher piles are more likely to heat excessively and may self-combust.

3. Orient the windrows with the long axes perpendicular to the slope to promote drainage.

4. Leave space between and around the ends of windrows to provide access for turning. Minimal space will be needed between windrows if these will be turned with a self-propelled straddle turner. For other equipment, windrows can be arranged in pairs, with a tractor width in-between each set of pairs. Consider leaving space between windrows for fire truck access.

5. The temperature within the windrow should reach 55-65°C within a few days to one week of the process commencing.

Turn the pile only after three successive days of high temperatures (>55°C). To achieve pasteurisation, the pile should be turned at least five times during the active phase after heating. Thorough turning and a sufficient number of turns ensures all material is exposed to the high temperatures that kill pathogens and weed seeds.

6. The active phase is considered complete when the pile no longer heats to >55°C after turning.

7. Monitoring during the active stage is essential to good management.

   a. Monitor temperature using a long probe thermometer inserted deep into the pile at ten separate spots along the length of the windrow. Temperature is a useful indicator of microbial activity during the composting process. A drop in temperature during the initial phase usually indicates that the material is too dry, although insufficient nitrogen can also be an issue.

   b. Moisture can be monitored by applying the squeeze test to handfuls of cooled compost from an arm-length depth at 10 sites along the windrow.

8. After completion of the active phase, the compost can be kept in a windrow or formed into a stockpile where it is allowed to cure for at least a month. The end product is a friable, humus-like soil conditioner.

Table 10.4 summarises the recommended composting parameters. Table 10.5 provides guidance for dealing with common composting problems.

Table 10.4 Recommended composting parameters

Parameter	Acceptable range	Optimum range
Carbon:nitrogen ratio	20-40:1 *	25-40:1
Moisture content (%)	45-65#	50-60
Core temperature (°C)	40-65^	55-65

* A C:N ratio within the acceptable range may result in higher ammonia-nitrogen losses than a C:N within the optimum range.

A moisture content or temperature within the acceptable range may result in a slower process than if values within the optimum range.

^ Temperatures outside the optimal range may result in slower breakdown than if values were within the optimum range.

Table 10.5 Troubleshooting for common composting problems

Problem	Cause	Solution
Anaerobic odour	Excess moisture	Turn windrow
	Temperature <55°C	Add carbon source
	Surface ponding on windrows	Turn windrow
		Increase windrow height
		Reform pile to facilitate drainage
		Cover windrow (e.g. with straw, finished compost or synthetic cover) until odour subsides
Low windrow temperature	Windrow too low	Form taller windrows
	Insufficient moisture	Add water while turning
	Poor aeration	Turn windrow or add carbon source
Excessive windrow temperature	Windrow too large	Reduce windrow size
		Check moisture content and add moisture or carbon source
Surface ponding	Depression or ruts around windrows	Fill depression or regrade
	Inadequate slope	Grade site to recommended slope design
Rodents and flies	Feed sources	Turn the pile to incorporate feed sources and kill maggots within the pile (elevated temperature)
		Cover with mature compost or high carbon material
		Use baits if necessary to control rodents and flies
		Remove garbage or use rat bait
Mosquitoes	Stagnant water	Eliminate ponding of free water

10.4.2.1 Aerated static pile composting

Forced aerated static pile composting uses perforated piping or mats placed under the manure to introduce air, avoiding the need for turning. Pumps or fans push air into the pile, allowing for good control over oxygen and moisture levels.

Advantages of this method include:

- options for smaller-scale and large operations
- lower labour requirement than for windrow turning
- smaller composting pad needed than for windrow turning
- reduced risk of odour and dust than for windrow turning since turning is not required.

However:

- an energy source is needed
- energy and equipment costs need to be considered.

10.4.3 Quantities of compost produced

The compost production rate depends on:

- the amount of manure at the start of the process
- whether co-composting materials are used
- the change in moisture content.

Due to losses of TS and moisture during the process and associated changes in bulk density, composting can reduce the incoming quantities of material by:

- mass: 40-50%
- volume: 30-70%.

Nitrogen losses of about 20% can also be expected.

10.4.4 Properties of manure compost

Manure compost has the following properties:

- friable soil conditioner
- good source of slow-release nutrients. Analysis is recommended to confirm levels as these vary with inputs and process
- rarely contains contaminants
- low odour
- nil to low levels of pathogens and weed seeds (if pasteurised). While most pathogens and weed seeds are likely to be killed by composting, the product cannot be guaranteed pathogen or weed-free without testing.

Manure compost must be fit for purpose depending on the planned end-use. Some composters use the voluntary Australian Standard AS4454-2012 *Composts, Soil Conditioners and Mulches* (Standards Australia 2012) which sets out processing standards for pasteurised and matured compost. Some state environmental agencies also have their own standards for pasteurised and matured compost; these are usually based on AS4454-2012.

10.5 Pelletisation and granulation

Manure and compost can be pelletised or granulated for use in traditional fertiliser spreaders. This also allows for blending of other nutrients or amendments to produce a more balanced or targeted product. This process has been adopted by a small number of intensive livestock organisations in Australia.

10.6 Advanced manure treatment

Researchers have investigated the potential to apply advanced treatment technologies to spent bedding and sludge. The most promising technologies appeared to be plug flow digesters and solid-state batch digesters. These would produce biogas that can be used as a heat and energy source within the piggery. However, these digester types are still in the experimental development phase for piggeries in Australia.

Other, high-rate digestion systems such as anaerobic filters, sludge blanket reactors and anaerobic membrane bioreactors are relatively complex and generally unsuitable for use at piggeries due to the demanding operational and maintenance requirements.

11 Reusing effluent, manure and compost

Piggery effluent, manure and compost can be valuable sources of nutrients and organic matter for improving soil properties and crop or pasture production. Good management is needed to gain the most benefit from these products while protecting the environmental and preventing impacts to neighbours. Appendix C provides a useful summary.

11.1 Benefits of reusing effluent, manure and compost

Benefits of responsible effluent, manure and compost reuse can include:

- increased soil organic matter, which:
  - enhances soil structure
  - may reduce erosion rates
  - improves rainfall infiltration
  - improves water-holding capacity of soil.
- improved soil fertility
- enhanced soil microbial communities
- increased plant yields
- reduced inorganic fertiliser costs
- potential income stream if provided to other farmers for use.

11.2 Importance of good manure and effluent management

The addition of organic matter and nutrients to Australian soils is usually beneficial but their entry to water resources (particularly nitrogen and phosphorus) is always detrimental. Organic matter and nutrients can enter waterways as runoff or eroded soil and can leach into groundwater. Elevated soil nutrient levels may also kill native flora, encourage weed growth and modify ecosystems.

When effluent, manure or compost is spread on land, salts are also applied. Salinity is often measured as EC, however this measurement includes beneficial components such as potassium. For this reason, interpretation of EC should focus on sodium and chloride levels since a surplus of these can lead to the degradation of soils and impact plant growth. An excess of sodium salts relative to calcium and magnesium may induce sodicity.

Sodic soils are more prone to erosion and compaction which may impede crop emergence and growth and water infiltration. Salt is unlikely to be an issue for separated solids or spent bedding. However, the salinity of effluent and sludge depends on the salt content of the piggery water supply, whether effluent is recycled within the piggery, evaporation and the quantity and frequently of effluent and sludge extraction from the effluent system.

11.2.1 Managing reuse to protect the environment

Good reuse practices will optimise the productivity of the land and any crops grown whilst minimising risks to the environment. Good reuse practices include:

- Applying effluent, manure or compost just before sowing or when plants are actively growing to maximise nutrient uptake and minimise losses.
- Applying these at sustainable rates that optimise plant uptake and minimise leaching risk. Consider nutrient content and availability, and expected nutrient removal from harvest.
- Applying effluent at a rate that does not result in runoff from the reuse area or have suitable runoff collection (surface irrigation).
- Using application methods that promote even and controlled distribution and do not promote effluent drift (avoid high pressure guns) or runoff losses.
- Incorporating manure or compost into the soil to a shallow depth (if this fits with agronomic practices). This reduces the nutrient concentration at the soil surface which may reduce losses by volatilisation (N), erosion or via stormwater runoff. However, modern cultivation equipment is often designed for minimal soil disturbance, making it difficult to incorporate manure.
- Avoiding spreading manure and effluent if the soil is very wet or if heavy rain is expected. This may promote drainage or runoff that poses a pollution risk to groundwater and surface waters.
- Testing the effluent, manure or compost so sustainable application rates can be planned.
- Monitoring soil nutrient levels on a regular basis. This helps in planning suitable reuse rates, understanding the ongoing suitability of reuse areas and identifying risks to the environment.
- Protecting amenity by using good practices and carefully timing reuse. Consider the prevailing wind direction in relation to nearby properties. Avoid spreading under overcast conditions as these impedes odour dispersion which may result in odour nuisance at nearby houses. Use methods that are unlikely to produce aerosols or drop effluent or manure from a height exceeding 2 m to avoid drift.
- Using secondary nutrient control measures to complement the sustainable reuse practices (above) as required. These may include:
  - buffers
  - vegetative filter strips (VFS)
  - contour banks
  - groundcover retention
  - terminal ponds (high risk sites only).

Buffers should be provided between reuse areas and watercourses. Suggested buffers are shown in Table 11.1. If it can be demonstrated that the environmental risk is low, narrower buffers may be acceptable.

Table 11.1 Buffers from reuse areas

Reuse category	Distance from major water supply storage (m)	Distance from watercourse (m)
Category 1	800	100
Effluent that is discharged or projected to a height in excess of 2 m above ground level		
Effluent that is direct irrigated without pond or equivalent treatment		
Effluent that is irrigated from a short hydraulic retention time (HRT) system (<30 days of pond storage)		
Surface irrigation system without an effective terminal pond or diversion drain		
Category 2	800	50
Mechanical spreaders and irrigators that project the discharged material to a height of less than 2 m above ground level, and irrigators with downward facing nozzles		
Manure products (e.g. separated solids, sludge or spent bedding) that will remain on the soil surface for more than 48 hours without being ploughed in		
Surface irrigation systems with an effective terminal pond or diversion drain		
Category 3	800	25
Discharge by injection directly into the soil (to a depth of not greater than 0.4 m)		
Spent bedding and manure solids that are incorporated into the soil within 48 hours of spreading		
Surface irrigation systems with collection and containment of all tailwater and runoff		

Note: distances should be measured from the perimeter of the area used for handling or reusing effluent or manure.

Ideally, buffers to waterways should be VFSs, which:

- can very effectively strip nutrients by slowing the water velocity and trapping sediment
- need to be designed according to risk. Wider VFSs trap larger amounts of soil eroded from upslope areas.

Refer to the *National Environmental Guidelines for Indoor Piggeries - Siting and Design* (APL 2025) for design details.

Contour banks on sloping land:

- reduce the velocity of runoff and erosion
- capture and redirect runoff from smaller areas of a paddock, preventing runoff from concentrating into larger streams that erode large volumes of soil
- may effectively prevent the loss of nutrients attached to soil, but do not prevent the loss of nutrients dissolved in runoff.

Maintaining continuous groundcover over reuse areas:

- promotes infiltration of rainfall and reduces runoff, water velocity and soil movement
- reduces nutrient removal due to soil erosion
- increases nutrient infiltration.

Terminal ponds:

- are designed to catch the first flush of runoff (typically 12 mm) from a reuse area
- need to be emptied (by irrigation) as soon as practical after collection
- are usually only needed on high-risk sites where stormwater runoff velocity and soil erosivity are a concern and waterways need protection.

11.2.2 Nutrient budgeting

Nutrient budgeting is the cornerstone of sustainable reuse. Appropriate rates can be determined using a mass balance approach that considers:

- nutrient status of soils
- nutrients (nitrogen [N], phosphorus [P] and potassium [K]) in effluent, manure and compost
- the availability of nutrients for crop uptake
- acceptable soil storage of stable nutrients (e.g. P)
- acceptable nutrient losses (i.e. ammonia-N losses)
- nutrient removals through crop harvest.

Soil nutrient status may influence the nutrient application rate. More nutrients can be applied if the soil is deficient, less if nutrients are in excess.

The nutrient application rate depends on the nutrient concentration of the effluent, manure or compost and its irrigation and spreading rates. The composition of effluent, manure and compost varies between farms and may change from year to year depending on management and weather conditions. Representative analysis data should be used to calculate application rates. In particular, the nutrient concentration of effluent is likely to vary. A sample should be collected and analysed annually just before the main irrigation or spreading time.

It is unlikely that all the nutrients contained in manure and compost will be available for uptake in the year of application. Nutrient availability typically ranges from 25-65% for N, 23-65% for P and >90% for K (Wiedemann & Gould 2018). However, over time, as nutrients from previous years are released, the amount available will more closely match plant requirements. The result is that the value of the manure or compost could be realised over several years as the nutrients become available to plants.

As P is a conservative element that can tightly bind to clay particles in the soil, most soils with a reasonable clay content can safely store some phosphorus. Temporary P storage in the soil may be acceptable if soil tests (e.g. P sorption capacity or phosphorus buffering index) demonstrate that the soil has storage capacity. Manure and compost often have a relatively high phosphorus content, making it impractical to apply one years' crop requirement. It may be possible to apply P at rates that provide up to 3-5 years crop requirements on the understanding that the excess P will be removed by plant harvest before more is added. There needs to be a plan to remove stored phosphorus before more is added. Spreading at higher rates less frequently can help to:

- spread manure and compost more evenly – some spreading equipment needs a minimum application rate to achieve even spreading
- overcome some nutrient availability issues – not all P will be available immediately after spreading. Applying several years P at once helps to ensure sufficient nutrient is available for plant uptake
- minimise the need for regular soil disturbance that may damage soil structure
- reduce costs associated with more frequent spreading at lower rates.

Applying additional P to the soil may pose a risk of erosion, runoff or leaching losses. If P is to be stored in the soil, additional water protection measures may be required if the site is close to a watercourse (refer to Section 11.2.1).

When manure, compost or effluent are spread or irrigated, some gaseous losses of N are generally unavoidable. The reuse method affects the likely losses.

For effluent, total N losses could be:

- spray irrigation 20%
- surface irrigation 10%
- injection ~0%.

For manure, N losses can be minimised by promptly incorporating solids (where practical). However, total N losses at spreading could be:

- manure spread fresh 20%
- aged manure 10%
- compost 5%.

It is appropriate to consider the expected N volatilisation rate from the effluent, manure or compost when calculating spreading rates to ensure the net application rate provides sufficient N for the crop. For example, if the volume of effluent for irrigation contains 1,000 mg N/L and 20% volatilisation losses are expected, the effective concentration is 800 mg N/L (i.e. 1,000 kg x [1-20%]). Incorporating spread solids into the topsoil helps to reduce N losses. However, modern cultivation equipment usually minimises soil disturbance, resulting in minimal manure incorporation.

A reuse area can be considered suitably sized if there is a plan to remove nutrients added by reuse through crop harvest. N losses, adjustments for soil nutrient status and P storage should also be considered. Nutrient removal by plant harvest is the product of crop yield and nutrient content of the harvested material. High yielding fodder crops usually remove the most nutrients. For grain crops, nutrients can be removed through the harvest of grain and straw. Crop yields can vary widely. Historical yield data for the farm or other farms in the district can provide a guide.

In its simplest form, the nutrient mass balance equation is:

Nutrient application rate (kg/ha) = crop nutrient removal rate (kg/ha) + acceptable nutrient losses to the environment (kg/ha) (for nitrogen only)

If soil nutrient adjustments or P storage are to be considered, the nutrient mass balance equation can be expanded to:

Nutrient application rate (kg/ha) = crop nutrient removal rate (kg/ha) +/- soil nutrient adjustments (kg/ha) + acceptable nutrient losses to the environment (kg/ha) + nutrient safely stored in the soil (kg/ha)

Where:

- **Crop removal rate (kg/ha) = dry matter yield (t/ha) X nutrient concentration (kg/t)**
  - **For the crop nutrient removal rate, use long-term average yields representative of the local area. Approximate N, P and K removal rates for different crops and yield ranges are provided in Table 11.2.**
- **Soil nutrient adjustments might be additions (e.g. 20 kg P/ha) if the soil is deficient or could be reductions where ample nutrient is already present.**
- **Nutrient losses (N only) for different reuse methods are provided in this section. These need to be converted to a mass rate (kg N/ML for liquids and kg N/t for solids).**
- **If it is proposed to store P in the soil, the additional years of storage need to be added. For example, if the expected crop nutrient removal rate is 12 kg/ha and four years P is to be applied, an additional three year annual removal rate by the crop must be considered (36 kg/ha).**

Sources:

Data for dryland and irrigated pasture (Rugoho et al. 2017)

Data for lucerne hay, clover hay, forage sorghum, maize grain, oats straw and oats hay (Morris & Staines 2017)

Data for grain, grain straw, oilseeds, peas, beans and maize silage was sourced from GRDC.

The same formula needs to be applied to each nutrient (N, P and K). It also needs to be applied separately for any effluent or manure or compost for reuse.

Table 11.2 Approximate nutrient removal rates for various crops & yields

Crop	Dry matter nutrient content (kg/t)			Normal yield range (DM t/ha)	Normal nutrient removal range (kg/ha)		
	Nitrogen	Phosphorus	Potassium		Nitrogen	Phosphorus	Potassium
Grazed pasture					16-16.5	0.8-1.9	0.1-0.7
Dry land pasture (cut)	17.1	2.6	17.6	1-4	17-68	2.6-10.4	17.6-70.4
Irrigated pasture (cut)	17.1	2.6	17.6	8-20	137-342	21-52	141-352
Clover hay	25.4	2.4	15.8	5-15	127-381	12-36	79-237
Lucerne hay (cut)	31	3	24	5-15	155-465	15-45	120-360
Maize silage	12	2	10	16-22	192-264	32-44	160-220
Forage Sorghum	20.2	2.2	24	10-20	202-404	22-44	240-480
Grain barley	20	2.5	4.5	2-5	40-100	5-7.5	9-22.5
Barley straw		0.7	18	5-10	35-70	1.4-2.8	90-180
Grain wheat	20	3.5	5	2-5	40-100	7-17.5	10-25
Wheat straw	8	0.7	21	5-10	40-80	3.5-7	105-210
Grain triticale	21	3	5	1.5-3	31.5-63	4.5-9	7.5-5
Grain oats	17	2.5	4	1-5	17-85	2.5-12.5	4-20
Oats straw	6	1	22	5-10	30-60	5-10	110-220
Oats hay	13.8	2.6	18.7	5-10	69-138	13-26	93.5-187
Grain sorghum	25	2.3	4	2-8	50-200	4.6-18.4	8-32
Grain maize	15	3	4	2-8	30-120	6-24	8-32
Chickpea	34.5	3.3	9	0.5-2	17-69	1.7-6.6	4.5-18
Field peas	40	3.9	8	2-4	80-160	7.8-15.6	16-32
Faba beans	41	4	10	1-3	41-123	4-12	10-30
Lupins	51	4.5	9	0.5-2	25.5-102	2.3-9	4.5-18
Canola	40	7	9	1-3	40-120	7-21	9-27

[a] Yields may vary from these ranges (refer to historical data for the region for more accurate estimates).

[b] The grazing pasture example assumes a liveweight gain of 75 – 200 kg/ha/yr, with no ammonia volatilisation losses from the grazed animal's manure.

For example, effluent or manure might be applied to land used to grow a lucerne hay crop expected to yield 10 t DM/ha.

- The expected nutrient removal rate, from Table 11.2, is 310 kg N/ha, 30 kg P/ha and 240 kg K/ha (i.e. 10 t x accepted mid-range nutrient content).
- The expected N volatilisation rate for spray irrigated effluent is 20%.
- If the effluent or manure will only be applied once every three years, it might be possible to add an extra 60 kg P/ha (i.e. 2 x 30 kg P/ha removed by the lucerne crop) on the proviso that it will be removed by crop harvest before additional effluent is irrigated.
- No adjustments for soil nutrient levels are proposed.

To determine the target nutrient application rate, use the formula:

Nutrient application rate (kg/ha) = crop nutrient removal rate (kg/ha) +/- soil nutrient adjustments (kg/ha) + acceptable nutrient losses to the environment (kg/ha) + nutrient safely stored in the soil (kg/ha)

N application rate (kg/ha) = 310 kg/ha crop removal + 0 kg/ha soil nutrient adjustments
+ 20% x 310 kg/ha for volatilisation losses)
+ 0 kg/ha safely stored in the soil
= 310 kg/ha + 62 kg/ha + 0 kg/ha
= 372 kg/ha

P application rate (kg/ha) = 30 kg/ha
+ 0 kg/ha/ys of acceptable losses
+ 60 kg/ha safely stored in the soil
= 30 kg/ha + 0 kg/ha + 60 kg/ha
= 90 kg/ha

K application rate (kg/ha) = 240 kg/ha
+ 0 kg/ha/yr of acceptable losses
+ 0 kg/ha safely stored in the soil
= 240 kg/ha + 0 kg/ha + 0 kg/ha
= 240 kg/ha

Effluent irrigation rates are generally expressed as ML/ha or mm. The process for calculating these is provided in Section 11.3.1. Manure and compost rates are generally expressed as t/ha. The process is provided in Section 11.4.1.

Grazing removes only low levels of nutrients from reuse areas since most nutrients are recycled in manure. Thus, grazing systems typically require at least five to 10 times more area than cut and cart systems. For this reason, grazing alone is not a recommended land use for reuse areas. If this system is used, nutrients should be applied only at levels that improve the soil's nutrient status to good agronomic levels.

If a third party will be managing the crops grown on reuse areas, it is important that they understand the need to manage soil nutrient levels.

11.3 Irrigating effluent and liquid sludge

Effluent and sludge are good sources of nutrients for cropping systems when applied at sustainable rates. Section 11.2.2 shows the nutrient budgeting that is part of sustainable reuse. For practical reuse, the nutrient application rates (kg/ha) need to be converted into irrigation rates (ML/ha or mm). Irrigation equipment varies in the rates it can apply, the area it can cover, topography and labour inputs. A range of practical considerations can help in optimising nutrient usage and minimising risks to the environment and community amenity.

11.3.1 Determining irrigation rates

Effluent irrigation rates are generally expressed as ML/ha or mm. The nutrient mass balance equation is used to determine the mass of each nutrient that can be applied (see Section 11.2.2). Effluent composition data can then be used to find the appropriate application rate.

The quantities of nutrients calculated from the mass balance equation can be used to determine the sustainable annual application rate for effluent or liquid sludge based on its N, P and K content. The nutrient with the lowest rate, in this case P, determines the maximum average annual application rate.

The effluent or liquid sludge application rate is the target nutrient application rate (kg/ha) (see Section 11.2.2) divided by its concentration in the effluent or sludge. This needs to be done separately for N, P and K. It is important to use recent, site-specific analysis results for the effluent or sludge. The nutrient producing the lowest application rate is the limiting nutrient and usually determines the application rate.

Effluent or liquid sludge application rate (ML/ha) = nutrient application rate (kg/ha)/nutrient concentration (mg/L).

For example, if nitrogen is to be applied at 372 kg/ha and the effluent has a concentration of 600 mg/L, the calculation is:

Effluent or liquid sludge application rate (ML/ha) = 372 kg/ha / 600 mg/L

= 0.62 ML/ha

This can be converted to a mm rate by multiplying by 100, so 0.62 ML/ha becomes 62 mm.

Table 11.3 Analysis results for effluent

Element	Units	Raw effluent[a]	Final pond effluent[a]	Pond effluent[b]	Range for pond effluent[b]
Total solids	mg/L	49,500	3623	7900	1100-44,300
Volatile solids	mg/L		1809	1640	480-5,290
pH	mg/L	6.7	8.0	8.0	7.0-8.7
Total-N or (Total Kjeldahl N)	mg/L	2175	(384)	584	158-955
Ammonium N	mg/L	1800	249	144	25-243
Total P	mg/L	850	44	69.7	19.3-175.1
Ortho-P	mg/L		28.5	16.3	2.4-77.9
K	mg/L	618		491	128-784
Sulphur	mg/L		22		
Sulphate	mg/L	69	26	47.6	13.3-87.2
Copper	mg/L	2.43		0.09	0.00-0.28
Iron	mg/L			0.56	0.09-1.61
Manganese	mg/L			0.02	0.00-0.05
Zinc	mg/L			0.47	0.16-1.27
Calcium	mg/L			20.6	7.3 – 41.2
Magnesium	mg/L			25.0	6.6 – 72.3
Sodium	mg/L		603	399	41 – 1132
Chloride	mg/L		810	19.1	3.6 – 34.4
EC	dS/m	10.1		6.4	2.5 – 11.7

DEEDI = Department of Employment, Economic Development & Innovation, Qld, TKN = total Kjeldahl nitrogen

[a] Kruger et al (1995) - samples from piggeries in New South Wales, Queensland and Western Australia

[b] Unpublished data – samples from 10 piggeries in southern Queensland

Not all nutrients in effluent are immediately available for plant uptake. **Available nutrients** must be sufficient to optimise crop growth, and start-up fertiliser may be needed at planting, especially on new reuse areas.

Salts in effluent may burn plant leaves and contribute to soil salinity or sodicity. Consider the salt content of effluent if spray or drip irrigating growing plants. **Shandying** effluent with irrigation water may eliminate this problem. Leaching of salts is a natural process that helps to prevent soil salinisation.

11.3.2 Irrigation equipment

Irrigation equipment must apply the nutrients in effluent and sludge evenly and at the target rates.

A range of methods are used to irrigate effluent. These include:

- spray irrigator (e.g. hand-shift, travelling irrigator, centre pivot, lateral move)
- travelling drip irrigator (e.g. centre pivot, lateral move)
- surface flow/flood
- tanker or umbilical system with injection
- tanker or umbilical system with spray
- tanker or umbilical system with drip (e.g. dribble bar).

Any of these methods can be used for effluent, however:

- Liquid sludge would usually only be spread with a tanker or umbilical system.
- Applying effluent to land using a pipe or hose distributes effluent very unevenly and is not an acceptable reuse method.
- Static sprinklers are also undesirable as they require regular and frequent movement which tends not to happen.
- High pressure spray systems should be avoided as they break the effluent into a fine mist which can spread odour and pathogens off-site depending on weather conditions.

The most suitable irrigation method in a given situation depends on:

- topography (slope and uniformity)
- crop type
- soils
- costs (capital, labour and energy)
- shape of reuse area
- prevailing seasonal conditions.

Table 11.4 Spray irrigation methods

Irrigation methods	Key features
Hand shift spray irrigators	• Inexpensive • Generally only cover a small area at a time • Can be set up for paddocks of any shape • Labour intensive • Need to be regularly and frequently shifted to avoid soil nutrient overloading issues
Small travelling spray irrigators	• Relatively low-cost • Can apply effluent at low rates • Suit a range of terrain and paddock shapes • Restricted in how far they can travel and therefore are likely to be more useful on smaller farms
Lateral move and centre pivot spray irrigators	• High capital systems • Can deliver effluent at variable rates including low application rates • Because of their scale, they can irrigate large volumes quickly • Require solids removal to prevent nozzle blockage • Need line flushing with clean water after use to prevent corrosion from effluent

Irrigation methods	Key features
Travelling drip irrigators (lateral move or centre pivot)	• High capital cost systems • Can deliver effluent over a large area at low rates • Deliver large droplets that minimise spray drift that can carry odour and pathogens off-farm and may reduce N volatilisation and GHG losses • Moving irrigators can be fitted with tracking equipment and breakdown or stoppage alerts
Surface flow or flood irrigation	• Needs to be carefully designed and constructed to ensure maximum benefit and minimum risk to the environment (whole farm plan). This includes laser grading, check banks (as needed) and runoff collection and reuse • May be unsuitable for lighter soils, since effluent passes through these soils too quickly • Usually requires shandying with irrigation water to ensure there is sufficient volume for even application over the whole land area, The shandying enables both nutrients and water to be applied according to crop needs • Usually yields N, GHG and odour emissions relatively low because the effluent is applied directly to the land
Tanker or umbilical systems (general)	• Can deliver variable application rates based on flow and speed • Allow effluent or sludge to be applied at greater distances than small travelling irrigator • Are labour intensive
Tanker or umbilical injection	• Minimises N losses • Minimises GHG emissions and odour • Delivers nutrients to the root zone • Avoids effluent runoff
Tanker or umbilical spray/drip/dribble systems	• Produce large droplets, which reduces potential N and GHG losses and the risk of odour drift.

Table 11.5 provides a comparison of various spray and surface irrigation methods.

Table 11.5 Comparison of irrigation methods

Irrigation method	Typical area range (ha)	Typical operating pressures (kPa)	Site slope limitations	Typical application rates (mm/hr)	Comparative costs			Uniformity of application
					Capital	Labour	Energy requirement	
Sprinkler								
Small travelling irrigator	8-50	70-650	<7%	5-25	Low	Medium	High	Med/high
Centre pivot	30-200	100-300	<2%	Variable	High	Low	Low	Very high
Lateral move	50-200	100-300	<2%	Variable	High	Low	Low	Very high
Surface systems								
Flood irrigation	-	10-50	0.1-1.0%	5-10	Low*	Medium	-	Low to very high
Tankers and umbilical systems								
Vaccum tanker	-	-	-	Variable	Medium	High	Low	High
Umbilical system with a dribble bar#	-	-	-	Variable	Medium	High	Low	High
Contract spreader	-	-	-	Variable	N/A	V high	N/A	High

*Assuming reuse area is set up already for irrigation

^Low if not shandying, very high if blended with irrigation water

#Assuming tractor already owned

11.3.3 Practical effluent reuse

11.3.3.1 Timing of effluent reuse

Effluent applications:

- should be irrigated prior to planting or at times when crops are actively growing and can take up the applied nutrients
- will often be driven by the need to partially empty the ponds so they are ready to store future rainfall
- should never raise the soil moisture content above field capacity (i.e. don't irrigate soil that is already wet)
- must be controlled to ensure runoff does not occur, the exception being surface flow irrigation systems with terminal ponds. Runoff captured in terminal ponds and reuse systems should be irrigated as soon as soil conditions suit so the ponds are ready for the next irrigation event.

To avoid transfer of odour and possible pathogen transfers, effluent and sludge should not be irrigated:

- under heavy, overcast conditions
- on windy days when effluent may be carried off-site
- early in the morning or late in the afternoon when the atmosphere is heavy and dispersion is limited
- close to nearby houses when gentle winds are carrying towards the houses
- close to nearby houses on weekends and public holidays when neighbours are likely to be home.

To prevent effluent or sludge runoff from the site, avoid irrigating effluent onto wet soil or when significant rain is expected within 48 hours.

11.3.3.2 Withholding periods

Withholding periods are important for protecting the health of people consuming products grown on effluent reuse areas and stock kept on reuse areas.

- Specific requirements apply to fruit and vegetables, particularly those eaten raw or without processing. Refer to the Freshcare standards for current guidance.
- Broadacre crops (e.g. cereals and oilseeds) and fodder crops should not be harvested within 21 days of irrigation.
- To protect livestock from pathogen risks, a withholding period of at least 21 days is recommended for paddocks that have been irrigated with effluent.

11.3.3.3 Managing salts in effluent and liquid sludge

Elevated salt concentrations in effluent may cause:

- leaf burn
- yield reductions
- soil degradation.

To manage elevated sodium (Na) and chloride (Cl) in the effluent:

- dilute the effluent
- irrigate with clean water after effluent irrigation to remove salt from plant leaves
- apply effluent at low rates
- rotate which paddocks are irrigated with effluent (e.g. use one paddock this year and another the next)
- apply gypsum or lime to sodic soil
- grow salt tolerant plants if necessary.

11.3.3.4 Off-site reuse

In some cases, it may be necessary or desirable to send effluent or liquid sludge off-farm for reuse. Regulations for the transport and reuse of effluent or sludge apply in most states. Check requirements with the environmental regulator.

Providing end-users with recent analysis data and a duty of care statement (see Appendix D) is recommended.

11.3.3.5 Valuing effluent

Appendix E provides a pro-forma for valuing manure and compost. The principles that it contains can also be applied to liquid effluent or sludge.

11.4 Manure spreading

11.4.1 Determining manure spreading rates

Manure or compost spreading rates are generally expressed as t/ha. Once the nutrient mass balance equation has been used to determine the spreading rate for each nutrient (see Section 11.2.2), data for the manure composition can be used to find the target spreading rate.

Manure application rates can be determined on a dry matter basis and then converted to as-spread rates (which will always be higher because of moisture content).

Manure or compost application rate (t/ha) = nutrient application rate (kg/ha) / (nutrient concentration in manure or compost mg/kg / 1,000).

For example, if P is to be applied at 90 kg/ha once every three years, and the manure or compost has a phosphorus concentration of 1.0%, it contains 10,000 mg P/kg on a dry matter basis. Hence, the calculation is:

Manure or compost application rate (t DM/ha) = 90 kg P/ha / (10,000 mg P/kg / 1,000)
= 9 t DM/ha

If the manure has a dry matter content of 75% (from the manure analysis), the 9 t/ha will be divided by 0.75 to determine the as-spread rate of 12 t/ha.

Tables 11.6 and 11.7 show analysis results for pond sludge and spent bedding. These vary widely and a representative sample should be analysed before the main spreading event.

Not all nutrients in manure will be immediately available for plant uptake. Nutrient availability typically ranges from:

- 25-65% for N
- 23-65% for P
- >90% for K.

Suitable available nutrient levels are needed to optimise crop growth. Also, if manure is not incorporated into the soil, P deficiency may arise as the plant roots cannot access phosphorus near the soil surface. Start-up fertiliser may be needed at planting, particularly on new reuse areas (Wiedemann & Gould 2018).

More information on calculating spreading rates is provided in Appendix C.

Table 11.6 Piggery pond sludge analysis results

Element	Effluent at work	Wang et al. (2006)[b]	DEEDI data[c]	
			Average	**Range**
Total solids	-		13.1% **wet basis**	6.9-17.1% wet basis
Volatile solids	-		6.9% wet basis	5.3-9.5% wet basis
pH	7.3		-	-
C	-	12-13%	28.1%	22.5-37.1%
Total N or (Total Kjeldahl N)	(2617) mg/L	1.7-2.4%	3.41%	2.84-4.02%
Ammonium N	1156 mg/L	1100 mg/kg	2582 mg/kg	1472-4422 mg/kg
Nitrate-N	-	750-1100 mg/kg	-	-
Total P	1696 mg/L	2.8-3.8%	4.69%	2.83-5.9%
Ortho-P	1082 mg/L		-	-
K	-	6100-8400 mg/kg	0.75%	0.27-1.33%
Sulphur	-	0.58-0.61%	1.99%	1.53-3.08%
Copper	25 mg/L		1.02%	3.43-1.82%
Iron	-		1.17%	0.52 – 2.21%
Manganese	-		1050 mg/kg	786-1389 mg/kg
Zinc	-		3188 mg/kg	2184-3698 mg/kg
Calcium	2210 mg/L		7.08%	4.28-10.4%
Magnesium	-		1.93%	1.0-3.19%
Sodium	108 mg/L		0.52%	0.15-1.40%
Selenium	-		0.59 mg/kg	0.07-2.41 mg/kg
Chloride	232 mg/L		-	-
EC	8.5 dS/m		-	

DEEDI = Department of Employment, Economic Development & Innovation, Qld, [a] Kruger et al. (1995) - samples from piggeries in New South Wales, Queensland and Western Australia, [b] two samples of sludge, [c] Unpublished data – samples from 10 piggeries in southern Queensland.

Table 11.7 Spent bedding analysis results

	Units	Straw[1]	Straw[2]	Rice hulls[1]	Sawdust[3]
Moisture	% wb	41.6 (18-64)	48 (7-74)	36 (21-53)	40.8 (21-50)
pH	% db	6.8 (5.7-8.5)		7.1 (7-.3)	6.3 (6.2-6.3)
Total N or TKN	% db	0.8 (0.2-1.3)		0.7 (0.1-1.6)	0.9 (0.6-1.3)
Ammonium N	% db	0.5 (0-1.2)	2.9 (1.7-4.5)	0.3 (0.1-0.5)	0.6 (0.4-1)
Total P	% db	1.1 (0.2-2.5)		0.9 (0.6-1.3)	1 (0.4-1.3)
Ortho-P	% db	0.4 (0.2-0.6)	1.2 (0.5-2.6)	0.4 (0.3-0.6)	0.4 (0.2-0.5)
K	% db	1.8 (0.6-2.8)	2.0 (0.9-3.8)	1.8 (1.2-2.1)	1.8 (1.6-1.9)
Sulphur	% db	0.4 (0.1-0.7)	0.6 (0.4-1.0)	0.4 (0.3-0.5)	0.5 (0.4-0.5)
Copper	% db	0 (0-0.1)	0.01 (0-0.05)	0 (0-0)	0 (0-0)
Iron	% db	1.3 (0.1-3.2)	0.4 (0.09-1)	1 (0.7-1.6)	1.1 (0.5-1.6)
Manganese	% db	0.1 (0-0.8)	0.04 (0.02-0.06)	0.2 (0-0.8)	0.3 (0-0.8)
Zinc	% db	0.2 (0-0.4)	0.1 (0.03-0.4)	0.1 (0-0.3)	0.1 (0.1-0.2)
Calcium	% db	1.9 (0.4-3.1)	2.5 (0.9-5.4)	1.4 (1-2.1)	2.4 (2.1-2.7)
Magnesium	% db	0.7 (0-1.8)	0.04 (0.02-0.06)	0.4 (0-0.6)	0.4 (0-0.7)
Sodium	% db	0.4 (0.1-0.7)	0.7 (0.2-1.8)	0.3 (0.1-0.4)	0.4 (0.4-0.5)
Chloride	% db	0.8 (0.3-1.3)		0.6 (0.4-0.8)	0.7 (0.4-1.1)
EC	dS/m	11.7 (6.6-15.6)		9.6 (9.2-10)	13 (12.6-13.4)

Notes: Data provided as average and range (in brackets)

Nutrient contents based on a combination of fresh, stockpiled and composted spent bedding

Sources: 1 Black (2000); and Nicholas et al. (2006), 2 Craddock. (2011), 3 Nicholas et al. (2006)

11.4.2 Spreading equipment

Manure spreaders are designed for spreading relatively dry aged and composted solids. They should apply the nutrients in the manure and compost evenly and at the target rates. The most suitable spreader will depend on the:

- amount of material for spreading
- quality of the material
- proposed spreading rate.

Most manure spreaders are rear or side discharge systems with capacities of 1-20 t.

There are a number of features to consider when selecting a spreader. These include:

- Spreading pattern and width: to ensure an even spreading pattern and application rate are achieved. Some spreaders have an effective spreading width of 2 m while European specialised manure spreaders have a spreading width of up to 10 m. A greater spreading width reduces soil compaction.
- Horizontal versus vertical beaters: vertically-mounted beaters generally spread over a larger area with each pass, throwing manure beyond the width of the spreader. Horizontal beaters usually only spread about the width of the spreader. The beaters break up the lumps, enhancing spread ability of lumpy or high moisture spent bedding.
- Conveyor belt versus moving floor chains: movement of the manure to the back of the spreader can be achieved using a conveyor belt or chain and slats. Conveyor belts may need to be replaced more often as the belt wears more rapidly than the chains. Floor chains offer advantages over belts when spreading inconsistent or high moisture manure. Floor chain systems tend to have less problems with manure bridging when delivering manure to the beaters/spinners compared to conveyor belts. Bridging occurs when moist manure clumps together to form a “bridge” with a space underneath, stopping the feed of manure to the spreading devices.
- Beater/spinner design: the rotation speed of the beaters will affect the width of spread and application rate. Also consider the height at which the beaters are positioned on the spreader. Generally, the greater the height above the ground the greater the width of spread. The compromise is that high spinners or beaters also mean a high centre of gravity on the machine which can result in instability on uneven ground.
- Spreader power requirements: check the power requirements of the spreader in relation to the tractor or truck.
- Most spreaders need a minimum application rate of about 5 t/ha to achieve an even spread, and this may be higher for some spreaders. Fresh lumpy spent bedding is more difficult to spread evenly and is likely to be uneven at rates of less than 10 t/ha.
- Load capacity: larger capacity spreaders offer better efficiency by minimising time between loads. Spreader capacity ranges from under 3 m^3 to 15-30 m^3 models. Some spreaders can be fitted with extension side (“hungry boards”) to increase capacity.
- Design of sides: vertical sides are preferable to angled sides as these are less likely to result in manure “bridging”.
- Engineering: under-engineered spreaders may require increased maintenance (e.g. due to bearing failures, bent shafts) compared to those with more robust engineering.

Operator efficiency influences where manure is spread on the paddock and at what rate. This is especially relevant for spreaders where operation speed influences the rate applied. Ensuring that consistent spacings are achieved between spreader passes is important for covering the whole paddock evenly. GPS guidance aids the accuracy and efficiency of the spreading operation, reducing overlap and missed areas, compared to estimation by the operator.

11.4.3 Practical manure and compost spreading

11.4.3.1 Timing of reuse

The ideal time to spread manure and compost depends on:

- the timing of crop planting and management practices (e.g. cultivation to incorporate manure or compost)
- manure or compost maturity
- soil moisture conditions
- soil fertility
- weather conditions.

In broadacre cropping situations:

- manure or compost is generally spread prior to planting the crop
- cultivation associated with the seeder pass may be used to incorporate the manure
- spreading the manure immediately before sowing minimises N losses from the applied manure.

Spreading manure onto soils with low background nutrient levels just before sowing can result in less vigorous and lower-yielding crops than if inorganic fertilisers had been applied. This can occur because the nutrients in the manure are less available or less accessible for uptake by the plant roots or because N drawdown may occur. N and P are present in manure and compost in both inorganic and organic forms; the latter have to be mineralised into inorganic forms to be available for plant uptake. Most of the K in manure is in the inorganic form and available for uptake.

Nutrients are less accessible if manure isn't incorporated into the soil. N drawdown happens when soil microbes use soil N to break down fresh manure, especially spent bedding. This is less of a concern if the manure is composted, soils already have reasonable nutrient levels, or nutrients are allowed to mineralise over time.

Applying manure 4-6 months before sowing gives time for mineralisation but can increase N losses if manure isn't incorporated. Poor nutrient access can also limit crop vigour. In modern no-till systems, manure is broadcast before planting, resulting in little incorporation and poor nutrient proximity to seedling roots. Where ploughing occurs, spreading manure beforehand allows incorporation.

Reductions in crop vigour may be P-related and addressed with a starter fertiliser in the seed row, often at lower rates than usual. Soil testing helps determine whether inorganic fertiliser is needed alongside manure, with improved testing now offering greater confidence in these decisions.

To avoid transfer of odour and possible pathogen transfers, manure spreading should be avoided:

- under heavy, overcast conditions
- on windy days when manure may be carried off-site
- early in the morning or late in the afternoon when the atmosphere is heavy and dispersion is limited
- close to nearby houses when gentle winds are carrying towards the houses
- close to nearby houses on weekends and public holidays when neighbours are likely to be home.

To prevent erosion of nutrients in manure or compost from the site, avoid spreading if significant rain is expected within 48 hours.

11.4.3.2 Withholding periods

Withholding periods are important for protecting the health of people consuming products grown on manure and compost reuse areas and stock kept on reuse areas. In particular:

- Specific requirements apply to fruit and vegetables, particularly those eaten raw or without processing. Refer to the Freshcare standards for current guidance.
- Broadacre crops (e.g. cereals and oilseeds) and fodder crops should not be harvested within 21 days of irrigation.
- To protect livestock from pathogen risks, a withholding period of at least 21 days is recommended for paddocks that have been irrigated with effluent.

11.4.3.3 Off-site reuse

Some farmers may want to send manure or compost off-farm for reuse. Regulations for the reuse of manure and compost apply in some states. Compost may need to meet specified requirements for sale as compost. Check requirements with the environmental regulator.

Providing end-users with recent analysis data and a duty of care statement (see Appendix D) is recommended.

11.4.3.4 Valuing manure and compost

Appendix E provides a pro-forma for valuing manure and compost.

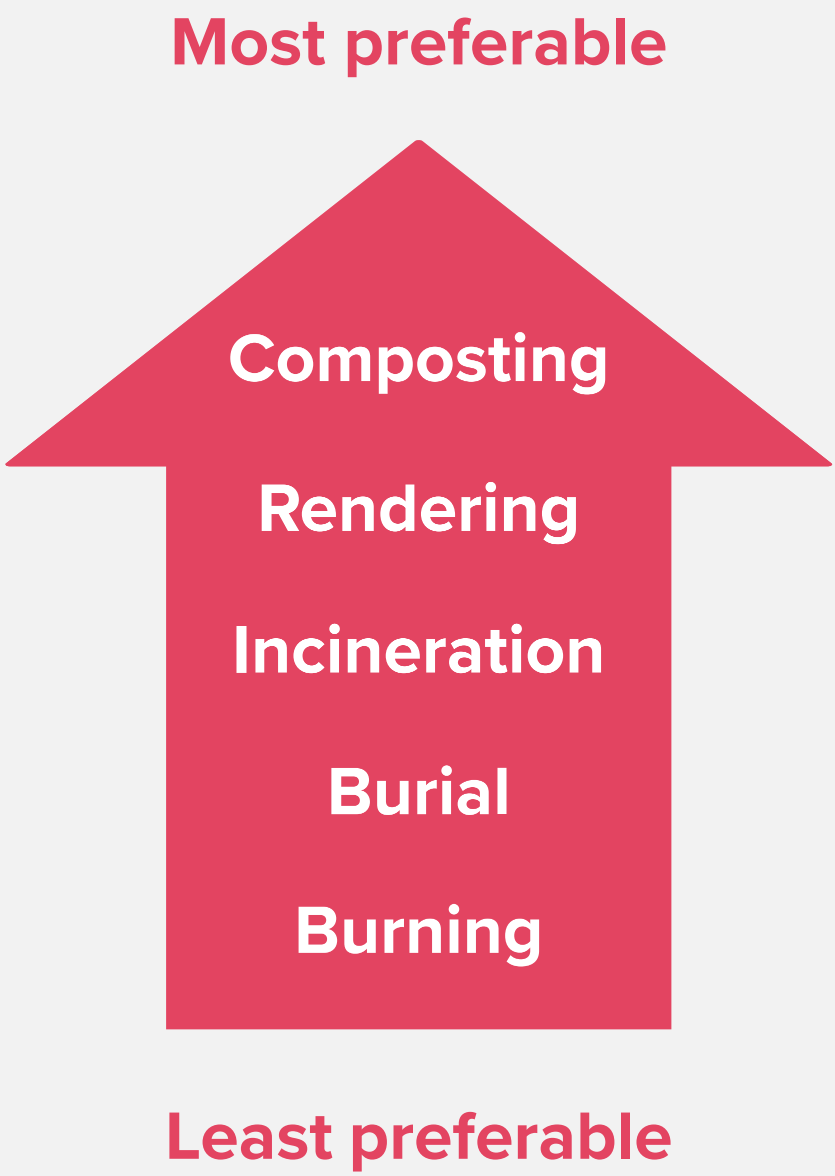
12 Managing mortalities

Good management of mortalities is essential in protecting:

- animal health and biosecurity
- the environment
- community amenity
- public health.

Options for managing mortalities are summarised in Figure 12.1. Each method has advantages and disadvantages.

Figure 12.1 Mortalities management hierarchy



Regardless of the management method used:

- Mortalities should be promptly removed from the pig accommodation to reduce the risk of disease transfer.
- Mortalities should be lifted and carried rather than being dragged so that body fluids are not released.
- Vermin must never be allowed to access mortalities as this could promote the spread of disease.
- Ruminant animals must be prevented from accessing mortalities as these are considered restricted animal material (RAM). Fencing will exclude both ruminants and scavenger animals such as feral pigs.

The number and mass of pig mortalities generally depends mainly on the size and herd composition of the piggery. Sow mortality rates are typically about 7.8%, while the wean-to-finish mortality rate is about 3.5% over all whole progeny (APL 2023). Plans need to be made to handle day-to-day mortalities, as well as those resulting from a mass mortalities event. This might mean providing additional capacity in the solid manure stockpiling or composting area.

Methods include:

- composting
- rendering
- incineration
- burial.

12.1 Composting

Composting has been widely adopted as a mortalities management method because it:

- is suitable at all sites but particularly those with highly permeable soils, shallow groundwater or sensitive receptors where burial or burning is environmentally unacceptable
- produces a soil conditioner that can be spread on cropping land
- generates little odour
- effectively kills most pathogens and weed seeds.

Mortalities composting can be undertaken using bays, bunkers or windrows set-up within a bunded area with an impermeable base. Often this will be part of the manure stockpiling or composting area since similar design and construction standards apply (see Appendix A for a pond and pad permeability specification).

In conventional composting processes, raw materials are mixed to provide a consistent mixture with a C:N ratio of ~20-40:1, a moisture content of ~45-65% and good porosity that is then regularly turned. However, mortalities composting needs to operate differently because pig bodies have a large mass, a high moisture content, a low C:N ratio and almost no porosity. Consequently, in the initial stage, the decomposition process close to the bodies is anaerobic. The fluids and gases released then move to an aerobic zone.

Like any composting process, mortalities composting requires adequate:

- carbon
- nitrogen
- oxygen
- moisture
- management.

Mortalities need to be composted with a co-composting material that:

- provides a good source of carbon to balance the high nitrogen content of the carcasses
- absorbs moisture
- introduces the oxygen needed by the aerobic microorganisms
- covers the mortalities to reduces odour releases that cause nuisance and attract vermin.

Recommended co-composting materials include:

- sawdust or wood shavings. These are an excellent carbon source (C:N ratio of 200-500:1 depending on the tree species). As sawdust has lower porosity than straw or wood shavings; blending sawdust in a 2:1 ratio with straw or wood shavings is recommended to ensure there is adequate oxygen
- straw
- rice hulls
- spent bedding
- compost blended with fresh co-composting material (50:50 mix)
- hot-mix between layers of pigs as this can accelerate the process. Hot-mix is organic material that is already actively decomposing and generating heat.

About 1.5-2 t of co-composting material or ~4.2 m^3 per tonne of carcasses is usually required.

Pig carcasses contain enough N to supply the composting process. However, because this is not evenly mixed through the co-composting material, the material around the carcass readily composts while the material further away does not. This problem can be overcome with turning after the initial phase.

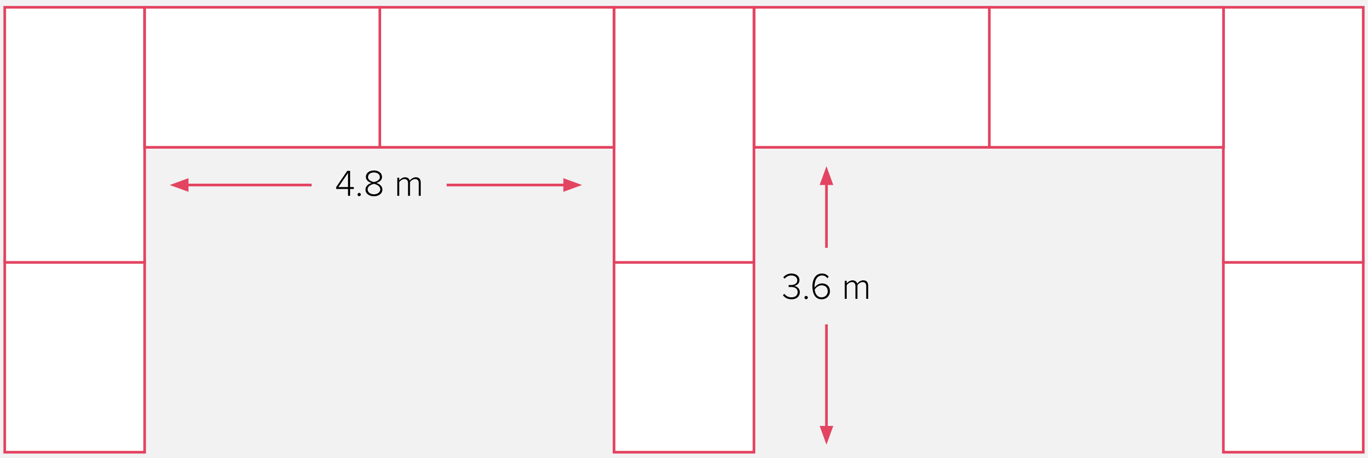
The right amount of moisture is needed to optimise the composting process. While decaying carcasses generally supply enough moisture, wetting the carcassesas they are added to the pile (one part water or effluent to three parts carcasses by volume) may accelerate the process by generating more microbial activity and heat. However, too much water (>60%) restricts air movement and results in odour, though excess moisture is unlikely to be a problem if the piles shed rainfall.

In Australia, pig mortalities are usually composted in bays or bunkers (like silage bunkers), although they can be composted in windrows.

For bay composting:

- The bays are often formed from large, square hay bales that are placed end-to-end to form a three-sided enclosure, but they can be formed from tilt-up concrete walls or other materials.
- At least two bays are needed – one for filling and active composting, one for curing (allowing partly composted materials to complete the process at lower temperatures).
- The number and volume of bays depends on the mass of mortalities produced per composting cycle.
- At least three months of composting time (from the placement of the last carcass) and three months of compost curing time is recommended.
- 2-2.5 m^2 of bay area or 4 m^3 of volume is needed for each tonne of mortalities produced annually.
- Two sets of bays made from 20 large square bales (i.e. walls stacked two to three high) could provide 17.3 m^2 of floor area per bay (see Figure 12.1). The bin height is 1.8-2.4 m depending on bale size. These bays should be sufficient for a piggery losing about 7-9 t/yr of pigs.

Figure 12.2 Plan view configuration of bays for mortality composting



For windrow composting provide 0.7 m of windrow length per tonne of mortalities produced annually for windrows with a base width of 3 m and a height of 2 m, or 0.5 m of windrow length for windrows with a base width of 4 m and a height of 2 m.

In Australia, most carcass composting systems use low input management. The recommended mortalities composting process involves:

- setting down a layer of co-composting material at least 300 mm thick on an impermeable base such as sawdust, straw, spent bedding or compost blended 50:50 with clean material, to provide carbon close to the underside of the carcasses and absorb leachate
- placing each body on this layer and opening the thoracic cavity of larger carcasses to release gases that accumulate in the abdomen during decomposition, reducing the likelihood of carcass exposure due to bloat
- completely surrounding the bodies with a good layer of co-composting material (at least 300 mm) to ensure no part is exposed. Using hot-mix (composting material still in the active or heating phase) can accelerate the process
- placing further layers of carcasses on top with 300 mm of co-composting material in between each layer and covering with at least 300 mm of co-composting material
- capping the pile with 300 mm of sawdust, straw or spent bedding to:
  - provide a carbon source
  - act as a biofilter (reducing odour and GHG emissions)
  - act as a barrier for vermin
  - assist in shedding water.
- monitoring the process by checking the temperature within the pile to ensure hot temperatures are achieved and sustained for at least three days
- turning the material (windrow) or moving it from one bay to the next (bay composting) about three months after the last carcasses were added. This mixes the material, improves air flow and accelerates the process. If soft tissue remains, add more carbon before recapping. If not turning the material, composting should continue for at least 9-12 months.
- allowing the compost to cure for a further 3-6 months once the active phase is complete and the pile temperature drops.

The finished material can be spread on land. However, some states do not allow mortalities compost to go off-farm for this purpose, as pathogen elimination is not guaranteed.

If pasteurisation is required, the compost must go through at least five turns after maintaining a temperature of 65°C for three consecutive days (including any turns within bats before moving piles to windrows).

Testing can confirm whether pasteurisation has been achieved.

Stock should not access mortality compost reuse areas for at least three weeks after spreading to allow for sufficient pasture growth to adequately minimise the risk of restricted animal material (RAM) ingestion; however longer periods of ruminant exclusion are required when pasture growth or rainfall are low. The nutrient value of the finished compost depends on:

- the type of cover material
- management practices
- whether the material has been recycled for several batches.

When sawdust is used as a bulking agent, typical nutrient analysis is 1.5% N, 0.5% P and 0.3% K when sawdust is used as a bulking agent (DAFF 2010).

12.2 Rendering

Rendering is an excellent mortalities management option as it:

- requires little management (for the piggery)
- produces few environmental impacts
- converts mortalities into meat and bone meal, meat meal and other products.

However, it is generally only feasible if the piggery is located close to a rendering plant. Mortalities need to be stored:

- on a bunded area with an impermeable base while they await collection
- in a cold room if same day collection is not possible.

Since a rendering plant may refuse mortalities depending on the cause of death, alternatives need to be in place.

12.3 Incineration

Correct incineration is rarely used on-farm. It requires expensive specialist equipment, similar to that used for disposal of clinical wastes. These typically include a:

- complex multi-chamber unit or a pyrolysis system
- final chamber that operates at 1,000°C with a residence time of at least one second to incinerate the odorous gases that may result from destruction of the carcass.

12.4 Burial

Burial:

- may be an easy and convenient mortalities disposal option
- may be prohibited or discouraged as poorly managed burial may pose a risk to:
  - amenity
  - public health
  - groundwater contamination risk, particularly in areas with porous soil and shallow groundwater
- requires immediate covering of mortalities after placement to control odour that may cause amenity issues and attract vermin and scavenger animals
- may be permissible under the direction of the Chief Veterinary Officer in response to a disease outbreak or mass mortalities incident.

If burial is used:

- the pits should be sited on clay soils or lined with a clay layer
- the base of the pit should be at least 2 m above the highest water table
- earthen bunding around the pit should exclude stormwater runoff
- splitting the thoracic cavity of larger carcasses will release gases that accumulate in the body during decomposition, reducing the likelihood of exposure of bodies due to bloat
- each body should be completely covered with at least 300 mm of soil immediately after placement.

- filled pits should:
  - be covered with a further 300 mm of compacted clay soil
  - have a mounded shape as this helps to shed water and provides fill to compensate for subsistence of the bodies as they break down
  - be grassed over
  - not have trees planted over them.

Above-ground burial:

- is a hybrid of trench burial and composting
- may be an option when deep burial is not possible due to shallow groundwater or when co-composting materials are difficult to access
- needs to be done in a way that protects groundwater:
  - the base of pits should have a reasonable clay content
  - be >2 m above the shallowest seasonal water table
- trenches are easier to excavate than deep burial pits, although the footprint will be much larger.

Above-ground burial involves:

- digging a shallow trench (0.5-0.6 m deep)
- placing 300 mm of co-composting material over the base of the trench
- laying a single layer of carcasses on top
- covering these with 100-150 mm of co-composting material (optional)
- immediately covering mortalities and co-composting material with 500 mm of excavated earth that is graded to promote runoff
- grassing over filled trenches.

12.5 What not to do with mortalities

Mortalities should not be:

- burnt in open fires (unless under the direction of the Chief Veterinary Officer), as this releases smoke, odour, GHG and sometimes biological matter
- dumped in paddocks as this may cause odour nuisance and attract insect pests and scavengers, posing a biosecurity risk.

12.6 Mass mortalities management

Mass mortalities may result from natural causes or emergency disease outbreaks. Effective responses to emergency disease outbreaks require effective planning. This means having a plan in place should the worst situation happen. Suitable management options will depend on the site and cause of death (natural versus emergency disease event).

A suitable area:

- should be identified in advance
- could be on- or off-farm (e.g. land fill)
- must be readily accessible
- should be well separated from:
  - sensitive receptors and land uses
  - watercourses and flood prone land
  - groundwater and bores
- ideally will have low permeability soils or can be lined with low permeability material.

12.6.1 Natural causes

Natural causes could include deaths from fire, flood or high temperatures. Suitable management methods could include:

- composting
- rendering
- incineration
- burial
- land fill.

12.6.2 Emergency animal disease disposal

State government veterinary officers should be contacted immediately if a disease outbreak is suspected. They will provide advice on the appropriate disposal method for the given situation. The latest version of the *AUSVETPLAN Operational Manual: Disposal* (AHA 2021) and the *AUSVETPLAN Enterprise Manual: Pork Industry* (AHA 2021) provide practical information for managing mass mortalities disposal.

Although many decisions regarding disposal may be out of the hands of producers, being pre-prepared can facilitate a more rapid response and earlier re-entry back into production.

13 Chemical use, storage and handling

It is important to carefully use, store and handle chemicals as they have the potential to impact human health, air, land and water.

Each state has its own legislation and mandatory requirements for chemical use, storage and handling. Factors to consider to reduce environmental risk include:

- selecting chemicals with a low toxicity and low water contamination potential
- minimising the quantities of chemicals in storage and used
- storing and using chemicals and fuels in accordance with manufacturer's directions and workplace health and safety codes of practice
- having an emergency response plan and spill kits or absorbance material in place in case of a chemical spill
- storing and preparing chemicals in bunded areas with impermeable flooring
- correctly installing underground petroleum storage systems (UPSS) and ensuring these have an effective leak detection system
- using chemicals only for the intended purpose and in accordance with instructions
- ensuring fly and rodent baits are not accessible by pigs (refer to the *Industry Rodenticide Stewardship Plan* (APL 2021)
- disposal of empty chemical and vaccine drums and containers in accordance with manufacturer's instructions
- disposal of sharps in a suitable container and in an appropriate manner
- having material safety data sheets (MSDS) for all chemicals stored and used
- maintaining records of chemical use
- ensuring staff are suitably trained and hold current accreditation (where required) for the safe use and handling of chemicals
- providing staff with personal protective equipment to use when handling and using chemicals
- using accredited chemical contractors when required.

For further information on chemicals storage and handling see *AS2507-1998 The Storage and Handling of Agricultural and Veterinary Chemicals* (Standards Australia 1998).

14 Stormwater management

Stormwater is surface runoff from roofs, the ground and other hard surfaces resulting from rain and storms. Stormwater should be kept separate from manure and other contaminants to preserve the clean water as a resource for use in the piggery or elsewhere. For conventional piggeries, it can significantly reduce the volume of effluent for management and reuse.

To that end:

- Any construction needs to be carefully managed to prevent erosion and subsequent sediment entry into stormwater.
- The flooring and drainage system for the piggery should be managed to exclude the ingress of clean stormwater runoff and prevent the discharge of effluent, manure or potentially contaminated stormwater to adjacent areas.
- Prevent roof runoff from eroding soil under eaves and contaminating stormwater by installing gutters or hard material on the ground under eaves.
- Any area where manure, compost or mortalities are managed should have bunding to exclude the ingress of clean stormwater and the egress of contaminated runoff.
- Regularly inspect and maintain bunds, banks and other stormwater control structures to ensure they remain effective.

15 Traffic management

Traffic management should provide safe, effective and efficient all-weather access for vehicles that need to access the site. This is usually considered in the planning and construction phase. However, as part of ongoing management:

- Roads need to be maintained to provide all-weather access.
- Emergency vehicles must have clear access at all times.
- Clear signage of speed limits must be provided for safety and to minimise dust.
- Clear signage showing biosecurity check-in requirements and areas that are off-limits should always be maintained for biosecurity reasons.
- Suitable on-farm parking should be provided for staff and other expected vehicles.
- Signage should clearly identify that parking is not permitted in front of biogas installations.

Noise and light from traffic movements can annoy nearby residents. To protect community amenity, vehicles should be scheduled to occur during the day on weekdays to the extent possible. However, it is recognised that for welfare reasons, pig transport should be avoided in hot weather. Night or early morning transportation may be necessary in summer. Consider advising neighbours before this occurs.

Truck drivers and staff should be trained to drive carefully on local roads. Use of air brakes should be minimised.

16 Amenity protection

16.1 Odour management

Odour is the most common cause of nuisance by piggeries. It is helpful to understand the factors contributing to odour nuisance. These "FIDOL" factors include:

- Frequency of occurrence
- Intensity or strength
- Duration of exposure
- Offensiveness or character of odour
- Location of potential receptors.

The strength of an odour declines with distance from the source as the odour mixes with the surrounding air. Other factors affecting odour dispersion in a given direction include:

- terrain
- surface roughness e.g. vegetation
- wind patterns
- atmospheric conditions.

Some odours happen continuously (e.g. odour from an effluent pond) and are difficult to control quickly. Others relate to activities and actions where the timing can be controlled. Scheduling these activities in consideration of wind patterns and atmospheric conditions can reduce the risk of nuisance odour.

For example, effluent irrigation and manure or compost spreading are activities with flexible timing, allowing for odour control. Managing this effectively requires a basic understanding of atmospheric conditions, as these drive odour dispersion. The different types of atmospheric conditions are:

- Unstable atmospheres:
  - occur on warm sunny days when hot eddies of air rise from the land surface and cause significant mixing of the atmosphere
  - promote rapid dispersion of odour, quickly reducing odour intensity away from the source
  - promote rapid dispersion
  - provide good conditions for undertaking odour generating activities.
- Neutral atmospheres:
  - occur on heavy overcast days
  - provide only moderate odour dispersion
  - may be suitable for undertaking odour generating activities (if needed) with good management.
- Stable atmospheres:
  - occur on cold, still clear nights when the air at the land surface stays cool and remains trapped below an inversion layer
  - result in little atmospheric mixing occurs below the inversion layer
  - restrict odour dispersion with odours remaining at relatively high intensities at some distance from the source
  - provide conditions that are unsuitable for activities that will release significant odour.

16.1.1 Odour sources

Odour can be emitted from a range of sources at a piggery, including:

- sheds
- channels, drains and pipes
- sumps
- solids separators
- effluent ponds
- manure or compost storage and management areas
- mortalities management areas
- reuse areas.

The design and standard of management of these influences how much odour they release. Generally more odour is created when effluent is agitated (e.g. pull plugs released, effluent dropped into pond, aerated, or irrigated).

16.1.2 Managing odour sources

Methods to manage odour sources are described below.

16.1.2.1 Sheds

Clean, hygienic conditions are vital in minimising shed emissions. It is important to:

- Keep the pigs clean and dry by using suitable stocking densities, maintaining animal health to minimise loose stools, and providing a good shed environment. Dirty pigs smell, as their body warmth encourages anaerobic breakdown of manure on their skins.
- Formulate diets to meet animal needs.
- Minimise feed wastage and dust by using suitable feed milling, pellets, liquid feeding or oils in diets. Replace floor feeding and high-wastage feeders. The expense is offset through reduced feed costs.
- Promptly sweep up and remove spilt or wasted feed.
- Clean flooring and other dirty or dusty surfaces frequently and regularly in conventional sheds. Slatted floors generally stay drier than solid floors.
- Provide good shed ventilation to reduce dust and odours.
- Flush effluent channels at least once a day using sufficient water volume to remove manure solids.
- Empty pull plug pits and static pits at least every one to two weeks, or more frequently if biogas is being collected from a covered pond. Add 5 cm of water to the bottom of the clean pit to prevent manure sticking. Empty different pits on different days to promote even flow of effluent to the treatment ponds.
- Use plenty of bedding in deep litter piggeries (0.5-1 kg straw/pig/day). Change bedding at least once every seven weeks and promptly repair any water leaks that may wet the bedding.
- Collect mortalities, afterbirth and foreign materials before they enter flushing channels or pits.
- For mechanically ventilated sheds, ensure vents release air upwards and run the exhaust fan at a speed that produces adequate mixing.

16.1.2.2 Channels, drains and pipes

Wet manure in channels, drains and pipes is an odour source. Channels, drains and pipes should therefore:

- be cleaned with a sufficient water volume to remove all solids
- be inspected daily (or after each use) with any remaining solids promptly removed.

16.1.2.3 Sumps

Where practical:

- release effluent into the sump close to or underneath the water level
- avoid sump agitation under still conditions or when the wind will carry odour towards neighbours.

If odour nuisance is a serious issue, consider:

- covering sumps
- placing a barrier upwind of the sump.

16.1.2.4 Solids separators

To minimise odour:

- maintain the solids separator to ensure it is effective
- avoid dropping liquid ex-separator into a sump from a height
- regularly transfer wet solids to the manure management and storage area or reuse area.

16.1.2.5 Effluent ponds

Since uncovered primary effluent treatment ponds are a major odour source at a conventional piggery, good management is critical in reducing overall emissions.

To manage effluent ponds:

- ensure a consistent effluent flow to the ponds through regular and frequent effluent channel flushing or pit emptying. Providing multiple inlets to the pond helps to spread the load
- ensure adequate active treatment volume is maintained. The pond outlet should be well separated from the inlets so that all active volume is utilised. Desludge ponds when solids start to impinge on the active volume
- avoid dropping effluent from a height into ponds. Ideally, release effluent under the water surface
- avoid aggressive aeration of ponds
- ensure pond chemistry is suitable for the treatment microorganisms. Aim for a pH of 6.8-8.0. Monitor salinity, particularly if effluent is recycled as flushing water, and dilute with fresh water if necessary
- consider potential impacts to neighbours when planning pond desludging.

16.1.2.6 Manure management and storage areas

To minimise odours from manure management and storage areas:

- limit the quantity of manure kept on-hand, although it may be necessary to provide capacity for 6-12 months manure to fit in with cropping cycles
- promote good drainage so water doesn't pool around manure piles
- consider blending very wet manure solids with drier material and regularly turning the manure to promote drying
- avoid turning or handling very dry manure, particularly under windy conditions. The dust produced can transport odour. Ideally wet the manure before handling using high pressure jets along the sides or micro-sprinklers along the window apex. Take care not to over-wet the manure or create runoff
- consider capping manure or compost piles with a high carbon material (e.g. straw or sawdust) or cured compost if odour is an issue.

16.1.2.7 Mortalities and afterbirth

To minimise odour, ensure:

- mortalities are removed from sheds within 24 hours of discovery
- extraneous stormwater is excluded from burial pits and composting areas
- composting mortalities are continually kept surrounded by at least 300 mm of bulky, high carbon material like sawdust. This is necessary for the composting process, but also acts as a biofilter to minimise odour
- buried mortalities are well covered with soil immediately after placement
- incineration of mortalities is only done using a purpose-built unit (see Section 12.3).

16.1.2.8 Reuse

Reuse of effluent and manure offers many benefits to farming systems. To prevent it from creating a nuisance:

- schedule reuse to occur at times when odour is less likely to cause nuisance (refer to Section 16.1.2.9)
- develop an annual reuse plan that considers seasonal wind directions, rainfall patterns and cropping plans. Different paddocks might be selected for reuse at different times of the year depending on risk
- avoid effluent irrigation onto wet soil, as it may stay on the surface where it remains an odour source.

- choose irrigation methods that minimise aerosol production. Aerosols are fine liquid droplets, or solids, suspended in air and can carry odour long distances. Use low pressure spray irrigators, tankers, travelling drip irrigators, surface irrigation systems or direct injection rather than high pressure spray irrigation
- spray or drop effluent, manure and compost close to ground level
- spread moist solids under warm conditions in thin layers to encourage drying
- avoid spreading very dry solids under windy conditions as dust produced can transport odour
- promptly incorporate manure and compost into the soil, if practical.

16.1.2.9 Managing the timing of odour releases

People vary in their sensitivity to odour. However, odour is more likely to create a nuisance if it occurs at times when neighbours are relaxing or socialising at home. There are opportunities to reduce odour impacts by controlling the timing of certain activities and by planning reuse areas according to prevailing wind direction throughout the year.

Aim to understand when odour is likely to be an issue for neighbours and manage the timing of controllable odour releases accordingly. This may be achieved by:

- building and maintaining a relationship with neighbours
- encouraging two-way dialogue and understanding the times when odour is likely to cause most nuisance
- contacting neighbours before scheduling odorous activities so they know what to expect, particularly infrequent activities like pond desludging. People are more tolerant if they understand that the increased odour is an infrequent event (e.g. annual manure spreading or desludging) or will only last for a short time
- contacting neighbours if conditions change and they are more likely to be affected by odour, to advise of the source and how long it is likely to last.

To minimise nuisance:

- schedule short-duration, regular activities like pit flushing or emptying to occur when neighbours are less likely to be home and good odour dispersion is expected, (mid-morning to mid-afternoon is usually the best time)
- undertake time-flexible activities, like effluent irrigation, manure spreading, manure turning or manure transport when conditions are conducive to dispersion. Avoid early morning, evening and overcast days
- use a wind vane or weather station so you know the wind direction, and how it might affect a particular neighbour, before commencing an activity that will generate odour and reschedule time flexible activities
- avoid scheduling odorous activities for weekends or public holidays
- consider the seasonal wind direction when developing an annual reuse plan, taking into account the location of different reuse areas in relation to sensitive neighbours, e.g. plan to use different areas when the wind is least likely to carry odour to sensitive houses or communities
- try to condense manure spreading, which often has to fit in with cropping cycles, into a short time frame to limit the length of exposure time for neighbours
- train all staff in odour dispersion.

16.1.2.10 Troubleshooting

To prevent odour issues, regularly review the operation of the whole piggery. If issues arise, consider having a piggery odour expert inspect the site to identify and prioritise potential problem areas that need to be addressed. Odour surveys may also be useful. Implement improvements for any major sources and areas that are easy and cheap to address.

If problems persist, consider:

- covering sumps or ponds
- tub-stacks with curved bases on fans ex-sheds to redirect odour upwards. Seek professional advice before considering stub-stacks
- placing as close as possible to the sources and upwind of odour sources so wind doesn't carry odour off-site. For a sump or other small source, add a barrier around three of four sides
- covering mortalities composting bays
- installing visual screens like trees or earthen banks to help stop neighbour from "seeing" odour. Well-designed, suitably located tree buffers promote air mixing and filter odour and dust. When placed upwind of effluent treatment ponds or manure storages they can reduce emissions by decreasing the wind speed over these sources.

16.2 Dust control

Dust from on-farm activities and traffic movements can cause nuisance for neighbours. Separation distances from the piggery complex for odour are often greater than those than those needed to prevent dust nuisance from on-site activities since dust generally settles over relatively short distances. However, other dust sources such as manure and compost reuse areas and unsealed roads may be located closer to sensitive receptors. Separation distances should not be a substitute for good management.

16.2.1 Dust sources

Potential dust sources at piggeries may include:

- feed mills
- sheds
- manure and compost management and storage areas
- mortalities management areas (if composting)
- manure or compost reuse areas
- traffic movements.

The siting, design and management of these influences the amount of dust released.

16.2.1.1 Managing dust sources

Control measures for the various dust sources follow.

16.2.2 Feed mills

Feed mills may generate dust. To minimise this:

- enclose equipment where practical
- regularly clean and service equipment.

16.2.3 Sheds

To minimise dust nuisance from sheds:

- use suitable feed milling, pellets, liquid feeding or oils in diets
- use enclosed feed delivery and distribution methods
- replace floor feeding and high-wastage feeders where practical; the expense is offset through reduced feed costs
- regularly inspect and maintain feeders
- frequently and regularly clean flooring and other dirty and dusty surfaces in conventional sheds
- maintain bedding in deep litter shelters (although this will usually be wet enough to suppress dust)
- provide good shed ventilation to reduce dust
- regularly clean fans if using mechanical ventilation
- use suitably located tree buffers to promote air mixing and filter dust from the air.

16.2.4 Manure and compost management and storage areas

For manure and compost management and storage areas:

- Avoid turning or handling very dry manure or compost, particularly under windy conditions. If necessary, wet the manure before handling.
- Cover loads when transporting spent bedding and other dry manure or compost.

16.2.5 Mortalities management areas

If composting mortalities:

- Avoid turning or handling very dry manure or compost, particularly under windy conditions. If necessary, wet the manure before handling.
- If dust from mortalities composting is an issue, consider capping with sawdust or other suitable material that will not blow away.

16.2.6 Reuse areas

To minimise the risk of dust nuisance from reuse areas:

- Avoid spreading very dry solids, particularly under windy conditions.
- Promptly incorporate manure into the soil, if this is practical.

16.2.7 Traffic movements

To manage traffic-related dust:

- Use appropriate speeds on unsealed roads (on and off-farm).
- Maintain the standard and surface of on-farm roads.
- Use water or other dust suppressants as needed.

16.2.8 Troubleshooting

If additional controls are needed to suppress dust, consider:

- covering manure, compost and mortalities piles with materials that will not be blown away
- using routes with sealed roads or greater distances to houses (where practical)
- putting barriers as close as possible to the source and upwind of manure and compost sources so wind doesn't carry dust from these off-site
- installing well-designed, suitably located tree buffers to promote air mixing and filter odour and dust.

16.3 Noise control

Noise is seldom an issue for piggeries as they are usually well separated from houses. However, noise may become a nuisance if activities such as manure or compost spreading and traffic movements occur close to homes. Separation distances should not be a substitute for good management. Managing the timing of noisy activities can often minimise the likelihood of nuisance.

16.3.1 Noise sources

Noise sources at a piggery could include:

- pigs (vocalisation)
- mechanical equipment
- vehicles, tractors and other similar equipment
- alarms.

16.3.2 Managing noise sources

Methods to manage noise sources are described below.

16.3.2.1 Pigs

Pig squealing can be loud. To minimise the likelihood of nuisance:

- Use ad lib feeding.
- Avoid hand feeding or hand feed at times when noise is less likely to create nuisance.
- Minimise disturbances and stress for pigs.
- Avoid moving pigs at night/early morning except where necessary for welfare reasons (heat load).

16.3.2.2 Mechanical equipment

For mechanical equipment:

- Minimise noise at the source through careful equipment selection.
- Ensure equipment is fitted with appropriate mufflers.
- Regularly inspect and maintain equipment.
- Use equipment in accordance with manufacturer's recommendations.
- Suitably enclose equipment where needed.
- Consider the timing of use for mechanical equipment. Using equipment during the day generally causes less nuisance than using it in the evening and at night.

16.3.2.3 Vehicles, tractors and other machinery

To manage traffic-related noise:

- Ensure vehicles are fitted with appropriate mufflers.
- Regularly inspect and maintain vehicles.
- Train staff and contractors to drive to road conditions.
- Avoid the use of air-brakes.
- Where practical, schedule vehicle movements at times that are less likely to cause nuisance. Noise from heavy vehicles is more likely to disturb neighbours at night or on weekends, so aim to operate during weekdays and daylight hours. Movements outside these times may be necessary for animal welfare (e.g. heat load) or other extenuating circumstances.

16.3.2.4 Alarms

External alarms may create a noise nuisance. Where practical use app-based alerts for breakdown warnings. Note: this may not be appropriate for some alarms such as fire or other safety alarms.

16.3.3 Troubleshooting

If noise problems persist, consider:

- using sound-absorbing materials around equipment where needed
- using earthen berms or tree buffers to absorb and deflect noise
- using routes with greater distances to houses in needed and where practical.

16.4 Visual amenity

Landscaping can be used to reduce the visibility of a piggery, if this is a concern. It may also help in reducing odour complaints by removing the visual reminder of the piggery from a neighbours' view.

To enhance visual amenity:

- Consider the visibility of the piggery from nearby houses and public roads and where screening may improve visual amenity.
- Use vegetative screening or earthen bunds as needed. For vegetative screens:
  - select a mix of plants that provide coverage from the ground up
  - use different species of mixed heights to help disperse odour and dust, and absorb noise
  - select plants that need minimal upkeep and will thrive under site conditions, for example plants indigenous to your location
  - look after plantings during establishment (e.g. watering, fertiliser application and use of tree guards and stock-proof fencing)
  - replace diseased or dead plants in established screens.

Any landscaping must be located where it will not compromise airflow to naturally ventilated sheds.

16.4.1 Light spill

Light can cause nuisance if it interferes with people living nearby. This can include light from the piggery complex (although this is rarely an issue due to separation distances) and light from traffic movements. Light spill can be managed by positioning or baffling external lights so they don't shine towards nearby houses and scheduling vehicle movements to occur during the day where practical.

17 Biosecurity and health considerations

Good biosecurity is imperative in protecting the high health status of Australian piggeries. Maintaining high standards also protects the health of those working or living near piggeries.

17.1 Protecting biosecurity

Protecting biosecurity includes:

- developing and implementing a site-specific biosecurity plan
- displaying biosecurity signage at all entry points
- managing the entry of all people and vehicles coming onto the piggery
- carefully sourcing and quarantining pigs coming onto the farm from outside farms
- ensuring swill is not fed. Feeding swill to pigs is illegal in Australia since foods that either contain meat or may be contaminated by meat may contain viruses that are extremely harmful to the health of pigs, other livestock and even humans
- requesting commodity vendor declarations to ensure feed is always fit for purpose
- maintaining clean conditions within sheds
- effectively managing pests and vermin particularly feral pigs (see Section 17.2)
- preventing livestock access to mortalities, manure and compost management and storage areas as these materials are restricted animal materials (RAM)
- implementing suitable livestock withholding periods for reuse areas due to RAM considerations (see Sections 11.3.3.2 and 11.4.3.2)
- inspecting feed commodities and bedding for weeds seeds
- monitoring the piggery surrounds and reuse areas for weeds and controlling appropriately.

Further information is available on the APL website https://australianpork.com.au/biosecurity and at www.farmbiosecurity.com.au.

17.2 Control of pests and vermin

Flies, mosquitoes, rodents, birds, feral pigs, and other pests and vermin may pose a biosecurity risk. It is important to use an integrated approach by eliminating habitats, keeping facilities clean and using targeted control measures. These could include:

- fencing the piggery complex, including manure management and storage areas and mortalities management areas to prevent access by feral pigs and scavengers
- minimising vegetation close to sheds, around effluent ponds, and around and in other water storages
- eliminating stagnant water sources that provide breeding sites for mosquitoes and attract waterfowl and feral animals
- maintaining buildings to minimise habitats such as holes in walls where pests and vermin may live
- maintaining clean conditions within sheds to avoid odour
- keeping feedstuffs and feed in vermin-proof storages
- cleaning up feed spills that may attract pests and vermin
- strategically using target-specific, environmentally safe baits for rodents and insects
- implementing a control program for feral animals as required.

Pigs must not have access to baits because this can result in a breach of chemical residue limits affecting future market access. The *Australian Pork Industry Rodenticide Stewardship Plan* (APL 2021) provides further information.

17.3 Worker safety

Worker safety must be considered in all aspects of piggery operation. Like any workplace, state and territory occupational health and safety regulations apply. Suitable measures and training are essential. For some activities, certification may be required.

To protect worker safety in relation to effluent and manure management it is particularly important to:

- prevent anyone accessing confined spaces such as pits, tanks or silos unless confined spaces training has been undertaken and all requirements are followed
- display prominent warning signs on:
  - enclosed pits and other confined spaces
  - effluent ponds (including covered ponds) and other deep water
  - biogas installations which may release gases (flammable and toxic)
  - chemical storage areas
  - other relevant areas.
- display signs alerting people to dangers such as:
  - toxic gases, particularly within confined spaces
  - deep water and drowning risks
  - smoking or using equipment that may spark near gas or biogas installations
  - flammable and harmful chemicals.
- eliminate drowning risks on effluent pits, sumps and ponds through the use of covers and fencing. Staff should also be trained in the dangers pertaining to working close to deep water
- design ramps to ponds or pits such that they are wide and structurally stable enough to support service vehicles
- provide appropriate personal protective equipment (PPE) and encourage staff to use it
- ensure appropriate storage, use and disposal of chemicals, pharmaceuticals and containers. Chemical user training is required for the use of some chemicals
- develop and implement a Biogas Safety Management Plan for farms with biogas systems alinging with the APL *Code of Practice for On-farm Biogas Production and Use* (Piggeries) (Davidson et al. 2013) and all relevant legislation.

17.4 Public health

Public health risks are usually low because most piggeries are well separated from houses and site access is very restricted. However, reuse areas may be closer to neighbouring houses and may pose different risks.

APL has investigated the pathogens present in pig effluent and the public health risks associated with effluent reuse (Blackall 2004 and Blackall 2001). The research found that Australian piggery effluent contains a much narrower range of pathogens than human sewage and lacks many major pathogens of concern in sewage reuse, such as Vibrio cholerae and human pathogenic viruses like noroviruses. The only virus likely to be present–rotavirus–does not generally cross the species-host barrier. Of the pathogens potentially present in piggery effluent, *Campylobacter, Salmonella, Erysipelothrix* and *E. coli* (as an indicator organism) are probably of most interest from a public health perspective. Analysis of effluent from the effluent ponds of 13 south-east Queensland piggeries identified low campylobacter counts in eleven final ponds, and low *Salmonella* counts in only three. *Erysipelothrix* and rotavirus were not detected in any final pond.

Using a quantitative microbial risk assessment based on effluent reuse for turf irrigation, the study found that relatively small separation distances (e.g. 125 m at 0.5 m/s wind speed and 300 m at 2.5 m/s) were sufficient to minimise health risks from aerosolised *Campylobacter* and *Salmonella*.

Measures that minimise public health risks include:

- providing separation distances from the piggery complex and reuse areas to sensitive land uses
- selecting low-risk crops for reuse, for example avoiding human food crops that may be eaten raw or without processing
- selecting an effluent irrigation method that minimise aerosols (e.g. low pressure spray or droplet irrigation with application of effluent close to the ground)
- aging or composting manure prior to spreading to reduce pathogen loads
- avoiding the spreading of dry manure or compost as this may create dust
- avoiding effluent, manure or compost reuse under weather conditions that may carry aerosols or dust to sensitive land uses
- ensuring a minimum 21 day withholding period between reuse and plant harvest for broadacre crops to allow for UV penetration and wind desiccation
- adhering to Freshcare Standards (for human food crops)
- using good reuse practices (refer to Section 11).

18 Environmental risk assessment

The purpose of an environmental risk assessment is to identify risks that a piggery may pose to the environment and then manage these to minimise the likelihood of harm. It must consider inter-related factors and how to minimise or mitigate all environmental risks through design, management or monitoring. A risk assessment provides opportunities to demonstrate that risk is being minimised, or to improve design or operation to further reduce risk.

It is important to undertake an environmental risk assessment when there are planned changes to the siting, design or management of a facility or reuse area.

An environmental risk assessment process involves:

- identifying the hazards or ways in which the piggery may pose an environmental risk, e.g. an effluent pond spill could pose a risk of elevated nutrient levels in watercourses
- considering the level of consequence if the hazard were to occur (low, minor, moderate, major or severe)
- considering the likelihood of occurrence (rare, unlikely, possible, likely or and certain)
- evaluating the risk level (low, medium, high or extreme) based on consequences and likelihood:
  - Low risk: siting, design and management are acceptable
  - Medium risk: additional controls should be considered and implemented to reduce the risk to low
  - High risk: additional controls must be implemented
  - Extreme risk: additional controls must be implemented immediately; for existing farms, this may include ceasing some site activities
- identifying practical controls that could reduce risk
- re-evaluating the risk level with the new controls in place.

A risk assessment process for piggeries is provided in Appendix F.

19 Risk based environmental monitoring

19.1 Introduction

Environmental monitoring, including using productivity and sustainability indicators to interpret results, is critical to the overall environmental management of a piggery. It provides a mechanism to assess the effectiveness of strategies chosen to minimise environmental risk.

Appendix H provides suggested sampling protocols and methodology for soils, effluent, manure and compost. State environment departments may also have sampling methodologies and analysis requirements.

It is extremely difficult to identify indicators of sustainability that cover all situations. In some situations, indicators for determining sustainability may overstate the likely environmental risk. They may also conflict with land productivity. Sometimes alternative indicators or methods may provide a better indicator of sustainability. Consequently, where a significant level of environmental risk or impact is identified, it is critical to investigate the result.

Electronic monitoring equipment can also be used for day-to-day management. Alerts for power, water, effluent system and reuse equipment failures can help to mitigate environmental harm.

19.2 Community amenity

People living near piggeries have the right to amenity, or the comfortable enjoyment of life and property. Odour, dust and noise can create a nuisance, particularly if they occur at times when neighbours want to relax or socialise at home, and this can result in complaints. Good communication with neighbours, and proactive responses to complaints, are fundamental to protecting community amenity.

19.2.1 Community liaison

A good relationship with neighbours helps address nuisance complaints. Aim to build and maintain open communication so sensitivities are understood and issues can be identified and resolved early.

Understand specific neighbour concerns (e.g. odour, road dust or truck noise) and the times of days of the week when the occupants are less likely to be bothered. schedule odorous, dusty or noisy activities and manure or effluent spreading at times least likely to cause nuisance.

A weather station may assist with management. Some automatic weather stations can send notifications to a phone or computer when wind conditions reach certain speeds or directions, enabling proactive management. Encourage two-way dialogue and open, frank discussion.

19.2.2 Routine checks

It is good practice to regularly inspect the site to identify potential causes of odour, dust and noise nuisance so mitigation can be implemented as required. High risk areas like effluent ponds and reuse areas warrant particular attention. This should include checks at the property boundary. Weekly checks are recommended.

19.2.3 Managing complaints

The number or pattern of complaints received is one measure of the impact of a piggery on community amenity. While this measure is imperfect, it helps to identify when receptors perceive that the piggery is unreasonably affecting their enjoyment of life and property.

Manage complaints by:

- talking with the complainant about the issue to find out:
  - what the concern is (e.g. odour, dust, noise)
  - what date and time it occurred
  - how long the nuisance lasted
  - whether the complainant can help identify the cause
  - any other useful information
- investigating possible sources, including:
  - sheds
  - sumps
  - effluent ponds
  - manure storage and composting areas
  - mortalities management areas
  - reuse areas
- considering what activities were being undertaken where, and the weather and wind conditions at the time the nuisance occurred
- gathering evidence and identifying and implementing strategies to remedy the problem and prevent it from happening again
- talking with the complainant about the cause, actions taken whether the issue is now resolved (if not, repeat the process)
- recording all details of the complaint, the investigation, actions taken and communication with neighbours
- monitoring the effectiveness of the implemented strategies on an ongoing basis and adjusting if necessary.

Many nuisance incidents are closely related to weather conditions, so consider these when evaluating complaints. Large enterprises, or those with a history of complaints, may find that an on-site automatic weather station that continuously monitors wind direction and speed, along with other climatic conditions, can be useful for complaint validation and investigation.

19.2.4 Complaints register

Full details of the complaints received, results of investigations into complaints, and corrective actions should be recorded in a complaints register. An example of a complaints register form is provided in Appendix G.

19.2.5 Assessing amenity impacts

Impacts to community amenity are very difficult to measure. However, a change in the number or pattern of complaints received may indicate a change in nuisance levels. This may be the result of a change in the habits or composition of the neighbours. Regular checking for odour, dust and noise at the property boundaries may detect potential issues, allowing for corrective action to be taken before they create a problem.

19.3 Effluent, manure and compost for reuse

19.3.1 Effluent, manure and compost sampling

Effluent, manure and compost for reuse should be analysed annually using the parameters suggested below before the main reuse period. Determine reuse rates based on the results. Analysis results should also be provided to offsite re-users.

19.3.2 Effluent, manure and compost analysis parameters

Tables 19.1 and 19.2 provide the recommended monitoring parameters for effluent and manure and compost, respectively. Compost may also need to be tested to demonstrate pasteurisation or other properties. Additional parameters for compost are included in *AS 4454-2012 Composts, Soil Conditioners and Mulches* (Standards Australia 2012).

Table 19.1 Recommended effluent analysis parameters

Test parameter	Justification
Total nitrogen or TKN	Measure of nitrogen applied for mass balance calculations
Ammonium-nitrogen	Measure of nitrogen available or potentially lost as ammonia volatilisation
Nitrate-nitrogen	Measure of nitrogen immediately available for plant uptake
Total phosphorus	Measure of phosphorus applied for mass balance calculations
Ortho-phosphorus	Measure of phosphorus available for plant uptake
Potassium	Measure of potassium applied for mass balance calculations
Electrical conductivity and chloride	Measures of effluent salinity
Sodium	Measures of effluent salinity
Chloride	Measures of effluent salinity
SAR	Measure of effluent sodicity

TKN = total Kjeldahl nitrogen; SAR = **sodium absorption ratio**

Table 19.2 Recommended manure and compost analysis parameters

Test parameter	Justification
Dry matter	To calculate nutrient applied
Total nitrogen or TKN	Measure of nitrogen applied for mass balance calculations
Ammonium-nitrogen	Measure of nitrogen available or potentially lost as ammonia volatilisation
Nitrate-nitrogen	Measure of nitrogen immediately available for plant uptake
Total phosphorus	Measure of phosphorus applied for mass balance calculations
Ortho-phosphorus	Measure of phosphorus available for plant uptake
Potassium	Measure of potassium applied for mass balance calculations
Organic carbon	Influences soil stability
Electrical conductivity and chloride	Measure of solids salinity
Copper	Measure of trace nutrient
Zinc	Measure of trace nutrient
Manganese	Measure of trace nutrient
Boron	Measure of trace nutrient

TKN = total Kjeldahl nitrogen

19.3.3 Evaluating effluent, manure and compost results

The analysis results should be used to determine reuse rates. The total quantity of nutrients in effluent, manure and compost, along with their availability for plant uptake or loss are both important. Not all nutrients will be immediately available for plant uptake. Start-up nutrients may need to be applied at planting, particularly in new reuse areas.

The EC of piggery effluent may be dominated by potassium and ammonium, so its EC level should be considered more flexibly than that of irrigation waters where the cation composition is often dominated by sodium-chloride. It may be more appropriate to calculate a corrected EC including only the four alkaline cations and to use this value when assessing the suitability of piggery effluent for irrigation. Nevertheless, even after this correction, the EC of piggery effluent remains relatively high (Smiles & Smith 2003). Sodium and chloride levels may provide useful information.

19.4 Reuse monitoring

19.4.1 Recording of reuse and nutrient data

Whenever effluent, manure or compost are reused on-farm, it is important to record:

- the names of paddocks where reuse occurred, the date reuse occurred, the product applied (e.g. effluent or sludge) and the applicate rate
- the calculated nitrogen, phosphorus and potassium application rates (kg/ha) (use the application rate and analysis data to calculate)
- the crops grown and the harvested yield
- the calculated nitrogen, phosphorus and potassium harvest rates (kg/ha) (use the dry matter yield and data in Table 11.2 to calculate).

To calculate the nutrient application rate (kg/ha), multiply the annual reuse rate (ML/ha) by the nutrient content (mg/L) for each nutrient of interest (nitrogen, phosphorus and potassium).

For solid manure and compost, nutrient analysis results are generally expressed on a dry matter basis. Therefore, the application rate must first be converted to a dry matter spreading rate. Multiply the dry matter content (%) by the as-spread reuse rate (t/ha).

For example, if the manure has a dry matter content of 60% (or a moisture content of 40%) and is spread at 10 t/ha, the dry matter rate is calculated as:

60% × 10 t/ha = 6 t/ha.

To determine the nutrient application rate (kg/ha), multiply the annual dry matter reuse rate (t DM/ha) by the nutrient content (g/kg) for each relevant nutrient (nitrogen, phosphorus and potassium).

Appendix C provides further details.

19.4.2 Measuring effluent and liquid sludge application rates

A flow meter can accurately measure the effluent flow rate through the irrigation pipeline. In-line flow meters should be non-corrosive. Alternatively, non-contact ultra-sonic doppler and non-contact magnetic flow meters that clamp to the outside of the pipe are available, although they are expensive.

A depth gauge in the pond, used with a storage capacity curve, can provide an estimate of the irrigation rate when large volumes are irrigated at a time. The curve shows the volume of effluent in the pond when filled to any depth. The change in depth from the start to the finish of the irrigation must be measured.

For a single pipeline, the pumping rate can be estimated from the time taken to fill a container of known volume. The flow rate must be measured from the irrigation nozzle. A plastic hose fitted over the nozzle and a 10 L bucket will help.

For a sprayline, the outflow from at least three nozzles should be measured. Both sides of double- sided nozzles should be measured. As long as there are not too many pipe-join leaks, this method will provide a good estimation.

If effluent is pumped from a tank or sump of known capacity, daily or weekly irrigation volumes may be estimated from the sump or tank volume and the emptying frequency.

If tankers are used to spread effluent, tanker volume and emptying frequency provide a good estimate of the irrigation rate.

19.4.3 Manure & compost reuse

If a manure or fertiliser spreader is used, the reuse rate can be calculated by multiplying the number of loads applied per hectare by the estimated weight of each load. The spreader should be calibrated from time to time to ensure the target spreading rate is being achieved.

19.4.4 Off-farm reuse

Piggery operators have a duty of care when effluent, manure and compost are sent off-farm to third-party end-users. In most states and territories, regulations apply to off-site reuse of effluent, manure and compost. Maintain records of the following:

- the date the material left the site
- quantity of material involved
- type of material (e.g. effluent, sludge, aged spent bedding, compost)
- recipient's name and contact details
- proposed use if known (e.g. where the material will be irrigated or spread, the land use of the area involved and the application rate).

Provide end-users with a product knowledge statement and nutrient analysis so they can calculate appropriate irrigation or spreading rates and adopt environmentally sustainable practices. Appendix D provides an example duty of care statement. Appendix C may also assist with calculating spreading rates.

19.5 Soils

19.5.1 Soil sampling

There are many guides available for interpreting soil tests, but they mainly focus on the quantities of nutrients needed to grow good crops. The application of manure and effluent to reuse areas changes the properties of soils and can result in an excess or imbalance of nutrients or concerns like sodicity. A risk assessment can be used to assess the likelihood of adverse impacts to the soils in manure and effluent reuse areas.

Where the risk of soil-related impacts is:

- Low, and at least three years of annual monitoring shows the system is sustainable, representative soils from reuse areas should be tested at least every three years.
- Medium, and at least three years of monitoring data shows the system is sustainable, soils from reuse areas should be sampled and analysed at least every two years.
- High, annual soil monitoring is recommended. For sites that will be loaded with several years' worth of a crop's phosphorus requirement in a single year, testing for phosphorus sorption capacity of buffering index (PBI) is recommended (see Section 11.4.1).

Soil sampling should:

- occur at the same time of year each year
- occur prior to planting as this provides the best information on soil nutrient status enabling decisions on appropriate nutrient application rates
- be avoided immediately after prolonged wet weather.

19.5.1.1 Soil analysis parameters

The minimum recommended soil monitoring parameters are given in Table 19.3. However, as spent bedding and sludge may contain high levels of zinc and copper (Wiedemann & Gould, 2018) consider testing for these metals along with manganese and boron, particularly if the manure is being sold. Appendix H provides a suggested sampling methodology. Analysis results should be compared with the sustainability indicator limits given in Section 19.5.1.2. Where soil analysis results exceed these limits, further investigation is triggered to identify whether effluent, manure or compost reuse is sustainable.

Table 19.3 Recommended soil analysis parameters

Soil test parameter	Depth (down profile)	Justification
pH	0-0.1 m 0.3-0.6 m or base of root zone	Influences nutrient availability
EC_{se} (can measure EC1:5 and convert to EC_{se})	0-0.1 m[a] 0.3-0.6 m or base of root zone[b]	Measure of soil salinity
Nitrate-nitrogen	0-0.1 m 0.3-0.6 m or base of root zone	Measure of nitrogen available for plant uptake, and also to detect leaching
Colwell phosphorus and phosphorus buffering index (PBI)	0-0.1 m[c] 0.5-0.6 m or base of root zone for sandy soils	Measure of phosphorus available for plant uptake, and also to detect leaching
Potassium	0-0.1 m 0.3-0.6 m or base of root zone	Measure of potassium available for plant uptake, and also to detect leaching
Sulfur	0-0.1 m	Necessary nutrient for plant growth
Organic carbon	0-0.1 m	Influences soil stability, and consequently, soil erosion
Chloride	0-0.1 m	Measure of soil salinity
Exchangeable cations (calcium, sodium, potassium, magnesium) and cation exchange capacity (CEC)	0-0.1 m 0.3-0.6 m or base of root zone	Needed to calculate ESP, EKP and Ca: Mg, which have important implications for soil structure Na is a measure of soil salinity

EC = electrical conductivity; CEC = cation exchange capacity; ESP = exchangeable sodium percentage
EKP = **exchangeable potassium percentage**.

[a] EC_{se} level in the top soil is not intended to be a direct sustainability indicator but will provide useful agronomic information and information on soil salt movements.

[b] Measuring chloride at 0.3-0.6 m (or base of root zone) may also be warranted if further investigations or actions for salinity are required.

[c] Subsoil testing may be appropriate for very sandy soils.

19.5.1.2 Evaluating soil monitoring results

Most soil nutrient recommendations understandably focus on the nutrient levels needed to grow crops, and on other elements (pH, salinity, sodicity) that may impede crop growth by interfering with the availability of other nutrients or cause soil structural issues. Soil nutrient levels will fluctuate throughout the year depending on the stage of the cropping cycle, agronomic practices and other factors. Available nutrient levels will need to be higher while the crop is growing to optimise yields and will generally be lowest after harvest or at the end of the main growth phase when most of the available nutrients have been taken up.

Matching nutrient levels to crop requirements is consistent with good environmental practice. However, any nutrients in excess of crop needs pose some environmental risk. In practice, it is very difficult to ensure soil nutrient levels continuously match crop needs, particularly considering the range of factors affecting crop growth and nutrient availability. Not all nutrients in effluent and manure will be immediately available for plant uptake. Nutrient availability typically ranges from 25-65% for nitrogen, 23-65% for phosphorus and >90% for potassium (Wiedemann & Gould 2018). For this reason, higher total nutrient levels may be needed at the start of the crop or forage growth period. On the other hand, elevated nutrient levels at the end of the cropping phase may pose a significant environmental risk since no nutrient removal is occurring and available nutrients may leach or be removed in runoff or as soil erosion. For this reason, environmental soil monitoring should occur before planting or the main reuse period.

As well as providing information for assessing environmental risk, soil testing prior to planting or before the main reuse period provides useful information for planning sustainable reuse rates. The challenge is to specify soil nutrient, pH and salt trigger levels that indicate that the system may pose an environmental risk without being overly onerous.

To that end, this section provides suggested trigger values to assist in deciding if reuse practices are sustainable. A result exceeding a trigger value does not identify that the system is unsustainable or high risk, only that further investigation is warranted. Soil properties vary widely and the suggested trigger values will not always be the most appropriate measures of sustainability. Further investigation may well begin with a comparison with soil analysis data from a background data. The ideal site from which to collect background data would:

- be close to the area of interest
- have a similar soil type
- have a similar land use to the reuse area, but would not have received piggery effluent, manure or unusually heavy fertiliser applications.

It may be necessary to analyse soil samples from multiple background sites, or to use local land and soil management references, to interpret results for both background and effluent and manure reuse areas. Comparison with historical data and trend analysis may also be useful.

Further details on sustainability indicators for reuse areas are provided in McGahan and Tucker (2003) and Redding and Devereux (2005).

19.5.1.3 Nitrogen

Nitrate-nitrogen is extremely mobile allowing for uptake by plants but also ready leaching. Additionally, high nitrate-nitrogen levels in the subsoil may pose a risk to groundwater quality. If soil nitrogen and nitrate-nitrogen leaching rates are high, soil acidification may occur.

A nitrate-nitrogen limit equivalent to a soil solution concentration of 10 mg/L below the active root zone is a trigger for further investigation or action. This is to protect the future uses of any receiving aquifer. The soil solution concentration of 10 mg NO_3N/L is based on drinking water standards contained in the *Australian Drinking Water Guidelines* (NHMRC and NRMMC 2011). Applying a drinking water quality standard is likely to be too stringent in many cases. Also, this limit is commonly exceeded in normal agricultural soils. Hence, this is a trigger for further investigation only.

When assessing the sustainability of a reuse practice based on nitrogen levels, consider a number of risk factors, including:

- the value or use of surrounding groundwater resources (human consumption, animal consumption, irrigation etc.) Water containing less than 90 mg NO_3N/L is generally suitable for livestock consumption (ANZECC 2018)
- the depth to groundwater and aquifer type; the risk is greater for shallow or unconfined aquifers
- the soil type overlying the groundwater (e.g. clay) and the expected deep drainage

- baseline nitrate-nitrogen levels in the soil below the active root zone.

The root zone depth depends on:

- the crop type
- soil depth
- climate
- whether the crop is irrigated.

In some cases, the active root zone depth may be 1.5-2.0 m and even deeper (e.g. dryland lucerne). Therefore, sampling below the root zone may not always be practically and economically feasible. Sampling to a depth of at least 0.6 m is recommended, although deeper sampling (to the base of the root zone) may be required if there are concerns about nitrate-nitrogen leaching.

For different soil types, Skerman (2000) calculated nitrate-nitrogen concentrations equivalent to 10 mg/L NO_3-N in soil solution (see Table 19.4). This trigger value applies at a depth of 0.6 m, or at the base of the root zone. However, soil nitrate-nitrogen concentrations, both in reuse areas and conventional cropping systems using inorganic fertiliser, often exceed those shown in Table 19.4. A nitrate-nitrogen root-zone concentration of 20-50 mg/kg generally provides enough nitrogen for cereal cropping and intensive grazing. The highest nitrate-nitrogen concentration given in Table 19.4 is 4.5 mg/kg. Hence, depending on soil type, nitrate-nitrogen concentrations ranging from 1.2 mg NO_3N/kg to 4.5 mg NO_3N/kg at the base of the root zone would trigger further investigation. It is important to measure the nitrate-nitrogen at the base of the root zone as these concentrations in the root zone are considered very low for crop production.

Table 19.4 Nitrate-nitrogen concentrations corresponding to a soil solution

Soil texture	Soil gravimetric moisture content at field capacity (g water/g soil)	Limiting soil nitrate- nitrogen concentration (mg NO_3N/kg soil)
Sand	0.12	1.2
Sandy-loam	0.15	1.5
Loam	0.17	1.7
Clay-loam	0.20	2.0
Light clay	0.25	2.5
Medium clay	0.35	3.5
Self-mulching clay	0.45	4.5

Nitrate-nitrogen levels throughout the soil profile provide an indication of nitrogen availability for crop growth and sustainability. Once nitrate-nitrogen moves below the plant root zone, it is no longer available for plant uptake, but can leach to groundwater. Compare the results for reuse areas:

- with those for background sites
- with historical data
- by trend analysis (as data is collected over time).

If the nitrate-nitrogen concentration below the active root zone shows signs of build-up over time, review reuse practices.

19.5.1.4 Phosphorus

The main pathways of phosphorus loss are through erosion of soil particles or through runoff from manure or soil with a high surface phosphorus concentration. Macropore flow (leakage down cracks in the soil) also causes phosphorus loss below the plant root zone. Leaching and runoff can occur when the soil is heavily overloaded with phosphorus or when applied phosphorus is not being removed from a reuse area.

Moody (2011) reviewed the literature and concluded that there is no universally accepted environmental risk indicator for soil phosphorus status. He identified that the widely used Olsen-P, Colwell-P and PBI tests were useful for assessing the phosphorus status of the soil and the risk of off-site movement of dissolved and particulate phosphorus. The PBI measures the soil's ability to store phosphorus. Soils with a high PBI can bind more of the phosphorus, making it unavailable for plant uptake but also for leaching. Clay soils typically have a higher PBI than sandy soils, although site-specific testing is needed. He noted that the phosphorus soil levels needed to ensure optimal agronomic outcomes were well established, providing a link between the phosphorus levels needed for production, and environmental risk. However, he also observed that there is a need to set trigger values that reflect the likely impact of phosphorus in runoff or suspended sediment.

Moody and Bolland (1999) provide generalised interpretation guidelines for soil phosphorus based on crop demand using the combination of Colwell-P and PBI. They included values for:

- three levels of soil phosphorus status (low, medium, high)
- two levels of soil phosphorus sorption capacity based on PBI (low or moderate to high)
- three different crop phosphorus demands (low, moderate or high).

These recommendations are for agronomic indicators. Care is necessary when applying these as indicators of environmental sustainability. The upper values for soils with a medium soil phosphorus status for crops with a low and moderate demand for phosphorus could serve as preliminary triggers for further investigation for soil tested post-harvest or at the end of the main pasture growth period. The applicable values are presented in Table 19.5.

Table 19.5 Suggested trigger levels for investigation for phosphorus in topsoil

PBI*	P sorption category	Colwell phosphorus (mg/kg) by crop type#	
		Low demand (e.g. dryland pasture)	Moderate demand (e.g. grain crops)
Up to 140	Low	30	45
141-840	Moderate to high	60	90

Notes:

* Some soils e.g. krasnozems may have very high PBI levels (>840). Higher Colwell P levels would be expected to be acceptable for these soils. Hence, these values should be regarded only as trigger values for further investigation only.

\# These levels are only applicable for soils sampled before the main crop growth period. Under highly productive agricultural systems, considerably higher levels would be expected during the crop production phase.

To investigate the possibility of phosphorus leaching through sandy soils, measurement of available phosphorus levels at 0.5-0.6 m (or the base of the root zone) is also suggested.

Soils vary in their capacity to absorb and store phosphorus. If phosphorus storage is to be used, it should be regarded as a temporary measure. Phosphorus removal over a maximum of five years with good agronomic practices is recommended.

19.5.1.5 Potassium

Using a simple mass balance approach, potassium is often determined to be the limiting nutrient for cropping systems that use piggery effluent. Since salinity would generally cause environmental problems before potassium on its own, it rarely needs to be considered when sizing sustainable reuse areas. However, if present in high concentrations, the resulting cation imbalance may induce dispersion, which may cause soil structural decline. High exchangeable potassium levels, relative to exchangeable magnesium levels, may also induce hypomagnesia (grass tetany) in grazing ruminants.

19.5.1.6 Salts

Electrical conductivity (EC) and total dissolved solids (TDS) are partial indicators of soil salinity. They measure the total concentration of ions or solids dissolved in water–not just harmful salts.

EC and TDS readings reflect contributions from both beneficial and potentially harmful substances. Valuable plant nutrients such as nitrogen compounds, sulphate, magnesium, calcium, iron and manganese, as well as buffering agents like bicarbonate and carbonate, all contribute to EC and TDS, along with sodium and chloride. In piggery effluent, ammonium and phosphorus are typically the most abundant cations, followed by sodium, then calcium and magnesium. A significant proportion of the ammonium is lost through ammonia volatilisation during irrigation. The remainder is either converted to nitrate through oxidation or taken up by plants.

Reuse areas should not show increases in soil salinity that pose a risk to long-term land productivity. Pronounced increases in soil salinity, particularly in the topsoil layer, may result from additions of effluent or manure. These increases need to be offset by leaching losses to ensure no consistent and significant increases in soil salinity in the subsoil layers.

In dry years in particular, leaching rates will decline, delaying salt removal. Soils with an EC_{se} of up to 1.9 ds/m fall into the ‘very low’ to ‘low’ salinity rating. Thereafter, any increase in EC_{se} of 2.5 ds/m would shift the soil salinity rating by less than one salinity class. Consequently, triggers for further investigation or action include:

- any EC_{se} increase of 2.5 ds/m, compared with similar soil sampled from background sites
- any result that places the salinity rating at ‘medium’ or higher.

ECse at the base of the root zone would act as a sustainability indicator, but surface and upper subsoil levels should also be monitored for agronomic purposes, and to monitor salt movements through the soil profile.

If further investigation or actions are warranted, the soil sodium and chloride concentrations throughout the profile should be measured in both reuse areas and the background sites, since sodium chloride is the main salt of interest from a soil degradation perspective. The sodium and chloride concentrations of the soil should be less than 150% of background levels.

19.5.1.7 Sodicity

Sodicity is important in effluent reuse schemes because of the relatively high sodium content of the effluent, and the adverse effects of sodicity on soil structure.

The primary sustainability indicator for soil sodicity is the exchangeable sodium percentage (ESP) measured at depths of 0-0.1 m and 0.5-0.6 m (or base of root zone). ESP is defined as the percentage of a soil’s cation exchange capacity occupied by sodium. A trigger for further investigation or action is a soil ESP exceeding 6%, in which case, comparison with the soils of a background site is necessary. Alternatively, comparison with historical data and trend analysis may be appropriate.

An ESP level exceeding 150% of background (e.g. from 6% to more than 9%) in any soil layer is considered unsustainable. It is acknowledged that soil with an ESP exceeding 6% is not necessarily dispersive, particularly if saline. However, non-dispersive saline soils with a high ESP can become dispersive if the soil salinity declines in the future. For example, during high rainfall, salinity may fall more rapidly than sodicity through increased drainage of the more soluble salts. Declines in soil salinity through drainage may also be more rapid than falls in sodicity after effluent is no longer used. Both these scenarios can lead to soil dispersion. Consequently, calcium application (gypsum or lime) is recommended where the topsoil ESP exceeds 6%, and strongly recommended where it exceeds 9%.

19.5.1.8 pH

Soil pH influences the availability of some nutrients. Ideally, the pH throughout the profile should be within the range of 5-8 (1:5 soil: water). Soil pH may inhibit the availability of desirable nutrients to plants and may increase the availability of toxic elements. The application of lime will raise the pH. It is rarely economical to lower the pH of alkaline soils.

19.6 Surface water

19.6.1 Surface water sampling

Surface water quality monitoring is rarely relevant to piggeries as they do not normally discharge to watercourses. However, in the event of an incident (e.g. effluent pond spill, runoff of irrigated effluent into watercourses) where there is a possibility of organic matter and nutrients entering watercourses, surface water testing may be appropriate. There is also a close link between alluvial groundwater and watercourses. Shallow groundwater on sloping land may be able to enter watercourses and other surface waters. If nearby alluvial or shallow groundwater has elevated nutrient levels, surface water monitoring may sometimes be warranted.

Surface water quality monitoring would typically involve sampling and analysing any effluent or contaminated runoff entering a waterbody as well as water from the affected waterbody. For a watercourse, sampling upstream and downstream of the effluent entry point is recommended. Careful sampling is needed to achieve meaningful results. Appendix H provides suggested sampling methods.

Vulnerable watercourses should also be inspected after rainfall events to identify algal blooms that are indicative of elevated nitrogen and phosphorus concentrations. Affected water should not be used as a pig drinking water source until tested and deemed safe.

Surface water usage should be monitored.

19.6.2 Surface water analysis parameters

Typical analysis parameters include:

- total nitrogen
- total phosphorus
- EC or TDS
- pH
- BOD
- *E. coli*.

19.6.3 Evaluating surface water monitoring results

Resources for evaluating surface water monitoring results include the most current edition of:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2018)
- *Australian Drinking Water Guidelines* (NHMRC and NRMMC (2011).

Comparison of nutrient, BOD and *E. coli* levels between upstream and downstream results can also help identify whether watercourse contamination is occurring, although it is important to consider other possible inflows.

Use of surface water should not exceed any allocations set by water authorities. Another sustainability indicator is the adoption of water-saving strategies that reduce overall water consumption, while still maintaining the production and hygiene standards of the piggery.

19.7 Ground water

At many sites, groundwater quality monitoring is not warranted as the particular hydrogeology of the site and the design and management of the piggery provide confidence that the water is well protected. However, at vulnerable sites groundwater monitoring may be appropriate.

For reuse areas, subsoil monitoring usually provides for earlier problem detection and remediation than direct groundwater monitoring. Groundwater monitoring may still be warranted on sites with sandy soils and vulnerable groundwater due to the higher leaching risk (nutrients may move more quickly through light soil and into groundwater).

19.7.1 Groundwater sampling

Ideally, groundwater monitoring involves comparing analysis results from water sampled from up-gradient and immediately down-gradient of the areas of interest. These areas often include effluent treatment ponds or manure management and storages but could include reuse areas.

The appropriate siting of the monitoring bores (piezometers) depends on the formation, depth, flow direction and connectivity of aquifers to other aquifers or surface waterbodies. Consultation with a hydrogeologist during the planning stage is recommended.

Where groundwater is very shallow, leakage detection systems for pond liners may be appropriate. An engineer should be consulted to assist with system design.

The groundwater sampling and testing frequency should match the risk but once or twice a year is typical.

Appendix G provides suggested sampling protocols and methodology for groundwater.

19.7.2 Groundwater analysis parameters

Typical groundwater monitoring parameters include:

- depth to groundwater
- total nitrogen
- nitrate-nitrogen
- total phosphorus
- EC or TDS
- pH
- BOD
- *E. coli.*

19.7.3 Evaluating groundwater monitoring results

Comparison of water test results for up-gradient and down-gradient bores and trend analysis for each monitoring point can detect whether groundwater contamination may be occurring. Under these circumstances, professional help should be sought to further investigate and, if necessary, address the issue.

19.8 Effluent pond system monitoring

19.8.1 Effluent pond sampling

It is rarely necessary to routinely monitor effluent pond system function. However, this can be used to confirm satisfactory effluent treatment or for trouble-shooting if there are problems with the operation of the pond.

19.8.2 Effluent analysis parameters

It can be useful to monitor the:

- TS of the inflow and outflow from the pond
- VS of the inflow and outflow from the pond
- pH
- EC.

19.8.3 Evaluating effluent monitoring results

Effluent ponds should achieve a VS rate of at least 50%, ideally 70-90%. The treated effluent should usually have a VS concentration of less than 1%.

Because effluent varies in composition, 20 sub-samples should be collected and mixed from both the inflow and outflow of the effluent pond before testing. Volatile solids (VS) reduction can be calculated by dividing the outflow concentration by the inflow concentration and expressing as a percentage. A lower VS reduction rate or a VS concentration exceeding 1% should trigger further investigation. In some cases desludging may be necessary.

The pH of pond effluent should be neutral to alkaline with an ideal range of 6.8 to 8.0. An acidic pH may indicate or cause incomplete anaerobic digestion, as the microorganisms responsible for producing low-odour methane have a narrow pH range. The best way to maintain pH is to feed the pond regularly by emptying pits or flushing channels regularly, and frequently and avoiding shock loading.

Salt can also affect reuse. Effluent pond salinity may increase over time due to evaporation. Irrigation of effluent helps reduce salt build-up. Monitoring the EC trend helps in identifying whether there is a need to manage effluent for reuse (e.g. shandying with clean water or avoiding irrigating effluent onto sensitive crops or foliage).

19.9 Monitoring during the composting process

19.9.1 Compost sampling

Composting involves the active management of manure or spent bedding. Monitoring needs to be undertaken throughout the active stage to optimise the process. Measuring temperatures and evaluating moisture content at least every three to seven days is recommended. The final product also needs to be tested to quantify nutrient levels and confirm it meets other standards. Appendix H provides a sampling methodology.

19.9.2 Monitoring during the composting process

The key parameters to monitor during the composting process are:

- carbon to nitrogen ratio (C:N) of the feedstocks
- temperature throughout the process
- moisture throughout the process.

The C:N of the materials for composting is essential in optimising decomposition, conserving nitrogen and minimising odours. C:N can be measured or found in various literature sources.

It is necessary to monitor the temperature and moisture content throughout the process to ensure the pile is heating sufficiently and to allow adjustment of these parameters to ensure an effective process and a quality product. Testing the final product is also recommended. This may include chemical, microbial and other tests depending on how the product will be marketed. Refer to the Australian Standard *AS4554-2012 Composts, Soil Conditioner and Mulches* (Australian Standards 2012). Some state and territory environmental agencies and the horticulture industry also have their own standards.

19.9.3 Evaluating composting results

An initial carbon to nitrogen (C:N) of 25-40:1 is desirable for effective composting.

The core temperature within composting piles should be sustained at 55-65°C for a minimum of three days prior to turning. Maintaining these high temperatures reduces both pathogen levels and weed seed viability.

The moisture content of the composting material can be assessed at the same time using a squeeze test. If the material can be formed into a ball from which only a few drops of moisture can be squeezed, the moisture content is likely within the desirable range (50-60%).

Table 10.4 summarises the acceptable and optimal C:N, moisture and temperature ranges for composting.

19.10 Biogas systems

19.10.1 Biogas sampling

It is necessary to monitor biogas systems to ensure they are working effectively and optimally and to meet emissions reduction fund (ERF) obligations.

Monitoring for biogas systems may involve:

- sampling the influent and effluent
- measuring biogas production or amount of electricity generated
- any measurements required for an ERF project, which may include:
  - the proportion of methane in the biogas being produced
  - records that confirm when biogas use equipment (e.g. flare, biogas-fired hot water system) was operational during a particular monitoring time period.

Influent and effluent are sampled in the same way as effluent for reuse (refer to Appendix H).

Biogas production, electricity and equipment usage are measured with meters. Continuous data records are needed for Emissions Reduction Fund (ERF) reporting.

Biogas composition can be measured using a pre-calibrated biogas composition meter. It is important to collect a representative sample from biogas flowing within the pipeline to the end-use equipment (e.g. flare or generator). If manual sampling is required, a tap-off point should be installed on the biogas pipeline.

Because biogas contains highly toxic (potentially fatal) gases, the tap-off point must be in a well-ventilated location and have a fine-gauge shut-off valve to minimise flow. Some biogas composition meters (e.g. those with glass sorption tubes) are sensitive to the pressure of the biogas flow. In these cases, the biogas should be collected into a purpose-designed sample bag. The meter is then connected to the bag and light pressure is applied to allow gas to flow into the meter. In all cases, always follow the meter supplier's instructions. Biogas composition should be measured at the frequency required for ERF reporting.

19.10.2 Biogas monitoring parameters

Monitoring for biogas projects include:

- performance measurements:
  - effluent pH
  - VS content in the effluent
  - volumetric production of biogas and/or amount of electricity generated
- measurements required of an ERF project where relevant:
  - the proportion of methane in the biogas produced
  - measurement records that indicate whether biogas use equipment was operational during a particular monitoring time period.

An example of instrumentation for monitoring biogas systems was outlined in Skerman and Tait (2019).

19.10.3 Evaluating results for biogas systems

A pH range of 6.8-7.8 indicates typical operation for a biogas system, whereas a pH falling outside of this range could indicate that the anaerobic digestion system is not performing optimally or is under stress.

The VS to TS ratio in the effluent varies between systems and may require expert interpretation. Generally, values less than 0.65 indicate that manure organic matter is being efficiently converted into biogas.

Biogas production is directly related to the amount of manure or co-digestion materials entering the biogas system. However, it takes 6-18 months for a new system to reach full operation depending on whether pond seeding was successful and whether or not any issues arose. If biogas production is substantially lower than the expected range, this could indicate inaccuracy in the load to the system.

If biogas production is substantially higher than the expected range, this could indicate that extra organic matter is being added, biogas is elevated seasonally or inaccuracies in the inflow estimate.

The methane content in biogas can vary depending on inputs (e.g. by-products) but should be at least 50% by volume and should generally be between 60-75%. Values of less than 50% could indicate a significant leak, or stressed digestion microbiology. Values exceeding 75%, while atypical do not necessarily represent a process concern, but may indicate that meter calibration is required.

19.11 National pollutant inventory reporting

Operators of indoor piggeries must report emissions to the National Pollutant Inventory (NPI) if they emit over 10 t/yr ammonia, or for emissions to air associated with fuel and or waste combustion that exceed 400 t/yr or 1 t/hr at any time in the reporting year (DEWR 2007).

From the *National Pollutant Inventory Emission Estimation Technical Manual for Intensive Livestock: Pig Farming* (DEWR 2007), reporting is likely to be triggered for ammonia at a capacity of about:

- 1,100-1,200 SPU for a conventional piggery
- 2,000 SPU for a deep litter piggery that stockpiles spent bedding on-farm
- 7,100 SPU for a deep litter piggery that sends the spent bedding off-farm without storage.

Access the current technical manual

Refer to the NPI emissions.

20 Environmental management plans

An Environmental Management Plan (EMP) focuses on monitoring, managing and minimising the environmental risks of the whole farm. An EMP is recommended for all piggeries as it helps to manage risk and demonstrates that the operator is operating in an environmentally sustainable manner.

An EMP provides a system for documenting:

- the environmental risks of a piggery
- how risks will be minimised (by design or management)
- contingency plans to address emergency situations that could cause environmental harm or impact on management practices
- measurement of the effectiveness of these strategies (by monitoring)
- how monitoring results will be reported
- action plans that specify actions that will be undertaken to further reduce risk.

An EMP is not a static document. It provides for dynamic, adaptive management and should encourage continuous improvement. It includes the monitoring and feedback loops that provide assurances that environmental risks can be detected and resolved. Proactive and genuine handling of complaints is an integral component of the monitoring and feedback loops.

20.1 Components of an EMP

An EMP typically includes:

- identification and contact details
- introduction
- environmental management commitment
- operating permissions
- site description
- piggery design and management
- environmental risks assessment
- environmental monitoring
- contingency plans
- environmental training
- record keeping
- EMP review.

An EMP should include all components, but the structure may vary depending on personal preference. Some information may be presented outside the EMP within a suitable cross-reference (e.g. to an APIQP✓® standard operating procedure [SOP]).

20.2 Identification and contact details

For important contacts within the piggery, this should include:

- names
- phone numbers
- email addresses.

For large organisations, an organisational chart may be appropriate.

20.3 Introduction

This section should briefly describe the farm including details like:

- the herd type (e.g. farrow-to-finish, breeder unit, weaner unit or grower unit)
- size
- housing type
- manure and effluent management
- a plan of the piggery complex
- a plan showing reuse areas and buffers.

It would also identify the purpose of the EMP which is usually to:

- minimise risks to the environment
- describe the siting, design and management of the piggery
- provide for the day-to-day management of the piggery to minimise risks to the environment
- identify site specific environmental risks
- detail ongoing environmental monitoring
- provide contingency plans to manage emergency situations that could pose a risk to the environment
- facilitate continuous improvement through regular reviews.

20.4 Environmental management commitment

This is a statement about how the piggery will operate to protect the environment by minimising environmental risks. It may include a commitment to:

- operating in accordance with the *National Environmental Guidelines for Piggeries* (APL 2004)
- complying with relevant environmental acts
- meeting the GED or similar obligations.

This section could also include site specific environmental objectives and targets.

20.5 Operating permissions

This will include a summary of any:

- planning or development approvals or existing use rights
- environmental approvals
- water licences.

20.6 Site description

The site description should cover:

- real property description (e.g. lot and parcel numbers)
- the location of the property and nearby sensitive land uses (e.g. houses, rural residential areas and towns)
- climate including wind roses
- soil type and properties
- proximity to watercourses and flooding
- depth, vulnerability and quality of groundwater
- native vegetation (if applicable)
- areas of cultural heritage sensitivity (if applicable).

20.7 Piggery design and management

This section typically provides an overview of the design and management, including:

- pig housing and facilities (e.g. feeding systems)
- effluent collection and management (if applicable)
- biogas (if applicable)
- manure and spent bedding storage and composting areas (if applicable)
- reuse areas including nutrient budgeting and management principles
- mortalities management (including mass mortalities)
- vermin and pest management
- stormwater management
- traffic management
- chemical use, storage and handling
- landscaping
- management of other farms wastes
- cleaner production (e.g. measures to reduce inputs, reuse of manure and effluent, recycling of wastes).

20.8 Environmental risk assessment

This section should identify environmental risks and detail any mitigation or management strategies. Appendix F provides a risk assessment tool.

20.9 Environmental monitoring

An environmental monitoring program should be developed based on the risk assessment and management. Section 19 provides guidance on environmental monitoring.

At a minimum, all EMPs should include a complaints management process and complaints register.

If there is reuse of effluent, manure or compost, regular analysis of these is recommended. Soils of reuse areas should also be regularly tested.

20.10 Contingency plans

Emergency preparedness is very important. The EMP should identify emergency situations that may arise and contingency plans to address these. Some contingency plans may be detailed elsewhere (for example, as a standard operating procedure [SOP] in an APIQP✓® system) and cross-referenced in the EMP. Examples of emergency situations that may apply could include:

- mass mortalities
- natural disasters e.g. fire or flood
- biogas system failure
- power failure
- water supply issues
- failure of key equipment
- transport issues for pigs
- contractual issues that may increase environmental risk e.g. inability to transfer effluent, manure or compost, or cessation of mortalities collection.

20.11 Environmental training

Environmental training undertaken by staff and staff accreditations should be recorded.

Any areas where training is required (e.g. chemical handling) or would be beneficial (e.g. soil or water sampling training) should also be identified.

20.12 Record keeping

Records should be kept of:

- any environmental monitoring
- training
- suggested changes or required amendments to the EMP.

20.13 EMP review

An EMP should be periodically reviewed to ensure it reflects:

- any changes in regulatory requirements
- the environment (e.g. construction of new houses closer to the piggery)
- piggery design or management.

This is important to ensure current environmental risks are reflected in the plan. At a minimum, an annual review is recommended.

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Appendix A

Pond & pad permeability specifications

A1 Introduction

Based on: Skerman, AG, Redding, MR and McLean D, 2002, *Clay Lining and Compaction of Effluent Ponds*, Department of Employment, Economic Development and Innovation, Brisbane.

This guide provides quantitative standards to assist the industry in constructing effluent ponds that meet the accepted maximum permeability of 0.1 mm per day.

Because in-situ and laboratory measurement of soil permeability is difficult and relatively inaccurate, rather than relying on permeability standards, this document provides recognised standards for clay lining materials and methods. By applying these standards, an acceptable degree of impermeability should be achieved consistently.

This guide is based on established engineering principles, however, the recommended methods may be revised from time-to-time, as new methods are developed. Proposals involving alternative materials or methods may be submitted to the administering authority for consideration.

A2 Constructing effluent ponds

A2.1 Material

The material used to clay-line the ponds must be well-graded, impervious material, classified as either CL, CI, CH, SC or GC in accordance with the soil classification system described in Appendix A (Table A1) of AS 1726 (Standards Australia 2017).

Note: The classification symbols represent inorganic clays having low, intermediate and high plasticity, clayey sands and clayey gravel, including gravel-clay-sand mixtures, respectively. Furthermore, the lining material must conform with the particle size distribution and plasticity limits in the table below.

Table A.1 Particle size distribution

AS metric sieve size (mm)	Percentage passing (by dry weight)
75.000	100
19.000	70-100
2.360	40-100
0.075	25-90

Table A.2 Plasticity limits on fines fraction, passing 0.425 mm sieve

Measure	Score
Liquid limit W_L	30-60%
Plasticity index I_p	>10%

If materials complying with the above plasticity limits are not readily available, clays with liquid limits between 60% and 80% may be used as lining material, provided that the clay lining layer is covered with a layer of compacted gravel (or other approved material). The compacted gravel layer should have a minimum thickness of 100 mm to prevent the clay lining from drying out and cracking.

Testing of materials to determine compliance with the above requirements must be carried out in accordance with the appropriate sections of AS 1289. The administering authority may direct the licensee to provide test results certified by an accredited soils laboratory (accredited by the National Association of Testing Authorities [NATA] or equivalent).

Topsoil, tree roots and organic matter must not be used as clay lining material. Furthermore, any other material, which does not compact properly must not be placed in any of the areas to be clay-lined.

Wherever non-dispersive materials are available, they are to be used in preference to materials shown to be dispersive using the Emerson test, as described in Method 3.8.1 of AS 1289. Note: A Class-8 material is considered to be non-dispersive.

A2.2 Placement of material

Effluent ponds capable of storing water up to a maximum depth of 2 m, must be lined with complying material to a minimum total thickness of 300 mm. Ponds capable of storing water at depths in excess of 2 m, must be lined with complying material to a minimum total thickness of 450 mm. This can be achieved by placing the material at the correct moisture content in progressive, uniform, horizontal layers, not exceeding 150 mm in thickness, after compaction.

Under no circumstances is the compacted thickness of clay lining material to be less than the required minimum thickness.

A2.3 Correct moisture content

Prior to compaction, all material used for lining purposes must be conditioned to have a moisture content within the range of 2% wet to 2% dry of the optimum moisture content required to produce the maximum dry density when compacted in accordance with Method 5.1.1 of AS 1289.

As a guide, the required moisture content is as wet as it can be rolled without clogging a sheep's-foot roller. A preliminary assessment of the moisture content can be made by rolling a sample of the material between the hands. If it can be rolled to pencil thickness without breaking, it should be satisfactory.

A2.4 Compaction

Each layer of material must be compacted to produce either a field dry density of at least 95% of the standard maximum laboratory dry density determined in accordance with Method 5.4.1 of AS 1289, or alternatively, a Hilf density ratio of at least 95% when tested in accordance with Method 5.7.1 of AS 1289.

This degree of compaction may generally be achieved by rolling each layer of material, placed at the correct moisture content, with at least eight passes of a sheeps-foot roller. As a guide, compaction will generally be sufficient when there is a clearance of 100 mm between the drum of the roller and the compacted material.

A2.5 Sheepsfoot roller

Sheepsfoot roller specifications for fulfilling compaction requirements:

- The diameter of the drum/s cannot be less than 1 m.
- The length of the drum/s should be approximately 1.2 times the drum diameter.
- The feet must extend approximately 175 mm radially from the drum and be of the taper-foot type, with a cross-sectional area close to the outer end of not less than 3200 mm^2 and not more than 4500 mm^2.
- The number of feet should be such that their total area close to the outer ends shall be between 5% and approximately 8% of the area of the cylinder, which would enclose all the feet, i.e. a cylinder having a diameter equal to the diameter of the drum plus twice the length of each foot.
- The roller ballast weight must result in a bearing pressure of no less than 1,750 kilopascals, calculated using the following formula:

Bearing pressure (kPa) = mass (kg) X 9.81 X 1000 ÷ area of contact of one row of feet ($mm^{2)}$).

Other types of rollers and configurations may be used provided that the required compaction is achieved.

A2.6 Testing for adequate compaction

The administering authority may request compaction testing. Compaction testing must be performed in accordance with AS 1289 and be certified by an accredited soils laboratory or equivalent. A copy of the certified test results is then forwarded to the administering authority.

If the test results fail to comply with the compaction requirements, remedial measures are to be implemented as directed by the administering authority before the pond can be used.

A2.7 Synthetic liners

Alternate material and installation specifications relating to the use of synthetic lining materials may be used instead of clay lining.

Note: The material classification symbols CL, CI, CH, SC and GC represent clays having low, intermediate and high plasticity, clayey sands and clayey gravels respectively.

A3 Earth pad preparation for deep litter piggeries, solid waste stockpiles and composting areas

Based on: Skerman AG (2005), *Earth Pad Preparation Requirements for Deep Litter Piggeries, Solid Waste Stockpiles and Composting Areas*, Department of Employment, Economic Development and Innovation, Brisbane.

A3.1 Clearing and grubbing

The area where the pad is to be established must be cleared of all trees, scrub and stumps. All tree roots should be grubbed to a minimum depth of 300 mm below natural surface. All trees, scrub, stumps and roots removed from the pad area should be transported to a location clear of the works area and stockpiled or disposed of to the satisfaction of the landowner.

A3.2 Stripping of topsoil

Because of its high organic matter content, topsoil is unsuitable for compaction in the pad foundation. Therefore, unless otherwise determined by the administrating authority, all topsoil should be stripped from the entire surface of the proposed pad area to a minimum depth of 150 mm. The stripped material shall be stockpiled or disposed of clear of the works area to the satisfaction of the landowner.

A3.3 Pad foundation preparation

Following topsoil stripping and prior to the placement of any fill material, the in-situ foundation should be prepared by the following operations, to produce a satisfactory bonding surface for the placement of subsequent layers of material:

- placement and compaction of suitable material into any holes or depressions resulting from the grubbing of tree stumps and roots
- scarifying or ripping with a tined implement, to a minimum depth of 150 mm
- watering to produce the correct moisture content, as specified in Section A3.6
- compaction in accordance with Section A3.7.

A3.4 Excavation and placement of pad material

The pad area should be cut or filled as required, to produce a smooth, uniform surface.

If topsoil stripping exposes a pad foundation material that meets the suitability requirements specified in Section A3.5, and no further excavation or fill placement is needed to achieve the design gradients, levels and dimensions, then the pad surface must be prepared as outlined in Section A3.3.

If the exposed pad foundation material does not comply with Section A3.5, further excavation must be undertaken to allow for the placement and compaction of at least 300 millimetres (after compaction) of suitable pad material, in order to achieve the required gradients, levels and dimensions. All fill material placed in the pad shall comply with the suitability requirements specified in Section A3.5. After preparing the pad foundation as described in section A3.3 above, all fill material must be conditioned to the correct moisture content as defined in Section A3.6, excavated, transported and placed on the pad surface in progressive, approximately horizontal layers. Each layer must have a uniform thickness of no more than 200 mm prior to compaction. All unsuitable material excavated from the pad area or external borrow area(s) shall be placed in spoil heaps, clear of the works area, to the satisfaction of the landowner.

A3.5 Materials

A3.5.1 Material specification

Material will be considered suitable for placement in the pad, subject to compliance with the following requirements:

- The material must be classified as either CL, CI, CH, SC or GC in accordance with the soil classification system described in Appendix A of AS 1726 (Standards Australia 2017).
- The material must conform with the specified particle size distribution and plasticity limits as shown in Tables A.3 and A.4.

Note: The material classification symbols CL, CI, CH, SC and GC represent clays having low, intermediate and high plasticity, clayey sands and clayey gravels respectively.

Table A.3 Particle size distribution

AS metric sieve size (mm)	Percentage passing (by dry weight)
75.000	100
19.000	70-100
2.360	40-100
0.075	25-90

Table A.4 Plasticity limits on fines fraction, passing 0.425 mm sieve

Measure	Score
Liquid limit W_L	30-60%
Plasticity index I_p	>10%

If materials meeting the above plasticity limits are not readily available, clays with liquid limits between 60% and 80% may be used for pad construction, provided the pad surface is covered with a compacted gravel layer (or other approved material) with a minimum thickness of 100 millimetres. This is necessary to prevent the clay from drying out and cracking. Topsoil, tree roots and organic matter must not be used in pad construction. In addition, any material that does not compact properly must not be placed in the pad area.

Wherever non-dispersive materials are available, they must be used in preference to materials identified as dispersive using the Emerson test, as described in Method 8.1 of AS 1289.

A3.5.2 Material suitability/identification

Visual identification methods described in AS 1726 may be used in the field during construction to assess whether a material complies with the above criteria. However, if there is any doubt about the material's suitability, laboratory testing must be undertaken in accordance with the relevant sections of AS 1289 to confirm compliance.

The administering authority may require the owner to submit laboratory test results certified by a soils laboratory accredited by NATA or an equivalent accreditation body.

Where locally available materials do not meet the specified criteria, alternative proposals may be considered acceptable.

A3.6 Correct moisture content

All material placed in the pad must be conditioned to a moisture content within the range of 2% above to 2% below the optimum moisture content required to achieve maximum dry density when compacted, in accordance with Method 5.1.1 of AS 1289.

Note: As a general guide, the correct moisture content for a clay material is as wet as can be rolled without clogging a sheepsfoot roller. A preliminary assessment can be made by rolling a sample of the material between the hands. If it can be rolled to pencil thickness without breaking, it is likely to be suitable.

If water must be added to achieve the required moisture content, it should be applied to the borrow area with sufficient lead time to ensure even distribution throughout the material before excavation. To support effective water distribution, the surface of the borrow material should be ripped prior to watering. Where it is not possible to apply the full amount of water in the borrow area, a portion may be added after the material is placed on the pad.

A3.7 Compaction

Each layer of material placed in accordance with Section A3.4 must be compacted to achieve either:

- a field dry density of at least 95% of the standard maximum laboratory dry density, as determined by Method 5.4.1 of AS 1289
- a Hilf density ratio of at least 95%, as tested in accordance with Method 5.7.1 of AS 1289.

Note: This level of compaction is typically achieved in clay material by rolling each layer, placed at the correct moisture content, with a minimum of eight passes of a sheepsfoot roller configured as described in Section A3.8. As a guide, compaction is generally considered sufficient when there is a clearance of approximately 100 mm between the drum of the roller and the compacted material.

A3.8 Sheepsfoot roller

The following specification describes a sheepsfoot roller which would be suitable for fulfilling the compaction requirements described earlier, for the materials specified in A3.5.1:

- the diameter of the drum(s) should be not less than 1 m
- the length of each drum(s) should be approximately 1.2 times the drum diameter
- the feet should extend approximately 175 mm radially from the drum and be of the taper-foot type, with a cross-sectional area close to the outer end of not less than 3,200 mm^2 and not more than 4,500 mm^2
- the number of feet should be such that their total area close to the outer ends should be between 5% and approximately 8% of the area of the cylinder that would enclose all the feet (i.e. a cylinder having a diameter equal to the diameter of the drum plus twice the length of each foot)
- the weight of the roller ballasted, should be such that the bearing pressure thus obtained shall be not less than 1,750 kilopascals, in accordance with the following formula:

Bearing pressure (kPa) = Mass (kg) x 9.81 x 1000 ÷ area of contact of one row of feet (mm^2)

Rollers of other types and configurations may be used provided that the required compaction is achieved in accordance with A3.7.

A3.9 Testing for adequate compaction

The administering authority may direct the owner to arrange for compaction testing to be carried out on nominated sections of the pad. Compaction testing is to be performed in accordance with the methods specified in Section A3.7 of this specification. The test results must be submitted to the administering authority, following certification by a soils laboratory accredited by NATA or a laboratory having equivalent accreditation for the tests performed.

A3.10 Final trimming

Following the completion of compaction, final trimming should be carried out to produce a smooth, uniform pad surface.

A3.11 Pad permeability

The procedures specified in this document are designed to produce a maximum pad permeability of 0.1 mm/day. These criteria may be used by the administering authority to ensure that the appropriate environmental protection standards have been achieved. The administering authority may direct the owner to arrange permeability testing on nominated section(s) of the pad. Laboratory testing must be carried out in accordance with either Part 6 of BS 1377 (Triaxial Permeability) or Section F7.1 of AS 1289. Test results must be certified by a laboratory accredited by NATA or an equivalent body, and submitted to the administering authority.

If the test results do not comply with the specified maximum permeability, the applicant will be prohibited from using the facility (e.g. stocking the piggery) until appropriate remedial measures are undertaken, as directed by the administering authority.

A3.12 Alternate methods

Alternative materials or installation methods may produce a suitable pad. Possible examples include the use of synthetic lining materials or soil stabilisation with products such as cement, lime, bentonite, etc. instead of clay lining.

Appendix B

Compost monitoring template

B1 Introduction

This appendix provides two alternative compost monitoring templates to assist with recording the management of the composting process. One template is in table format; the other is in figure format. Both templates capture similar data.

At each monitoring event, data should be recorded using the preferred template. Moisture content should be qualitatively assessed using the hand-squeeze method and categorised as wet, suitable or dry. Temperature should be measured with a long-stemmed thermometer. Testing methods are described in Section 9 of Appendix H.

Windrows or piles should only be turned once the core temperature has remained between 55°C and 65°C for three consecutive days. The date of turning should be recorded. If water or high-carbon material (e.g. straw or sawdust) is added, record the date, type of material and quantity. Any observations and actions taken (e.g. troubleshooting) should also be documented.

Table B.1 Windrow observation log

Windrow number: ______________________________

Date	Monitoring Location (along windrow or across pile)	Moisture (wet, suitable or dry)	Temperature (°C)	Date turned	Date of water or carbon additions	Observations & Actions
	1					
	2					
	3					
	4					
	6					
	7					
	8					
	9					
	10					
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					

Figure B.1 Alternative windrow observation log

Windrow/pile no.: ______________ Date started: ________________ Date finished/curing: ____________

Temp 1	Temp 2	Temp 3	Temp 4	Temp 5	Temp 6	Temp 7	Temp 8	Temp 9	Temp 10	Date monitored: Date turned: Date watered:
Moisture 1	Moisture 2	Moisture 3	Moisture 4	Moisture 5	Moisture 6	Moisture 7	Moisture 8	Moisture 9	Moisture 10	

Temp 1	Temp 2	Temp 3	Temp 4	Temp 5	Temp 6	Temp 7	Temp 8	Temp 9	Temp 10	Date monitored: Date turned: Date watered:
Moisture 1	Moisture 2	Moisture 3	Moisture 4	Moisture 5	Moisture 6	Moisture 7	Moisture 8	Moisture 9	Moisture 10	

Temp 1	Temp 2	Temp 3	Temp 4	Temp 5	Temp 6	Temp 7	Temp 8	Temp 9	Temp 10	Date monitored: Date turned: Date watered:
Moisture 1	Moisture 2	Moisture 3	Moisture 4	Moisture 5	Moisture 6	Moisture 7	Moisture 8	Moisture 9	Moisture 10	

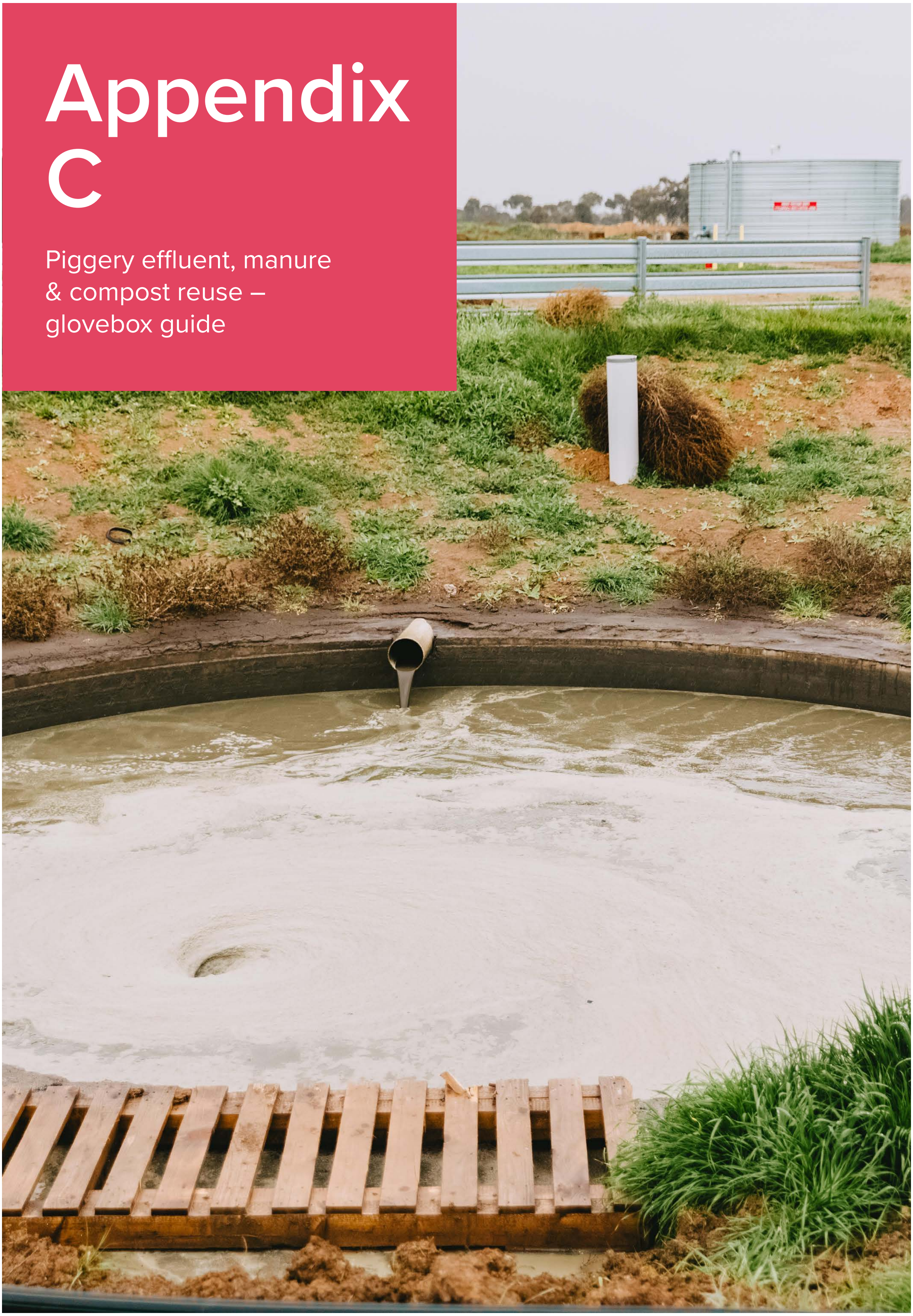
Temp 1	Temp 2	Temp 3	Temp 4	Temp 5	Temp 6	Temp 7	Temp 8	Temp 9	Temp 10	Date monitored: Date turned: Date watered:
Moisture 1	Moisture 2	Moisture 3	Moisture 4	Moisture 5	Moisture 6	Moisture 7	Moisture 8	Moisture 9	Moisture 10	

Temp 1	Temp 2	Temp 3	Temp 4	Temp 5	Temp 6	Temp 7	Temp 8	Temp 9	Temp 10	Date monitored: Date turned: Date watered:
Moisture 1	Moisture 2	Moisture 3	Moisture 4	Moisture 5	Moisture 6	Moisture 7	Moisture 8	Moisture 9	Moisture 10	

Observations

Appendix C

Piggery effluent, manure & compost reuse – glovebox guide



C1 Introduction

This glovebox guide provides information, worked examples and templates to determine application rates for effluent, manure and compost, and nutrient removal by crops and pastures for conventional and deep litter piggeries.

Piggery effluent, manure and compost can be valuable sources of nutrients and organic matter for improving soil properties and crop or pasture production. Good management is needed to gain the maximum benefit from these products while minimising environmental risks. Benefits may include:

- increased organic matter
- enhanced soil structure
- improved rainfall infiltration and water holding capacity of soil
- enhanced soil fertility
- reduced erosion
- increased plant yields
- reduced fertiliser costs.

To get the maximum benefits from effluent, manure and compost, sustainable reuse practices should be developed based on mass balance principles and monitoring.

There are a number of steps in the process:

1. Calculate expected nutrient removal rates of the crops to be grown on the reuse areas.
2. Determine the target application rate including the data from step 1 and any adjustments for nitrogen losses and soil storage of phosphorus.
3. Determine the effluent, manure or compost application rate (dry matter basis).
4. Calculate the practical spreading rate.

C2 Reuse of effluent, manure & compost

C2.1 Calculating nutrient removal by crop or pasture

Select the correct crop or pasture from Table C.1. Use the expected dry matter (DM) yield, the DM nutrient content in the crop and the calculation template below the table to calculate the likely nitrogen (N), phosphorus (P) and potassium (K) removal rate (kg/ha).

Table C.1 Approximate nutrient removal rates for various crops & yields

Crop	Dry matter nutrient content (kg/t)			Normal yield range (DM t/ha)	Normal nutrient removal range (kg/ha)		
	Nitrogen	Phosphorus	Potassium		Nitrogen	Phosphorus	Potassium
Grazed pasture					16-16.5	0.8-1.9	0.1-0.7
Dry land pasture (cut)	17.1	2.6	17.6	1-4	17-68	2.6-10.4	17.6-70.4
Irrigated pasture (cut)	17.1	2.6	17.6	8-20	137-342	21-52	141-352
Clover hay	25.4	2.4	15.8	5-15	127-381	12-36	79-237
Lucerne hay (cut)	31	3	24	5-15	155-465	15-45	120-360
Maize silage	12	2	10	16-22	192-264	32-44	160-220
Forage sorghum	20.2	2.2	24	10-20	202-404	22-44	240-480
Grain barley	20	2.5	4.5	2-5	40-100	5-7.5	9-22.5
Barley straw	7	0.7	18	5-10	35-70	1.4-2.8	90-180
Grain wheat	20	3.5	5	2-5	40-100	7-17.5	10-25
Wheat straw	8	0.7	21	5-10	40-80	3.5-7	105-210
Grain triticale	21	3	5	1.5-3	31.5-63	4.5-9	7.5-5
Grain oats	17	2.5	4	1-5	17-85	2.5-12.5	4-20
Oats straw	6	1	22	5-10	30-60	5-10	110-220

Crop	Dry matter nutrient content (kg/t)			Normal yield range (DM t/ha)	Normal nutrient removal range (kg/ha)		
	Nitrogen	Phosphorus	Potassium		Nitrogen	Phosphorus	Potassium
Oats hay	13.8	2.6	18.7	5-10	69-138	13-26	93.5-187
Grain sorghum	25	2.3	4	2-8	50-200	4.6-18.4	8-32
Grain maize	15	3	4	2-8	30-120	6-24	8-32
Chickpea	34.5	3.3	9	0.5-2	17-69	1.7-6.6	4.5-18
Field peas	40	3.9	8	2-4	80-160	7.8-15.6	16-32
Faba beans	41	4	10	1-3	41-123	4-12	10-30
Lupins	51	4.5	9	0.5-2	25.5-102	2.3-9	4.5-18
Canola	40	7	9	1-3	40-120	7-21	9-27

[c] Yields may vary from these ranges (refer to historical data for the region for more accurate estimates).

[d] The grazing pasture example assumes a liveweight gain of 75 – 200 kg/ha/yr, with no ammonia volatilisation losses from the grazed animal's manure.

Sources: Data for dryland and irrigated pasture (Rugoho et al. 2017), data for lucerne hay, clover hay, forage sorghum, maize grain, oats straw and oats hay (Morris & Staines 2017), data for grain, grain straw, oilseeds, peas, beans and maize silage was sourced from GRDC references.

Worked example

Crop type: grain barley Yield 3 t DM/ha

Parameter	N	P	K
Nutrient content (kg/t)	20	2.5	4.5
Nutrient removal rate (kg/ha)	20 kg/t X 3 t/ha - = 60 kg/ha	2.5 X 3 t/ha = 7.5 kg/ha	4.5 kg/t X 3 t/ha = 13.5 kg/ha

Calculation template

Crop type: Yield (t DM/ha)

Parameter	N	P	K
Nutrient content (kg/t)			
Nutrient removal rate (kg/h)			

C2.2 Determining target nutrient application rates

Determine target nutrient application rates using the nutrient mass balance equation:

Nutrient application rate (kg/ha) = crop nutrient removal rate (kg/ha) +/- soil nutrient adjustments (kg/ha) + acceptable nutrient losses to the environment (kg/ha) + nutrient safely stored in the soil (kg/ha)

This calculation needs to be applied for N, P and K. The inputs are:

- Nutrient removed by plant harvest – determined in previous step.

  For the example this is:

  N 60 kg/ha

  P 7.5 kg/ha

  K 13.5 kg/ha

- Acceptable nutrient losses to the environment. This generally only applies for N where ammonia (NH3) volatilisation losses occur on and after spreading or irrigation. Losses vary depending on the reuse method and what is being spread. As a percentage of N removed by the crop, these are typically:
  - spray or drip irrigation of effluent 20% of NH^3-N
  - surface flow irrigation of effluent 10% of NH^3-N
  - spreading of fresh bedding 20% of NH^3-N
  - spreading of compost 10% of NH^3-N
- Nutrient safely stored in the soil. This generally applies only to P. It varies with soil type and past land uses and should be determined by soil testing, although most soils with a reasonable clay content will be able to safely store 3-5 years phosphorus, noting that this must then be removed prior to any further reuse occurring.
- Potassium causes few environmental impacts and can be applied in excess of plant needs providing soil structure is monitored and any issues addressed. If the land will be grazed, soil cations will need to be monitored to assess grass tetany risk.

Use the nutrient removed by plant harvest (previous step), an allowance for N volatilisation losses and soil P storage (if appropriate to complete the calculation template below for N, P and K. Worked examples for barley yielding 3 t/ha are provided.

Worked example 1: Barley grown on an effluent reuse area

A spray irrigation system is used so expected NH^3-N losses are 20% of the crop removal rate. It is assumed that the paddock is irrigated every year, so no extra phosphorus storage is allowed. Crop nutrient removal rates come from the previous step.

Nitrogen application rate (kg/ha) = crop nutrient removal rate (kg/ha) + acceptable nutrient losses to the environment (kg/ha)

Amount of N applied (kg/ha) = 60 kg/ha + (20% x 60 kg/ha)

60 kg/ha + 12 kg/ha = 72 kg N/ha

Phosphorus application rate (kg/ha) = crop nutrient removal rate (kg/ha) + nutrient safely stored in the soil (kg/ha)

Amount of P applied (kg/ha) = 7.5 kg/ha + 0 kg/ha = 7.5 kg P/ha

Potassium application rate (kg/ha) = crop nutrient removal rate (kg/ha

Amount of K applied (kg/ha) = 13.5 kg K/ha

Worked example 2: Barley grown on a reuse area spread with spent bedding every four years

Because spent bedding is spread every four years, four years nutrients are applied at each spreading. Hence, the amount of nutrient applied is multiplied by four. Ammonia-N (NH^3-N) losses are 10% of the crop removal rate. Crop nutrient removal rates come from the previous step.

Nitrogen application rate (kg/ha) = crop nutrient removal rate (kg/ha) + acceptable nutrient losses to the environment (kg/ha)

Amount of N applied (kg/ha) = 4 x (60 kg/ha + [10% NH^3-N loss X 60 kg/ha])

4 x (60 kg/ha + 6 kg/ha) = 264 kg N/ha

Phosphorus application rate (kg/ha) = crop nutrient removal rate (kg/ha) + nutrient safely stored in the soil (kg/ha)

Amount of P applied (kg/ha) = 4 x (7.5 kg/ha + 0 kg/ha) = 30 kg P/ha

Potassium application rate (kg/ha) = crop nutrient removal rate (kg/ha)

Amount of K applied (kg/ha) = 4 x 13.5 kg/ha = 54 kg K/ha

Calculation template

Amount of N applied (kg/ha) = number of years x (N removed by plant harvest [kg/ha] + ammonia-N losses [% NH^3 loss x N removed by plant harvest] [kg/ha])

Amount of N applied (kg/ha) = number of years x (_________ kg/ha + [_________ % x _________ kg/ha])

Amount of N applied (kg/ha) = _______________ kg/ha

Amount of P applied (kg/ha) = number of years x (P removed by plant harvest [kg/ha] + nutrient safely stored in the soil [kg/ha])

Amount of P applied (kg/ha) = number of years x (_________ kg/ha + _________ kg/ha)

Amount of P applied (kg/ha) = _______________ kg/ha

Amount of K applied (kg/ha) = number of years x K removed by plant harvest (kg/ha)

Amount of K applied (kg/ha) = _______________ kg/ha

C2.3 Determining the effluent, manure or compost application rate

The effluent, manure or compost application rate is determined from the target nutrient application rate and the N, P and K concentration in the material. It is important to use recent, site-specific analysis results for the effluent, manure or compost being spread, particularly for effluent. The nutrient producing the lowest application rate is the limiting nutrient and generally determines how much effluent, manure or compost is applied. However, as potassium causes few environmental impacts it can be applied in excess of plant needs providing soil structure is monitored and any issues addressed. If the land will be grazed, soil cations will need to be monitored to assess grass tetany risk.

Table C.3 Typical nutrient contents

Product	Typical nutrient content			
	DM Content (%)	**Nitrogen**	**Phosphorus**	**Potassium**
Effluent	-	600 mg/L (158-955 mg/L)	70 mg/L (19-175 mg/L)	500 mg/L (128-784 mg/L)
Sludge	13% (7-17%)	3.4% (2.84-4.02%)	4.69% (2.83-5.9%)	0.75% (0.27-1.33%)
Spent bedding/ compost	58% (52-64%)	0.8% (0.2-4.5%)	1% (0.2-2.6%)	0.4% (0.2-0.6%)

Worked example 1: Effluent

This example assumes that a 3 t/ha barley grain crop is grown on the reuse area (as per previous). For the purpose of this example, it is assumed the effluent contains 600 mg N/L, 70 mg P/L and 500 mg K/L. It is very important to use recent, site-specific analysis results for the effluent being irrigated.

Effluent application rate (ML/ha) = nutrient application rate (kg/ha) / (nutrient concentration in effluent [mg/L])

To convert ML/ha to mm, multiply by 100.

To convert ML/ha to kL/ha, multiply by 1,000.

Effluent application rate for N (ML/ha) = 72 kg/ha ÷ 600 mg/L

= 0.12 ML/ha

Effluent application rate for P (ML/ha) = 7.5 kg/ha ÷ 70 mg/L

= 0.11 ML/ha

Effluent application rate for K (ML/ha) = 13.5 kg/ha ÷ 500 mg/L

= 0.03 ML/ha

The lowest application rate (0.03 ML/ha or 3 mm) is for K; the limiting nutrient. Hence, the maximum application rate is 0.03 ML/ha. Although, as mentioned above, potassium causes few environmental impacts and can be applied at higher rates providing soil structure is monitored and any issues addressed.

1 ML/ha is equivalent to an irrigation depth of 100 mm. Hence, 0.03 ML/ha = 3 mm.

Effluent may need to be diluted for practical irrigation at this rate. A significantly higher rate would be possible if a silage or hay crop were grown.

Calculation template: Effluent

Effluent application rate (ML/ha) = nutrient application rate (kg/ha) / (nutrient concentration in effluent [mg/L])

To convert ML/ha to mm, multiply by 100.

To convert ML/ha to kL/ha, multiply by 1,000.

Application rate for N (ML/ha) = ____________ (kg/ha) ÷ (____________ mg/L)

Application rate for N (ML/ha) = ____________

Application rate for P (ML/ha) = ____________ (kg/ha) ÷ (____________ mg/L)

Application rate for P (ML/ha) = ____________

Application rate for K (ML/ha) = ____________ (kg/ha) ÷ (____________ mg/L)

Application rate for K (ML/ha) = ____________

Worked example 2: Spent bedding

This example assumes that a 3 t/ha barley grain crop is grown on the reuse area and that spent bedding is applied once every four years (as per previous). For the purpose of this example, it is assumed the spent bedding has a dry matter content of 58% and contains 0.8% N, 1.0% P and 0.4% K on a DM basis. Convert these to kg/t by multiplying by 10 which gives 8 kg N/t, 10 kg P/t and 4 kg K/t (on a dry matter basis). If data are available, use recent, site-specific analysis results for the manure being spread.

Application rate (t DM/ha) = nutrient application rate (kg/ha) ÷ nutrient concentration in manure (mg/kg)

Note: "amount of nutrient" comes from previous step.

Application rate (t DM/ha) for N = 264 kg/ha ÷ 8 kg/t

= 33 t DM/ha

Application rate (t/ha) for P = 30 kg/ha ÷ 10 kg/t

= 3 t DM/ha

Application rate (t/ha) for K = 54 kg/ha ÷ 4 kg/t

= 13.5 t DM/ha

The lowest application rate (3 t DM/ha) is for P; the limiting nutrient. Hence, the maximum application rate is 3 t DM/ha. It is likely that additional N will need to be applied to the crop.

Calculation template: Manure and compost

Application rate (t DM/ha) = nutrient application rate (kg/ha) ÷ nutrient concentration in wastes (kg/t)

Application rate (t DM/ha) for N = ____________ (kg/ha) ÷ ____________ kg/t

Application rate (t DM/ha) for N = ____________ (kg/ha)

Application rate (t DM/ha) for P = ____________ (kg/ha) ÷ ____________ kg/t

Application rate (t DM/ha) for K = ____________ (kg/ha) ÷ ____________ kg/t

C2.4 Practical spreading rate: Manure and compost

The spent bedding has a dry matter content of 58%, so each tonne of spent bedding contains 580 kg of dry matter, and 420 kg of water. To calculate the practical spreading rate for manure and compost, these need to be converted from a dry matter basis to as-spread.

Practical spreading rate (t /ha) = DM spreading rate (t/ha) ÷ dry matter %

Practical spreading rate (t/ha) = 3 t DM/ha ÷ (58/100)

= 5.1 t/ha.

Calculation template: Practical spreading rate for manure and compost

Practical spreading rate (t/ha) = ___________ t DM/ha ÷ (_________ ÷ 100)

= ________ t/ha.

C2.4.1 Useful conversions

1 acre		0.405 ha	
1 ha		2.47 ha	
1%	10,000 mg/g	10 g/kg	10 kg/t
10,000 mg/L	10 g/L	10 kg/KL	
1000 mg/kg	1 g/kg	0.001 kg/t	
1 ML	1000 KL	1000 m3	
1 ML/ha	100 mm		
1 KL/ha	0.1 mm		

Appendix D

Duty of care statement

D1 Duty of care statement: Manure and compost

This duty of care statement is to assist people using manure and compost off-site.

Piggery effluent, manure and compost can be valuable sources of nutrients and organic matter for improving soil properties and crop or pasture production. Good management is needed to gain the maximum benefit from these products while minimising environmental risks. Benefits may include:

- increased organic matter
- enhanced soil structure
- improved rainfall infiltration and water holding capacity of soil
- enhanced soil fertility
- reduced erosion
- increased plant yields
- reduced fertiliser costs.

Manure and compost from piggeries are valuable sources of nutrients for plant growth and carbon for building soil structure. However, like inorganic fertilisers, they need to be spread on suitable areas at sustainable rates to protect the environment. Those utilising manure or compost must take all reasonable and practical steps to minimise risks to the environment and public health. Requirements for off-site reuse differ between states and territories. Some industries also have particular requirements for manure and compost reuse. For example, refer to the Freshcare standards for current guidance applying to fruit and vegetables, particularly those eaten raw or without processing.

Spreading of manure and compost needs to be managed to:

- protect the land, particularly with regards to nutrient levels
- avoid odour, dust and noise nuisance
- protect surface water and groundwater quality.

To minimise the likelihood of these potential impacts:

- Minimise the risk of manure or compost spillage during transportation by not overfilling the truck and by covering the load.
- Where practical, avoid transport routes with a large number of houses close to the road.
- Manure and compost should be spread promptly, unless there is a suitable storage area at the receiving site. They should not be stored on areas where they will pose a significant risk of nutrient transfer to watercourses (e.g. sloping land immediately abutting a creek) or an odour nuisance for nearby neighbours.
- Manure and compost should not be spread on areas that pose a significant risk of nutrient transfer to watercourses (e.g. sloping land immediately abutting a watercourse).
- Plan the timing of manure or compost spreading carefully to avoid causing odour and dust nuisance for neighbours. Avoid spreading just before weekends or during holiday periods, particularly if close to a public area. Check the weather before spreading, odour dispersion is best under warm, clear conditions; delay spreading under overcast conditions. Spreading from mid-morning to early-afternoon is usually best. Also check the wind speed and direction to ensure the prevailing wind is not blowing directly towards nearby residences.

- Delay spreading of manure and compost if heavy rain is expected or if the soil is still very wet following heavy rain to minimise the risk of nutrient losses.
- Avoid spreading dry materials under windy conditions to minimise dust.
- Avoid spreading spent bedding or compost close to sensitive neighbours at night when noise may create nuisance.
- Determine a suitable spreading rate based on the N, P and K content of the manure or compost, soil properties and the intended land use of the reuse area. The rate should be consistent with the ability of soils and plants grown on the area to sustainably use the applied nutrients.
- Calibrate the spreader to spread at the target rate.
- Monitor reuse areas for weeds and control these if necessary. Although the aging and composting processes usually destroy most weed seeds, some seeds may remain viable.
- For biosecurity reasons, do not allow grazing stock to access stored manure or reuse areas for at least three weeks after spreading.

A recent “typical analysis” sheet for the manure or compost should also be provided to the recipient.

Appendix E

Manure and compost valuation pro-forma

E1 Introduction

Manure and compost are commonly provided or sold to offsite reusers. This appendix provides a method, using the value of nutrients in fertilisers, to place a potential value on manure and compost macro-nutrients. Farmers looking to use pig manure and compost should consider the benefits they may receive from reuse but also factors affecting these benefits.

E2 Beneficial reuse of manure or compost

Benefits from the reuse of manure or compost may include the addition of:

- a range of macro-nutrients (N, P & K) and trace nutrients that are needed to optimise plant growth
- organic matter (OM) which helps to improve soil structure. The addition of OM creates pore spaces that encourage root penetration and ready movement of water, nutrients and air which in turn assist with the growth of beneficial micro-organisms.
- To determine the benefits and optimise plant needs:
  - Test the soil to identify which nutrients are beneficial for the intended crops. Manure and compost may contain nutrients that are not needed, affecting both application rates and value for the reuser. Reuse rates are typically based on macronutrient levels. As potassium (K) poses few environmental concerns, nitrogen (N) and phosphorus (P) are commonly used to determine sustainable rates. Surplus K has no value to the reuser and may increase grass tetany risk if grazing.
  - Supplement with inorganic fertilisers as needed to optimise crop yields. Manure and compost are not balanced fertilisers and may lack certain nutrients. Some nutrients may also be released gradually over several years.

Step 1: Quantify the nutrient content of the manure or compost

The manure or compost should be analysed to determine its nutrient content as this can vary widely in composition. Analysis of the manure after aging or composting is recommended and ideally close to when it will be spread. As an indication, aged straw-based spent bedding might contain about:

- 2.0% N which is equivalent to 20 kg N ÷ DM t
- 1.4% P which is equivalent to 14 kg P ÷ DM t
- 2.9% K which is equivalent to 29 kg K ÷ DM t.

Aged bedding typically has a moisture content (MC) of between 30% and 50% or a dry matter (DM) content of 50-70%. The concentration needs to be converted to an as-spread basis. With a DM of 60%, the concentration of each nutrient in the spent bedding can be estimated using the formula:

Nutrient concentration (kg/t as spread) = DM concentration (kg/t) x DM%N

= 20 kg ÷ DM t x 60%

= 12 kg/t or 1.2%P = 14 kg ÷ DM t x 60%

= 8.4 kg/t or 0.84%K = 29 kg ÷ DM t x 60%

= 17 kg/t or 1.7%

These values will be used in the calculations that follow. Different concentrations would apply to compost, although the calculation process is the same.

Step 2: Value the nutrients in inorganic fertilisers

It is possible to put a worth on the N, P and K in manure or compost using the value of these nutrients in inorganic fertilisers. Table E.1 shows the typical composition of a range of common fertiliser products. Commercial bulk fertiliser prices were obtained for common N, P and K fertilisers. These were $900/t for urea, $500/t for single superphosphate and $900/t for muriate of potash (Feb. 2024, excl. GST and spreading). These were used to calculate the values for N, P and K given in Table E.1.

Example

- Since urea is 46% N and costs $900/t, N can be valued at $1.96/kg (i.e. ($900/t ÷ 0.46) ÷ 000).
- Single superphosphate contains 8.8% P and costs $500/t. The P in triple superphosphate is worth about $5.68/kg (i.e. ($500/t ÷ 0.088) ÷ 1000).

Muriate of potash contains 50% K and costs $900/t. The K is therefore worth about $1.80/kg (i.e. ($900/t ÷ 0.5) ÷ 1000). Thus, for this exercise, N is valued at $1.96/kg, P at $5.68/kg and K at $1.80/kg.

Table E.1 Nutrient value per kilogram in common inorganic fertilisers

Nutrient	Fertiliser	Price	Nutrient content %	Nutrient value ($/kg)
Nitrogen (N)	Urea	$900	46%N	N = $1.96/kg
Phosphorus (P)	Single superphosphate	$500	8.8% P	P = $5.68/kg
Potassium (K)	Muriate of potash	$900	50% K	K = $1.80/kg

Step 3: Apply the fertiliser nutrient values to the nutrients in manure or compost

The nutrient values ($/kg) for N, P and K calculated in Step 2 can be multiplied by the N, P and K in the manure or compost (from Step 1) to obtain a potential macro-nutrient value. Table E.2 provides an example for spent bedding.

Greater accuracy can be obtained by using site-specific data for the composition of spent bedding or compost and up to date fertiliser prices.

Table E.2 Value of nutrients in aged spent bedding based on prices for common inorganic fertilisers

Parameter	Nutrient concentration* (kg/wet t)	Value# ($/kg nutrient)	Value of nutrients in spent bedding ($/t)
N	12	$1.96	$23.52
P	8.4	$5.68	$47.71
K	17	$1.80	$30.60
Total potential value			$108.83
	* from Step 1	# from Step 2	

Important points to remember when looking at these results include:

- The nutrients are only of value if they are needed in the cropping system. For instance, if the crop requires N and P but the soil already has ample K, the K provides no additional value. In this case, the value of the manure or compost is driven by the summed value of the N and P, but not the K, bringing the potential value down to $71.23.
- This valuation does not include the contribution of other elements like sulfur, zinc, calcium, magnesium, boron, copper and other trace elements that may be valuable depending on the soil nutrient status. If these are deficient, their value can be be added to the macro-nutrient value using the same steps.
- Manure and compost also add carbon to the soil. This helps to improve soil structure and water-holding capacity and reduce its erosivity. However, it is difficult to put a dollar value on these benefits.
- N losses after spreading must be considered. If the manure is not incorporated into the soil immediately, losses could be significant with a corresponding reduction in the value of the N contribution by the manure or compost.
- The benefits from the nutrients contained in manure and compost may be realised over several years due to the rates of nutrient availability. For example, only one-third of the N in the compost might be available in Year 1, however, this varies considerably. P availability also varies widely between soil types. The end result is that the value of the manure or compost could be spread over 2-3 years as nutrients become available to plants.
- Manure and compost rarely match ideal nutrient ratios or provide nutrients in fully available forms. They are best used alongside inorganic fertilisers. One approach is to meet P needs with manure or compost, and top up N with conventional fertiliser.

Alternatively, apply manure or compost to meet crop N requirements, only if soil testing confirms it can safely store surplus P. Most clay soils can store 3–5 years of P. Stored P must be used up before further manure or compost is applied. Step 4: Calculate the value of the nutrient applied. The potential value of nutrients applied as spent bedding with an application rate of 5 t/ha are shown in Table E.3. The value is determined by multiplying the value of each nutrient ($/t) by the spreading rate (5 t/ha).

Table E.3 Value of nutrients applied as spent bedding

Nutrient	Nutrients applied* (kg/t)	Value of nutrients applied# ($/t)	Nutrients applied @ 5 t/ha (kg/ha)	Value of nutrients applied @ 5 t/ha ($/ha)
N	12	$23.52	60	$117.60
P	8.4	$47.71	42	$238.55
K	17	$30.60	85	$153.00
Total potential value	-	$108.83	-	$509.16
	* from Step 1	# from Step 2		

Step 5: Determine the net potential benefit of spreading the manure

Table E.4 provides the net potential benefit of using spent bedding, taking into account all the costs of carting and spreading, compared to the calculated value of the nutrients contained in the bedding.

Table E.4 Net benefit of nutrients applied as spent bedding accounting for all costs

Item	Cost per t ($/t)	Total cost at 5 t/ha ($/ha)
Cost of bedding	$8.00	$40.00
Carting and spreading	$46.00	$230.00
Total cost	$54.00	$270.00
Potential value of nutrients applied*	$108.84	$509.16
Net potential benefit of using spent bedding	$54.84	$239.16
	* from Step 4	

In this example, if the N, P and K in the spent bedding is required by the crop, there is a potential economic advantage of about $239/ha in applying 5 t/ha of spent bedding. If potassium were not needed by the crop, this would reduce to $86.16/ha.

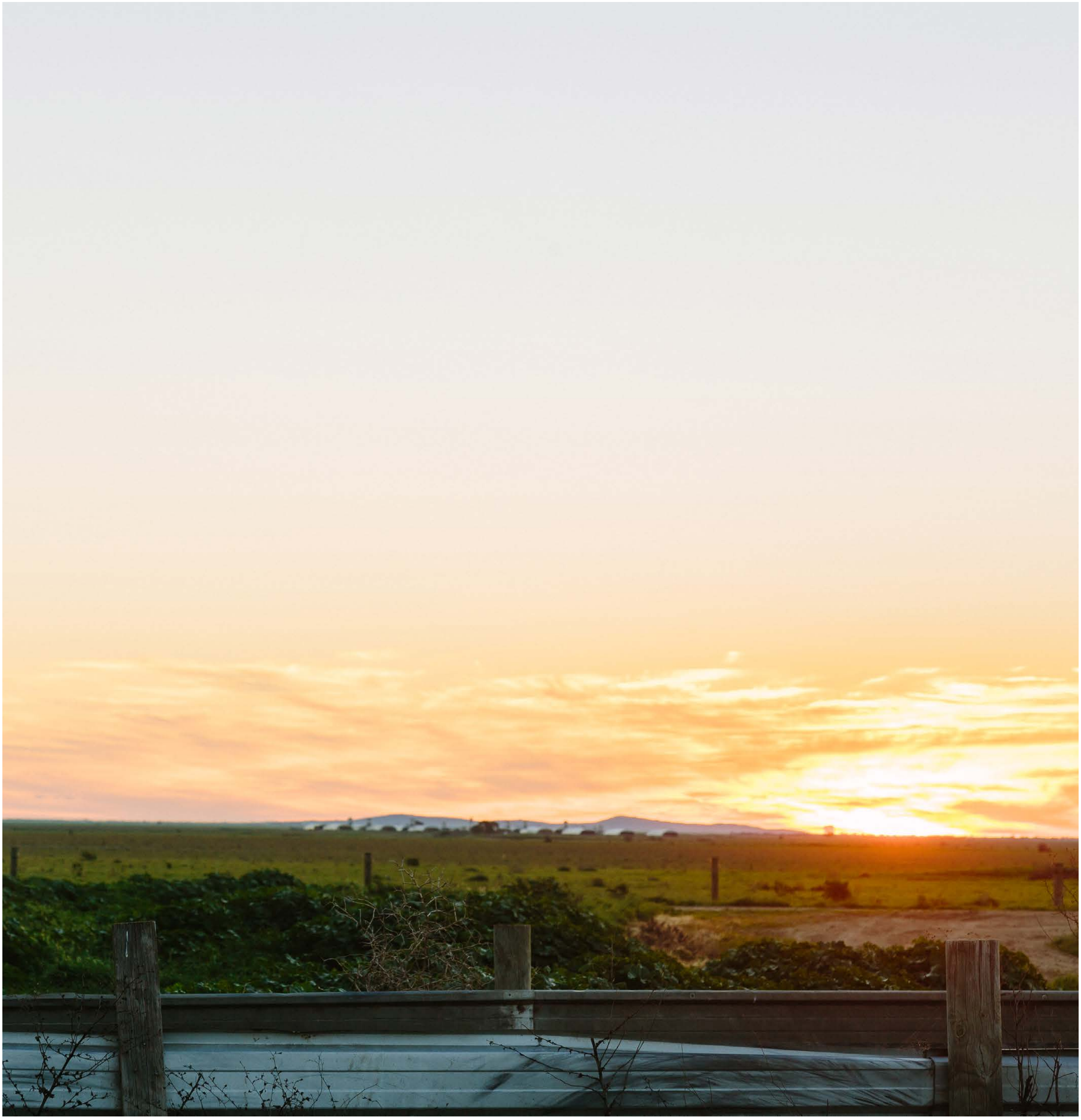
Appendix F

Environmental risk assessment

F1 Introduction

An environmental risk assessment identifies impacts or risks that a piggery, or proposed piggery development, may pose to the environment. It considers the likelihood and consequences of an impact occurring. This can help in selecting a suitable site and making design and operational decisions that reduce the likelihood of environmental harm.

This tool is for use with the environmental risk assessment framework. It outlines the necessary tools and steps to identify, assess, manage, monitor and review piggery environmental risks. The Standards Australia AS 31000:2018 *Risk Management - Guidelines* (Standards Australia 2018) provides further guidance.



F2 Environmental risk assessment process

The steps in the environmental risk assessment process are described below, with two examples followed through each step.

F2.1 Process overview

Risk identification involves:

- identifying hazards
- considering the level of consequence if the hazard were to occur
- considering the likelihood of occurrence
- evaluating the risk level
- identifying practical controls that could be used to reduce risk
- re-evaluating the risk level with the new controls in place.

APL has developed an environmental risk assessment methodology for piggeries which is summarised in Figure F.1 and provided in the sections that follow.

Figure F.1 Summary of risk assessment process

Identify hazards	• Identify hazards
Consequences	• Identify the consequences of the hazard occuring considering siting, design and management i.e low to severe
Likelihood	• Identify the likelihood of occurence i.e. rare to certain
Risk rating	• Determine level of risk to the environment i.e. low to extreme
Identify practical controls	• If acceptable risk, manage and monitor to ensure risk remains acceptable • If unacceptable identify new controls
Re-evaluate risk	• Re-evaluate risk with new controls

F2.2 Hazards

Hazards are the ways in which the piggery may pose a risk to the environment or public health. For example, effluent might pose a hazard if it spills posing a risk of polluting a watercourse.

Common hazard categories could include the potential for risks from:

- effluent
- manure (including spent bedding)
- mortalities
- odour
- dust
- noise
- pathogens
- chemicals
- wastes (rubbish and sharps).

F2.3 Consequences

This involves considering the level of harm that could occur should the hazard eventuate.

Each consequence should be rated as low, minor, moderate, major or severe. When deciding the rating, consider the existing or planned siting, design or management.

Table F.1 Consequences ratings

Low	No or minimal environmental or public health impact.
Minor	Low environmental impact or potential for public health impacts. Examples include: • effluent spill that does not leave the property boundary or enter a watercourse • nuisance resulting in an isolated community complaint.
Moderate	Medium level of harm to the environment or public health over an extended period of time. Examples include: • contained off-site environmental incident (e.g. effluent spill on road) • nuisance resulting in repeated community complaints from one incident.
Major	Serious harm to the environment or public health. An environmental impact that is severe and likely to impact beyond the immediate site and remain a problem in the medium term. Examples include: • significant effluent spill into a watercourse • nuisance resulting in ongoing community complaints.
Severe	Something that causes permanent or long term serious environmental harm or life threatening or long term-harm to public health. Examples include: • significant volumes of effluent regularly entering a **Ramsar wetland** or potable water supply • worker death resulting from untrained staff working in a confined space or hitting overhead power lines with machinery.

F2.3.1 Risk likelihood

Next, evaluate the likelihood of the hazard eventuating.

Table F.2 Risk likelihood definitions

Likelihood rating	Similarity
Rare	Could happen but probably never will
Unlikely	Not likely to happen in normal circumstances
Possible	May happen at some time
Likely	Expected to happen at some time
Certain	Expected to happen regularly under normal circumstances

Example 1:

If an effluent pond spill is likely to result in off-site water pollution, the consequence is “major”. If this is expected to occur about once every five years, the likelihood is “possible”. The risk is high. If controls were implemented to reduce the spill frequency to once every ten years, the likelihood would change to “unlikely”. The risk is now medium.

Example 2:

If spent bedding spreading occurs annually and results in odour nuisance complaints most of the time it is undertaken, the consequence is “minor” and the “likelihood” is likely. The risk is medium. If the spent bedding is aged before spreading and care is taken with scheduling spreading events, the complaints might reduce significantly (“unlikely” likelihood). The risk would reduce to low.

F2.4 Evaluating the risks

Use the risk rating matrix provided as Figure F.3 to rate the risk by considering consequence and likelihood together, where consequence x likelihood = risk rating.

Table F.3 Risk rating matrix

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Severe
Certain	Medium	High	High	Extreme	Extreme
Likely	Medium	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium

Example 1: moderate consequence x possible likelihood = medium risk.

The colour-coded output of the risk rating matrix identifies the overall level of risk. Figure F.4 can be used to guide the actions that follow:

- Low (green) – acceptable. The siting, design and management is acceptable. No corrective or preventative action is needed, although further controls may be considered to further reduce risk if this can be done with little cost and effort.
- Medium (yellow) – at this risk level consider additional controls to reduce the risk to low.
- High (orange) – the risk is unacceptable. Risk will need to be mitigated through the implementation of appropriate corrective or preventative actions.
- Extreme (red) – the risk is totally unacceptable. Immediate corrective or preventative action must be implemented, which could include ceasing some site activities.

Table F.4 Interpretation of risk level

Risk level	Action
Extreme	Implement corrective or preventative actions immediately to lower the risk to an acceptable level, which could include ceasing some site activities.
High	Implement controls as a priority to reduce the level of risk.
Medium	Consider implementing additional controls to reduce the risk level.
Low	No additional controls are needed although controls could be implemented to further minimise risk.

F2.5 Identifying practical controls

Where a risk needs to be addressed, consider the causes and use these to identify options to minimise the risk to the extent that is reasonably practicable considering effectiveness, feasibility and cost. This could be achieved by eliminating or reducing the hazard, consequence or the likelihood. Controls could involve changes to siting, design or management. For example, a risk to a watercourse could be reduced by relocating facilities or activities further away. A risk to groundwater from a manure storage area could be mitigated by constructing a bunded, impermeable pad for this activity. Odour nuisance could be mitigated by only irrigating effluent under conditions likely to promote good odour dispersion.

F2.6 Re-evaluate the risk

This step involves re-assessing the risks using the risk matrix to determine if the new controls will eliminate or lower the risk to an acceptable level. If not, the process should be repeated. This is illustrated in Figure F.5 below.
The first example could be for a proposed or existing piggery that has an acceptable level of risk (suitable controls).
The second example shows an unacceptable level of risk that is re-evaluated considering.

Table F.5 Risk re-evaluation

Risk rating with proposed or current controls					
Hazard	**Description of risk**	**Current controls**	**Likelihood**	**Consequence**	**Risk rating**
Effluent	Overflow of effluent to a watercourse	Effluent pond designed in accordance with NEGIP and located 200 m from creek	Rare	Moderate	Low
Leachate from manure storage	Groundwater contamination with nutrients (light soil, shallow groundwater)	Manure stored in piles in paddock	Likely	Moderate	High
Risk rating after new controls					
Hazard	**Description of risk**	**New controls**	**Likelihood**	**Consequence**	**Risk rating**
Effluent	Overflow of effluent to a watercourse	None warranted			
Leachate from manure storage	Groundwater contamination with nutrients (light soil, shallow groundwater)	Bunded low permeable pad, capture of runoff	Rare	Moderate	Low

F3 Guidance to assist in risk assessment

This section provides guidance to assist in the identification and assessment of common hazards that could occur at pig farms.

F3.1 Amenity and natural resources vulnerability

The purpose of this section is to identify sensitive land uses and natural resources that might be at greater risk from hazards. It provides a way to assess the vulnerability of the:

- soils of reuse areas
- groundwater–quality and availability
- surface water–quality and availability
- community amenity.

Guidance for assessing the vulnerability of sensitive land uses and natural resources is supplied in the tables below. Since it is not possible to represent all situations that will occur on all farms, discretion should be used when evaluating site vulnerability. For each parameter of relevance, consider which option best represents the piggery being assessed. The options are ordered from lowest to highest risk. Using the vulnerability templates will help pinpoint areas where better design and management may be needed to minimise risks to environment.

Example:

A hazard could be effluent that is being irrigated onto land. The groundwater vulnerability table includes a range of depths to groundwater ranked from lowest risk (deep groundwater) to highest risk (shallow groundwater). If the groundwater is present at a depth of greater than 20 m the risk is inherently lower than if it is less than 2 m below the ground surface.

Table F.6 Soil reuse areas

Criteria
Reuse areas are:
• Suited to growing a broad range of broad acre crops and pastures
• Suited to growing crops or pastures that can be cut and carted
• Unsuited to producing crops or pastures that can be cut and carted
Reuse areas have a soil depth of:
• At least 1 m
• At least 0.75 m
• At least 0.5 m
• Less than 0.5 m
Reuse areas have soils that are:
• Well structured, non-rocky, non-saline and non-sodic
• Non-rocky, non-saline and non-sodic
• Rocky, saline or sodic
Reuse areas have soils that are:
• Loam (25-30% clay) to medium clay (45-55% clay) in texture
• Sandy loam (10-25% clay) to heavy clay (>50% clay) in texture
• Sandy in texture
Reuse areas are:
• Not prone to waterlogging
• Prone to waterlogging
Reuse areas:
• Flood at a frequency of less than once every 10 years
• Flood at a frequency of less than once every 5 years
• Flood more than once every 5 years on average
Reuse areas have slopes that promote:
• Infiltration, rather than runoff or erosion
• Runoff or erosion

Table F.7 Vulnerability: Groundwater quality and availability

Criteria
Depth to groundwater is:
• Always at least 20 m below the ground surface or the base of any piggery infrastructure, or always at least 10 m beneath the surface or the base of any piggery infrastructure, and protected by a significant rock or clay band
• Always at least 10 m below the ground surface or the base of any piggery infrastructure, or always at least 5 m beneath the surface or the base of any piggery infrastructure, and protected by a significant rock or clay band
• Always at least 5 m below the ground surface or the base of any piggery infrastructure, or always at least 2 m beneath the surface or the base of any piggery infrastructure
• Sometimes present at a depth of less than 2 m below the ground surface or the base of any piggery infrastructure
If groundwater is used in the piggery, there is:
• Ample allocation and supply that is of a suitable quality to meet requirements
• Sufficient allocation and supply that is of a suitable quality to meet requirements
• Marginal or insufficient allocation or supply (and no other water source), or the water is of a marginal quality to meet requirements

Table F.8 Vulnerability: Surface water quality and availability

Criteria
The piggery is located:
• At least 200 m from the closest watercourse
• At least 100 m from the closest watercourse
• Within 100 m of the closest watercourse
The piggery is located:
• At least 800 m from the closest major water supply storage
• Within 800 m from the closest major water supply storage
Reuse areas:
• Comply with the **buffer distances** specified in the NEGIP, and there are additional protection measures (e.g. VFS or terminal ponds) between these areas and the closest watercourses
• Comply with the buffer distances in the NEGIP
• Don't comply with the buffer distances in the NEGIP, but there are effective VFSs, terminal ponds or other protection measures between these areas and all watercourses
• Don't comply with the buffer distances in the NEGIP and there are insufficient water protection measures in place

Criteria
The piggery is located:
• Above the one-in-100-year flood line
• Above the one-in-50-year flood line
• Within the one-in-50-year flood line
Reuse areas are located:
• Above the one-in-10-year flood line
• Above the one-in-five-year flood line
• Within the one-in-five-year flood line
If surface water is used in the piggery, there is:
• Ample allocation and supply that is a suitable quality to meet requirements
• Marginal or insufficient allocation or supply (and no other water source) or the water is of a marginal quality to meet requirements.
The piggery has received:
• No complaints from the public or regulators for at least five years
• Less than two complaints per year (on average) over the past five years
• Less than four complaints per year (on average) over the past five years
• Four or more complaints per year (on average) over the past five years
Levels of odour, dust and noise around the property boundary are:
• Checked at least weekly
• Checked at least monthly
• Checked occasionally
• Not routinely monitored
Surrounding land is:
• All designated rural, and is not designated for future development or rezoning
• All designated rural, but some is designated for either future development or rezoning
• Aot all designated rural

Criteria
The piggery is:
• Well concealed from roads and neighbours
• Fairly well concealed from roads and neighbours
• Partly concealed from roads and neighbours
• Clearly visible from roads and neighbours
The entrance point to farm provides:
• At least 300 m good visibility in both directions
• At least 200 m good visibility in both directions
• At least 150 m good visibility in both directions
• Less than 150 m good visibility in at least one direction
Vehicle movements and other noisy activities:
• Occur only during the day, except under exceptional circumstances
• Are generally scheduled to occur only during the day
• Occur at any time of the day or night
Mechanical equipment used on-farm is:
• All fitted with manufacturer-specified exhaust devices
• Generally fitted with manufacturer-specified exhaust devices
• Mostly not fitted with manufacturer-specified exhaust devices
Dust from traffic movements, manure handling and reuse and feed milling is:
• Controlled as needed
• Not specifically controlled but dust does not seem to cause nuisance
• Not specifically controlled and dust is an issue at times

Criteria
There is:
• A complaints management procedure in place that includes complaints recording, investigation and corrective action, along with appropriate consultation
• A complaints management procedure in place that includes complaints recording, investigation and corrective action
• No complaints management procedure in place, or the procedure that is in place does not include complaints recording, investigation or corrective action
Mediation is:
• Used to try to settle disputes with neighbours
• Generally used to try to settle disputes with neighbours
• Not generally used to try to settle disputes with neighbours

F3.2 Protection provided by design and management

The information in this section can be used to assess the risk mitigation offered by the design and management of:

- pig housing
- the nutrient content of manure
- the effluent collection system
- the manure solids separation system
- the effluent management system
- the manure storage and composting areas
- carcass management
- design and management of reuse areas
- chemical storage and use.

Not all the factors will be applicable to all enterprises. For example, not all piggeries will have a solids separation system. To evaluate the protection afforded by each element of design and management, read the statements and select the most appropriate one for the farm. These are ordered from lowest to highest risk. The guidance in these design and management templates can also be used to identify options to further reduce environmental risks.

Table F.10 Design and management: pig housing

Criteria
Sheds:
• Are oriented east-west and are constructed to maintain temperatures within the required range with no mechanical heating or cooling
• Are oriented east-west and are constructed to maintain temperatures within the required range with minimal mechanical heating or cooling
• Are constructed to maintain temperatures within the required range but require significant mechanical heating or cooling to maintain temperatures at the required range
• Have a strong reliance on mechanical heating or cooling to maintain temperatures within the required range
Sheds bases are:
• Concreted for conventional sheds and impervious for deep litter sheds (e.g. concreted or compacted for a permeability of 1 x 10-9 m/s for a depth of at least 300 mm)
• Formed from well-compacted clay or other low permeability material for deep litter sheds
• Not concreted for conventional sheds and not formed from low permeability material for deep litter sheds
Feeding systems:
• Minimise feed wastage
• Rarely allow feed to be visible on the floor or in the bedding near the feeders
• Often allow significant quantities of waste feed to be visible on the floor or in the bedding near the feeders
• Always have significant quantities of waste feed visible on the floor or in the bedding near the feeders
Naturally ventilated sheds are:
• Well ventilated, as the sheds are separated by a distance of at least five times their height
• Quite well ventilated, as the sheds are separated by a distance of at least four times their height
• Reasonably well ventilated, as the sheds separated by a distance of at least three times their height
• Not well ventilated
Stocking densities:
• Meet the requirements of the *Model Code of Practice for the Welfare of Animals: Pigs*
• Do not meet the requirements of the *Model Code of Practice for the Welfare of Animals: Pigs*

Criteria
Conventional sheds are:
• Frequently cleaned to maintain very clean lanes, pens and handling areas, and pigs are clean
• Regularly cleaned to maintain very clean lanes, pens and handling areas, and pigs are generally clean
• Regularly cleaned but the lanes, pens and handling areas are often visibly dirty and generally some pigs are dirty
• Not regularly cleaned, and pigs are generally dirty
The bedding in deep litter sheds (except for dunging areas):
• Is always kept dry and friable, pigs are clean
• Is mostly kept dry and friable, pigs are generally clean
• Causes most pigs to be dirty towards shed clean out, because of its moisture content
• Is frequently damp or wet and pigs are dirty
The inflow or outflow of effluent from sheds is:
• Prevented by controls
• Mostly prevented by controls
• Not well controlled
Water used to wash-down deep litter housing after spent bedding removal is:
• Always contained in a suitably sized sump or pond
• Mostly well contained in a suitably sized sump or pond
• not well contained

Table F.11 Design and management: Nutrient content of manure

Criteria
The quantities of:
• Effluent and manure used on-farm are measured and recorded each time reuse occurs, and each type of effluent or manure product used is tested at least annually
• Nutrients in the piggery effluent and manure used on-farm have been estimated using conservative figures in accepted industry nutrient mass balance models
• Nutrients in effluent and manure that will be applied to land on-farm are estimated using general data in publications
• nutrients in effluent and manure are not generally measured or estimated

Table F.12 Design and Management: Effluent collection system

Criteria
Stormwater runoff, including roof runoff:
• Is excluded from entering the effluent collection system (or the system is designed to handle the runoff)
• Is mostly excluded from entering the effluent collection system, and the system does not generally overflow as a result
• Enters the effluent collection system, and the system sometimes overflows as a result
• Enters the effluent collection system, and the system often overflows as a result
Effluent collection systems (e.g. channels, drains, pipes, sumps) for conventional sheds are:
• Impervious (no significant cracks) impervious and have good integrity (minimal cracking)
• Are pervious because they are not made from concrete (or similar), or because of deterioration of the material they are constructed from
Effluent pits, sumps, pipes and drains are:
• Sized and managed so that they do not spill
• Sized and managed so that they only spill infrequently
• Inadequately sized or managed and spill at least once a year
Effluent pits and drains:
• Are self-cleaning and manure solids are not present in these after flushing or draining
• Are not self-cleaning, but are cleaned at least weekly to remove manure solids
• Have manure solids present in them after flushing or draining that are removed at least monthly
• Have manure solids present in them after flushing or draining and these are removed less than once a month
There are:
• Appropriate contingency measures to prevent spills from the system
• Contingency measures to prevent spills from the system, but these need improvement to reduce the spill frequency
• No specific contingency measures to prevent spills from the system

Criteria
Flushing channels are flushed:
• At least daily and static pits and pull plugs are emptied at least weekly (or in accordance with design requirements), with pits emptied in rotation, to promote uniform loading of the effluent treatment system
• At least every second day, and static pits and pull plugs are emptied at least every two to three weeks
• At least twice a week, and static pits and pull plugs are emptied at least once every four weeks
• Less than twice a week, and static pits and pull plugs are emptied less than once every four weeks
Drains, pits and sumps are:
• Inspected after each flush or draining for solids accumulation, leakage and deterioration
• Inspected after every second flush or draining for solids accumulation, leakage and deterioration
• Inspected at least monthly for solids accumulation, leakage and deterioration
• Not regularly inspected for solids accumulation, leakage and deterioration

Table F.13 Design and management: Effluent solids separation system

Criteria
The solids separation system (including any short-term solids storage areas) has:
• An impervious base (e.g. comprising two 150 mm layers of material each, compacted for a design permeability of 1 x 10-9 m/s, or other impervious material (e.g. concrete)
• A well compacted base
• An uncompacted base
The solids separation system (including any associated storage areas):
• Sits within a controlled drainage area, and there is no uncontrolled outflow of effluent
• Does not sit within a controlled drainage area, or there is uncontrolled outflow of effluent
Effluent from the solids separation system and associated storage areas is:
• Directed to a storage designed to cater for this inflow
• Directed to a storage
• Not directed to a storage

Criteria
The out-loading bay, where present:
• Is kept clean of excess solids; there is no significant spillage from transport vehicles
• Is generally kept clean of accumulated solids; significant spillage from transport vehicles happens less than once a year on average
• Frequently contains accumulated solids, or there is significant spillage from transport vehicles twice a year on average
• Generally contains accumulated solids, or there is significant spillage from transport vehicles more than once every six months, on average
The solids separation system is:
• Checked daily and cleaned or maintained after this check, as needed, to ensure it is performing to the design specification
• Checked at least weekly and cleaned or maintained as needed to ensure it is performing to the design specification
• Checked at least fortnightly and cleaned or maintained as needed to ensure it is performing to the design specification
• Not checked and cleaned or maintained at least fortnight

Table F.14 Design and management: Effluent management system

Criteria
The effluent management system:
• Is designed to capture, treat, store and reuse all effluent. It has no isolated sections. Inlets and outlets are positioned to prevent short-circuiting
• Is designed to capture and store all effluent. However, treatment capacity is compromised because either the inlets and outlets are poorly positioned, or because significant isolated sections don't provide active treatment capacity
• Does not capture, effectively treat or store all effluent produced by the piggery
The effluent management system:
• Is designed and managed such that odour emissions are acceptably low
• Sometimes produces strong odours, but these don't generally impact beyond the property boundary
• Produces strong odours that can be detected beyond the property boundary

Criteria
The effluent management system is:
• Designed to allow for ease of desludging, or to store at least 10 years of sludge
• Designed to store at least five years of sludge
• Designed to store at least two years of sludge
• Difficult to desludge and designed with less than two years of sludge storage capacity
The effluent management system:
• Has a design permeability of 1 x 10-9 m/s for a depth of at least 300 mm of compacted clay for ponds up to 2 m deep; 450 mm of compacted clay for ponds deeper than 2 m, or is fitted with a well maintained impervious synthetic liner
• Has a design permeability of 1 x 10-9 m/s for a depth of at least 300 mm of compacted clay
• Is lined with well compacted clay
• Is not lined with well compacted clay or a well-maintained impervious synthetic liner
The depth to the water table from the base of the effluent management system is always:
• At least 2 m
• Sometimes less than 2 m
The depth to the water table from the base of the effluent management system is always:
• At least 600 mm is provided on any effluent management system
• Less than 600 mm is provided on one or more effluent management system ponds
The effluent ponds is designed for an overtopping frequency:
• Not exceeding 1-in-10 years where reuse is practiced, or not exceeding 1-in-20 years where effluent disposal is by evaporation
• Exceeding 1-in-10 years where reuse is practiced, or exceeding 1-in-20 years where effluent disposal is by evaporation

Table F.15 Design and management: Manure storage

Criteria
Manure storage areas:
• Sit within a controlled drainage area, and all leachate is directed to effluent ponds, or storages designed to receive this inflow
• Sit within a controlled drainage area and leachate is directed to storages
• Are not within a controlled drainage area, or leachate is directed to effluent ponds not sized to receive this inflow

Criteria
The bases of manure storage areas are:
• Impervious (e.g. concrete or clay compacted for a design permeability of 1 x 10-9 m/s for a depth of 300 mm)
• Well compacted clay or other low permeability material
• Not built from well compacted clay or other low permeability material
The depth to water tables beneath the base of manure storage areas:
• Exceeds 2 m at all times
• May be less than 2 m
Manure stockpiles/windrows are:
• Always managed to maintain low odour emissions
• Generally managed to maintain low odour emissions, but significant odour releases occur about once a year on average
• Generally managed to maintain low odour emissions, but significant odour releases occur up to four times a year on average
• Not managed to maintain low odour emissions, and significant odour releases occur more than four times a year on average
Spilt or spoilt feed or leachate from wet feedstuffs is:
• Promptly cleaned up
• Cleaned up within four days
• Cleaned up within seven days
• Frequently present in the mill area

Table F.16 Design and management: Mortalities management

Criteria
Dead pigs are:
• Always removed from the sheds or pens within 12 hours of discovery
• Almost always removed from the sheds or pens daily
• Usually removed from the sheds or pens daily
• Frequently left in the sheds or pens for more than 24 hours

Criteria
Mortalities management (e.g. placement in a composting pile, burial etc.):
• Always occurs within 24 hours of death
• Always occurs within 36 hours of death
• Always occurs within 48 hours of death
• Does not always occur within 48 hours of death
Mortalities management is by:
• Rendering or composting
• Burial in a clay-lined pit or proper incineration
• Burning or dumping
Mortalities management areas:
• Always provide at least 2 m depth between base level and groundwater; and are impervious (e.g. concreted or sealed to a design permeability of 1x10-9 for a depth of 300 mm)
• Always provide at least 2 m depth between base level and groundwater; and are lined or built from compacted clay or gravel
• Sometimes provide less than 2 m depth between base level and groundwater; or are not on a well-sealed site
Where mortalities management is by composting or burial, carcasses are:
• Always promptly covered with at least 300 mm of sawdust or alternative carbon source (if composting) or soil (if burying) and continuously kept covered
• Generally promptly covered with at least 300 mm of sawdust or alternative carbon source (if composting) or soil (if burying) and continuously kept covered
• Generally not promptly covered with at least 300 mm of sawdust or alternative carbon source (if composting) or soil (if burying) or not continuously kept covered
Where mortalities management is by composting, burial or burning this:
• Occurs within a controlled drainage area with stormwater diverted away from the area
• Does not occur within a controlled drainage

Criteria
In the case of mass mortalities event, there is:
• A suitable site selected and a detailed plan for managing mass mortalities including emergency contact details
• A suitable site selected and a plan for managing mass mortalities including emergency contact details
• A suitable site selected and a list of emergency contact details, but no real plan for managing mass mortalities
• No site selected or plan for managing mass mortalities

Table F.17 Design and management: Reuse areas

Criteria
The nutrients in effluent and manure are:
• Budgeted to ensure they are applied at rates that are based on expected nutrient removals by crop or pasture harvest using average historical property crop or pasture yields with higher rates used if justified based on site-specific soil test results
• Budgeted to ensure they are applied at rates that are based on expected nutrient removals by crop or pasture harvest using average district crop or pasture yields with higher rates used if justified based on site-specific soil test results
• Budgeted to ensure they are applied at rates that are based on nutrient removals by crop or pasture harvest using generic yields
• Are not budgeted using mass balance principles, or the recommendations from soil test results
Nutrient export from reuse areas is:
• Minimised through good management and physical barriers (e.g. appropriately designed VFS; terminal ponds to catch the first 2 mm of runoff; contour banks; or maintaining average groundcover over whole area of at least 70%) and good farming practices (e.g. conservation tillage)
• Minimised through good farming practices (e.g. conservation tillage)
• Not specifically prevented
Effluent irrigation occurs:
• Only when the soil is dry enough to absorb the water and when rain is not expected
• Only when the soil is dry enough to absorb the water
• Irrespective of soil moisture conditions or expected weather conditions

Criteria
Effluent and manure are spread:
• Evenly and at times when active plant growth is expected
• Evenly but not always at times when active growth is expected
• Somewhat unevenly, but generally only spread when active plant growth is expected
• Very unevenly or at times when active plant growth is not likely
High-pressure irrigation guns that may create aerosols are:
• Not used
• Used
Flood irrigation is used:
• Only on sites with an even grade and loam or heavier soils, and with good flow control and runoff collection
• On sites with uneven grades and sand-sandy loam soils or inadequate flow control and runoff collection
Effluent and manure are:
• Only irrigated or spread when weather conditions are conducive to odour dispersion, and not on weekends or public holidays
• Generally only irrigated or spread when weather conditions are conducive to odour dispersion, and not normally on weekends or public holidays
• Irrigated or spread at any time of the day, but not normally on weekends or public holidays
• Irrigated /orspread at any time of the day, or commonly on weekends or public holidays
Soils of reuse areas are:
• Tested at least annually, and the results considered when determining future reuse rates
• Tested at least annually
• Regularly tested
• Not regularly tested

Table F.18 Design and management: Chemical use and storage

Criteria
SDSs, emergency response plans for spills and spill kits or suitable clean up equipment are:
• Provided for all chemicals used
• Not provided for all chemicals used

Criteria
Quantities of chemicals stored on-farm are:
• Minimised
• Not minimised
Chemicals with a low toxicity and low water contamination potential are:
• Preferentially selected
• Not preferentially selected
Chemicals and fuel are:
• Always stored and used in accordance with manufacturer's instructions and legal requirements, and only in accordance with the registered use. Records of use are maintained
• Not always stored and used in accordance with manufacturer's instructions or legal requirements, or are not always used in accordance with the registered use
Staff members are:
• Trained in the correct handling and use of all chemicals of relevance to their position
• Not trained in the correct handling and use of all chemicals of relevance to their position
Empty container and sharps disposal is:
• Always in accordance with manufacturer's instructions
• Generally in accordance with the manufacturer's instructions
• Not generally in accordance with the manufacturer's instructions
Where there are underground petroleum storage systems (UPSs) on-site:
• Applicable regulatory requirements for monitoring are always followed
• Applicable regulatory requirements for monitoring are not followed
Where chemical contractors are used:
• Only accredited contractors are engaged
• Accredited contractors are generally engaged
• Non-accredited contractors are commonly engaged

Note that the information in this appendix is designed to help in assessing the risk of environmental harm. It is not designed to provide a guide to risk in other areas (e.g. workplace health and safety).

References

Standards Australia (2018), AS31000: 2018 Risk Management – Guidelines, Standards Australia, Homebush

Appendix G

Complaints register

G1 Complaints register

The number of complaints received is an imprecise measure of community amenity impacts because these can be difficult to validate. However, a change in the people complaining, the number of complaints or complaints frequency may indicate an issue. Hence, any complaint should be taken seriously by the piggery operator and should be recorded and properly investigated. Full details of complaints received, results of investigations into complaints, and corrective actions should be recorded in a 'complaints register'. An example of a complaints register form is below.

Table G.1 Complaints register

Complaint details	
Date of complaint:	Time of complaint:
Nature of complaint: ☐Odour ☐Noise ☐Water ☐Dust ☐Other:	
Name of person advising of complaint:	
Method of complaint: ☐Phone ☐Email ☐In-person ☐Other:	
Complainant name (if known):	
Complainant contact details (if known):	

Investigation details
Temperature at time of complaint: ☐Cold ☐Cool ☐Mild ☐Warm ☐Hot ☐Very Hot
Wind strength at time of complaint: ☐Calm ☐Light ☐Moderate ☐Fresh ☐Strong ☐Gale
Wind direction at time of complaint: ☐N ☐NE ☐E ☐SE ☐S ☐SW ☐W ☐NW
Direction from piggery to complainant (if known):
Distance to complainant (if known):
Person responsible for investigating complaint:
Investigating method:
Significant activities at the time of the complaint:
Findings of investigation:

Action taken
Corrective actions:
Communications with complainant:

Appendix H

Sample collection

H1 Introduction

This appendix details methods for collecting, storing, handling and treating samples of surface water, groundwater effluent, manure, compost, plants and soil in order to determine their composition.

Before any sampling, the following factors must be determined:

- sampling locations and the sampling frequency or triggers
- a suitable laboratory capable of undertaking the required sample analyses
- transport of samples to the laboratory
- sampling equipment
- sampling procedures: there are two main types of samples. A grab sample is a single sample collected at a particular time and place, which represents the composition of the material being sampled. Composite samples consist of multiple grab samples that are bulked together to provide a representative sample
- monitoring parameters.

Many approved authorities have their own monitoring guidelines and requirements.

Seek advice from the approved authority when planning sampling and monitoring, particularly where requirements are specified by a licence or other permission.

In the absence of specific advice from the approved authority, the following guidelines may be used.

Always consider personal safety when sampling and use appropriate personal protective equipment.

H2 Laboratories

The National Association of Testing Authorities (NATA) Australia accredits laboratories, and those with this (or equivalent) accreditation are preferred for sample analysis. Analysis methods vary between laboratories, which may affect results. For this reason, using the same laboratory each year is recommended. Some regulators may also have specific laboratory testing method requirements, so it is important to check any requirements thoroughly. It is worth contacting the laboratory about analysis requirements, as they will often:

- provide suitable clean sample containers and preservatives (if required)
- issue analysis request forms
- advise which days are best for receipt of samples
- confirm requirements for storage (e.g. ice, preservatives) and transit times.

H3 Sampling equipment

The sampling equipment that may be required is listed below:

- appropriate sample containers and preservatives. For liquid samples most laboratories will supply or advise on suitable sample containers and any necessary preservatives. Obtaining sample containers or advice from the laboratory reduces the chance of sample contamination and ensures the sample size is adequate. For soil, manure or compost, ziplock plastic bags are generally suitable. Paper bags are needed for plant tissue samples
- personal protection equipment (e.g. rubber gloves and face mask)
- if sampling surface waters, liquid sludge or effluent directly from a source: a sampling rod. A rod with a large clamp for holding the sampling container allows greater reach when sampling liquids. If a sampling rod is not used, the sample should be taken from upstream of the feet to ensure that disturbed sediment is not collected
- if sampling from bores or piezometers: a sampling bailer or pump to draw water from the monitoring bores and a tape measure and plopper or fox whistle to determine depth to groundwater. A bailer is cheap. However, bailing is time consuming and impractical for deep bores. It is also important to ensure the bailer is clean before use. A pump is convenient to use
- if sampling manure, compost or soils: equipment to collect the sample (e.g. shovel, auger, post hole digger, hydraulic soil sampling rig), trowel, clean plastic sheet, ruler or tape measure and clean buckets
- cheap, styrofoam eskies
- plenty of crushed ice to pack around the samples in the eskies
- a waterproof pen to mark sample bottles
- waterproof tape to seal eskies
- analysis request forms.

H4 Recording of sampling details

At each sampling, record:

- the location and name of sampling site (e.g. piezometer 3, compost area)
- the date and time of day that sampling occurs
- weather conditions at the time of sampling
- for surface waters, a general description of the flow rate or approximate depth of water in dams or storages
- for groundwater, depth to groundwater
- the method of sampling (grab or composite samples)
- the name of the sampler
- the date and time of sample dispatch to laboratory
- a method for preserving samples (e.g. sample immediately put on ice in esky)
- analysis parameters requested (keep a copy of the original analysis request forms).

H5 Surface water sampling

H5.1 Sampling location

Sampling sites must provide representative samples and need to be accessible. Discuss selected sampling locations with the relevant environmental authority before sampling, to ensure the results will be acceptable.

In the absence of specific guidance, samples should be taken immediately upstream, and approximately 100 m downstream of an area of interest. The downstream sample should be taken some distance from the area of interest to allow for mixing of any runoff with the stream water. However, if the distance between sampling points is too great, inflows from other sources may affect the results. If another watercourse enters the relevant stream between the two sampling points, samples should also be taken from the secondary watercourse, close to its junction with the watercourse of interest.

H5.2 Sampling procedure

In most states, the environmental regulator will have a water sampling methodology that should be followed. In the absence of a suitable methodology, the following can be used:

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. Deep Creek upstream of effluent irrigation area) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.
2. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (from the sample bottles), sampling location, sampling date and analysis parameters.
3. Organise bottles and rods for sample collection. Composite samples consisting of five grab samples should be collected, particularly if there is little movement in the watercourse or for a dam. These should be collected using a sample bottle similar to the one that will be submitted to the laboratory. An equal sub-sample from each grab sample can be poured into a second bottle to make up the composite sample. Stream samples should be collected midstream, clear of bank edges and other potential contaminant sources. Use a sampling rod to collect samples so that it is not necessary to enter the watercourse (this can be dangerous and may also stir up sediment that contaminates the samples).
4. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Collect the sample by facing the mouth of the sampling container downwards and plunge into the water. Turn the sampling container to a horizontal position facing the current, preferably 0.2 m below the water surface (this avoids sampling surface scum). If necessary, create a current by dragging the container away from yourself. Remove the container as soon as it completely fills and empty it into the sample bottle. If taking a composite sample, pour a portion of the sample into a second sample bottle before discarding the balance and collecting the next sample. Repeat until all the sub-samples have been collected and combined. Add any required preservative and replace the lid. For some samples (e.g. EC, pH, total organic carbon and BOD) the bottle should be filled right to the top, whereas for other samples (e.g. most nutrients, turbidity and total suspended solids) the bottle should be filled only to the shoulder to provide air space. Two samples may be needed, depending on the testing requirements.
5. Immediately place the sample in an esky, pack crushed ice completely around it and replace the esky lid. Store the esky in a cool spot.
6. If samples will take longer than 48 hours to get to the laboratory, they may need to be frozen. Seek advice from the laboratory on this. Remember to leave some expansion space in the bottle. Do not store samples in a freezer used for food storage.
7. When all other surface water or groundwater samples have been added to the esky, seal it with the waterproof tape. Do not put effluent samples in the same esky as surface water samples. Put the sample analysis form in an envelope and tape firmly to the top of the esky.
8. Arrange for sample delivery to the laboratory. Confirm that they have been received.

H6 Groundwater sampling

H6.1 Sampling location

If groundwater monitoring is to be undertaken, suitable monitoring bores or piezometers must be identified or installed. A piezometer is a non-pumping well, generally of small diameter, with a short screen through which groundwater can enter. These must be installed correctly with depth and casing particularly important. Monitoring bores or piezometers may also need to be registered before construction. The approved authority should be consulted.

As groundwater may move extremely slowly, bores or piezometers should be located in close proximity and downstream of the area for monitoring. It is also advisable to locate a bore or piezometer above the area of interest to allow for comparison. Both bores should access water from the same aquifer. While a network of bores provides better information, this can become expensive. Hence, it is worth consulting a hydrogeologist, or specialist consultant, for advice on the location, installation and sampling of bores.

H6.2 Sampling procedure

In most states, the government environmental agency will have a water sampling methodology that should be followed. In the absence of a suitable methodology, the following can be used:

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, telephone number, a unique sample number, the sampling location (e.g. upslope bore) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.
2. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (matching those recorded on the sample bottles), sampling location, sampling date and analysis parameters.
3. The standing water in the bore may be stratified and interactions between the water and the bore casing and the atmosphere may have influenced water properties. Therefore, pumping several bore volumes from the casing is recommended to ensure stagnant water is not being sampled.

Bore volume (L) = ([3.14/1,000] x [radius m^2]) x water depth (m)

For shallow piezometers, it may be appropriate to empty the piezometer 1-2 days before sampling, and then to allow it to refill. Allow the bore to recharge with groundwater before sampling. If it is not possible to purge the bore before sampling, the sampling process should not disturb the water within the bore.

4. Measure the depth to groundwater.
5. Collect a grab sample using a bailer or pump.
6. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Rinse the sample bottle with the water to be collected. Fill the bottle directly from the bailer or pump. Remove the bottle from the flow as soon as it completely fills. Note that for some samples (e.g. EC, pH, total organic carbon and BOD) the bottle should be filled right to the top, whereas for other samples (e.g. most nutrients, turbidity and total suspended solids) the bottle should be filled only to the shoulder to provide air space. Two samples may be needed, depending on the testing requirements.
7. Add any required preservative and replace the lid.
8. Immediately place the sample in an esky, pack crushed ice completely around it and replace the esky lid.
9. If samples will take longer than 48 hours to get to the laboratory, they may need to be frozen. Seek advice from the laboratory on this. Do not completely fill the sample bottle if the sample will be frozen. Do not freeze samples in a freezer used for food storage.
10. When all other surface water or groundwater samples have been added to the esky, seal it with the waterproof tape. Do not put effluent samples in the same esky as groundwater samples. Put the sample analysis form in an envelope and tape firmly to the top of the esky.
11. Arrange for sample delivery to the laboratory. Confirm that they have been received.

H7 Effluent sampling

H7.1 Sampling location

Effluent should be sampled from the sampling stopcock, priming plug or main outlet of the effluent irrigation pump. If this is not possible, collect the sample from the pond from which irrigation water will be drawn using a sampling bottle on a sampling rod.

H7.2 Sampling procedure

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, telephone number, a unique sample number, the sampling location (e.g. secondary effluent pond) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.
2. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (from the sample bottles), sampling location, sampling date and analysis parameters.
3. Put on disposable gloves before sampling effluent. Avoid splashing eyes with effluent or sample preservatives. Avoid inhaling aerosols from the effluent being sampled or the preservatives. Do not eat, drink or smoke; carry out standard hygiene practices.
4. If sampling from a pump, start the pump and allow it to run for at least 10 minutes before collecting samples. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Sub-samples to make up a composite sample should be collected using a sample bottle. An equal quantity of ten grab samples can be poured into a separate sample bottle to make up a composite. Once this bottle is full, add any required preservative and replace the lid. Note that for some samples (e.g. EC, pH, total organic carbon and BOD) the sample should be filled right to the top, whereas for other samples (e.g. most nutrients, turbidity and total suspended solids) the bottle should be filled only to the shoulder to provide air space. Two samples may be needed, depending on the testing requirements.
5. If sampling directly from the pond use a sampling bottle on a sample rod to collect grab samples of effluent from 0.2 m below the water surface (this avoids sampling surface scum). Each grab sample should be taken from a different part of the pond. Add each grab sample to the bucket. When 10 samples have been collected, thoroughly mix these by swirling the bucket before pouring the composite sample into a sample bottle. Add any required preservative and replace the lid.
6. Immediately place the sample in an esky, pack crushed ice completely around it and replace the esky lid.
7. If samples will take longer than 48 hours to get to the laboratory, they may need to be frozen. Seek advice from the laboratory on this. Do not completely fill the sample bottle if the sample will be frozen. Do not freeze samples in a freezer used for food storage.
8. When all other effluent samples have been added to the esky, seal it with the waterproof tape. Do not put clean water samples in the same esky as effluent samples. Put the sample analysis form in an envelope and tape firmly to the top of the esky.
9. Arrange for sample delivery to the laboratory. Confirm that they have been received.

H8 Manure & compost

H8.1 Sampling location

Separate samples are needed for each type of manure product. This could include screenings, sludge, spent bedding and compost.

If manure is stored or composted before reuse, then the stored or composted product would generally need to be analysed prior to reuse.

H8.2 Sampling procedure

1. Assemble the sample containers or bags and any required sample preservatives. With a waterproof pen, label the sample containers (not the lids) or bags with the enterprise name, telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. compost pile) and the date of sampling.
2. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers, sampling location, sampling date and analysis parameters.
3. Put on disposable gloves and dust mask (if sampling dusty products). When sampling, do not eat, drink or smoke; carry out standard hygiene practices.
4. If sampling from a pump (e.g. sludge), start the pump and allow it to run for at least 10 minutes before collecting samples. Samples to make up a composite sample should be collected using a sample bottle similar to the one that will be submitted to the laboratory. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Pour an equal quantity of each of 10 sub-samples into a second bottle to make up the composite sample, add any required preservative and replace the lid.
5. If sampling from a stockpile (screenings, spent litter, compost), use a clean shovel or trowel to collect at least 10 cup-sized grab samples spread throughout the pile or from along the windrow or pile. Put each sample in the bucket and thoroughly mix with the garden trowel. Place about four cup-sized samples of the mixed sample into a bag and seal. Put the bag inside another bag and seal well.
6. If high moisture samples will take longer than 48 hours to get to the laboratory, they may need to be frozen. Seek advice from the laboratory on this. Do not completely fill the sample bottle if the sample will be frozen. Do not freeze samples in a freezer used for food storage.
7. Immediately place the sample in an esky, pack crushed ice completely around it, replace the esky lid and tape shut. Do not put any clean water samples in the same esky. Put the completed sample analysis form in an envelope and tape firmly to the top of the esky.
8. Arrange for sample delivery to the laboratory. Confirm that they have been received.

H9 Composting process

H9.1 Sampling location

Compost needs to be monitored during the process to ensure suitable temperatures are being maintained for a minimum of three days after turns. Windrow temperature is very dependent on the moisture content of the material. A minimum of two measurements should be taken per windrow or pile. For windrows greater than 10 m in length, taking 10 temperature measurements or at least one every 10-15 m along the windrow is recommended.

H9.2 Sampling procedure

The sampling procedure is as follows:

1. To measure temperature, a 1 m long temperature probe or sensor should be inserted to a depth of 1 m halfway up the pile to ensure the core temperature is recorded.
2. The moisture content is assessed at the same time using a squeeze test. This involves taking a handful of material and squeezing it. The sample should be collected from within the pile, not the surface, and this material may need to cool before it can be squeezed. If the material falls apart, cannot be formed into a ball and no water is released when a handful is squeezed, it is too dry. If it feels wet and drips water, the moisture content is likely took high. If it can be formed into a ball from which only a few drops of moisture can be squeezed, the moisture content is likely within the desirable range (50-60%).
3. Because composting material should sustain a minimum temperature of 55°C for at least three days after each turn, with five turns typically required. Record keeping is important.

H10 Soils

H10.1 Sampling location

Sampling locations should be chosen to represent the major soil types and land management practices (including land use and effluent or manure reuse rates). Soil sampling should always occur at the same time of year. The end of the cropping cycle is a good time, since nutrients remaining in the soil at this time are vulnerable to leaching. Sampling should not occur immediately after prolonged wet weather.

The following steps will help decide how many sampling locations are needed:

1. Examine the soil type of each reuse area. Soil type may vary across reuse areas. Different soils vary in their capacity to retain nutrients and in their productivity. Dig some holes and compare the soils of each hole.
2. Consider the number and type of land uses across the reuse areas, since this affects the sustainable spreading rate. Areas with different land uses should be monitored separately. However, it is not necessary to provide a monitoring plot in each separate paddock if there are similar land uses between paddocks with the same soil type.
3. Divide each area on the basis of effluent or manure product type (e.g. effluent, screenings, sludge, spent litter or compost) and application rate.

Example: If there is one soil type across the reuse areas of the farm, two land uses on these areas and only one manure or effluent product used on farm, the number of soil sampling sites would be two.

H10.2 Sampling Procedure

1. Assemble the sample containers and the sample preservatives.
2. With a waterproof pen, label the sample bags with the enterprise name, telephone number, a unique sample number, the sampling location (e.g. Paddock 5), the sampling depths (e.g. 0-10 cm, 30-60 cm) and the date of sampling.
3. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (from on the sample bags), sampling location, sampling date and analysis parameters.
4. Collect samples. There is a range of acceptable soil sampling methods. These include variations on:
   - monitoring plot: a 20 m diameter monitoring plot is selected in a location that is representative of the paddock or the area most at risk (e.g. the area likely to receive the highest effluent or manure application rate). The selected area should be free from stumps, atypical rockiness, tracks, animal camps and other unusual features. The location of each monitoring plot should be recorded on a property map or as GPS coordinates, so the same sites can be used in subsequent years.
   - grid: samples are collected from a series of parallel transects evenly distributed across the paddock. The pattern of sampling across the paddock forms a grid. The number of samples required depends on the area of the paddock.
   - zigzag: samples are collected in a zigzag pattern across the paddock. The pattern of sampling across the paddock forms a zigzag or "W" shape. The number of samples required depends on the area of the paddock.
   - random: samples are collected from random locations across the entire paddock. The number of samples required depends on the area of the paddock.

In all cases, collection of 20 grab samples of top soil (0-0.1 m) and at least five samples of subsoil (0.3-0.6 m or to bottom of root zone) to produce a topsoil and a subsoil composite sample for each sampling site, is recommended.

5. In some instances, it may be worth monitoring background soil nutrient levels on an area with a similar soil type that has not been used for effluent irrigation, manure spreading or conventional fertiliser spreading. The sampling method adopted for the reuse areas or a monitoring plot can be used. It is recognised that it is not always easy to find a suitable background plot. The location of each background plot should be recorded on a property map or as GPS coordinates so the same sites can be used in subsequent years.
6. As the samples are collected, record a description of the soil sampled (one description will generally suffice if the monitoring plots method is used). Combine all of the topsoil samples in a bucket and thoroughly mix using a hand trowel. Combine all the subsoil samples in a separate bucket and thoroughly mix. Remove rock fragments exceeding 2 cm diameter and large roots. Break up large clods. Never bulk (mix) soils of two different types. Never mix soil layers (profiles) that are clearly different from each other (e.g. sand and clay loam).
7. Pour the mixed composite topsoil sample into a pile on the plastic sheet. Divide the pile into four quarters. Discard three and thoroughly mix the remaining quarter. Repeat the procedure with the remaining quarter until the sample size is small enough to fill the sample bag (generally about 1 kg). Fill the sample bag and immediately place it in an esky. Repeat the process for the subsoil samples. Do not put effluent samples in the same esky as soil samples. Store the esky in the shade.
8. When all of the samples have been added to the esky, seal it with the waterproof tape.
9. Complete the analysis request forms and keep a copy. Put the sample analysis form in an envelope and tape firmly to the top of the esky.
10. Arrange for sample delivery to the laboratory. Confirm that they have been received.
11. While sampling, it is useful to record any unusual changes in the soils and plants of the reuse areas. These include:
    - Free water on the soil surface. This may indicate waterlogging. Other signs include reduced plant growth, growth of weeds (dock, nutgrass) and drooping foliage with pale leaves.
    - Invasion of an area with nettles or fat hen. This may indicate a surplus of nitrogen.
    - Yellow or browned-off vegetation. This is indicative of toxic nutrient levels or nutrient deficiencies.
    - Bare patches in paddocks. These may indicate poor germination due to excess salinity, uneven nutrient distribution, inadequate nutrients or nutrient overloading.
    - White crusting on the soil surface in dry times may indicate evaporation from a shallow saline water table.
    - Areas in effluent-irrigated paddocks that are consistently bare of vegetation may indicate too much salinity, inadequate nutrients or nutrient overloading.

H11 Plant tissue samples

Each time crops are harvested from reuse areas, the yield harvested should be recorded, and the dry matter yield and the approximate nitrogen and phosphorus removal rates calculated. Hence, plant tissue samples should not generally need to be collected. However, for precision systems, plant tissue analysis can provide data for more accurately calculating the mass of nutrients harvested.

Measure the yield of crops or fodder harvested by weighing or by estimating the weight from the number of truck-loads removed. Record the yield per hectare (t/ha) and the total mass removed. The yield should then be converted to a dry matter yield. As a guide, grain crops have a dry matter content of about 88% and hay has a dry matter content of about 90%. Fresh harvested forage crops vary more.

E.g. if 4 t/ha of barley is harvested, the dry matter yield is approximately 3.5 t/ha (4 t/ha x 88/100). A 4 t/ha barley crop removes about 20 kg N/t and 2.5 kg P/t. Hence, the 3.5 t/ha crop will remove about 70 kg N/ha and 8.75 kg P/ha.

H11.1 Sampling location

Any plant samples taken should be representative of the material being harvested. For a grain crop, collect samples from the field bin (or similar). For a baled crop, collect samples of hay. For a silage crop, collect several samples of freshly cut material.

H11.2 Sampling procedure

1. Assemble the sample containers and the sample preservatives.
2. With a waterproof pen, label the sample bags with the enterprise name, telephone number, a unique sample number, the sampling location (e.g. wheat from home paddock) and the date of sampling.
3. Complete as many details of the analysis request forms as possible. This should include: contact details, sample numbers (matching those recorded on the sample bottles), sampling location, sampling date and analysis parameters.
4. Collect the sample. If possible, this should occur between 8 am and 11 am.
5. For grain, collect at least five samples from the field bin. These should be placed in the bucket and thoroughly mixed with gloved hands. A subsample should then be used to fill the sample bag.
6. For hay or cut forage, collect five sub-samples, thoroughly mix together in a bucket using gloved hands, and sub-sample to fill the sample bag.
7. Leave the tops of the paper bags open to allow excess moisture to escape.
8. Put the bags in an esky and leave in the shade or a cool place. Do not seal plant or grain samples in plastic bags or leave samples in the sun as they will sweat and degrade.
9. When the samples are ready for delivery, fold the tops of the bags over and fasten with staples or sticky tape. Place back in the esky.
10. Complete the analysis request forms and keep a copy. Place the original forms in an envelope. Firmly tape the envelope to the top of the esky. Store the esky in the shade.
11. Arrange for sample delivery to the laboratory. Confirm that they have been received.

Glossary

Ad libitum allowing pigs to eat an unrestricted amount of feed

Adult any pig over the age of nine months

Aerobic conditions where oxygen is present

Aerobic digenstion process whereby microorganisms that require oxygen for survival breakdown organic matter in the presence of oxygen

Amenity the comfortable enjoyment of life and property, particularly particularly in terms of air quality (i.e. odour and dust), noise, lighting and visual appearance

Anaerobic conditions where there is an absence of oxygen

Anaerobic digestion process whereby microorganisms breakdown organic matter in the absence of oxygen

Anaerobic pond or lagoon a pond that uses anaerobic microorganisms to treat the effluent. These are micro-organisms that do not need free oxygen from the air to function. These ponds are usually quite deep (typically 4 m or deeper)

Approved authority local or state government entity with relevant statutory authority

APIQ✓® the Australian pork industry on-farm quality assurance program

Available nutrient the portion of any element in the soil that can be readily absorbed and assimilated by growing plants

Background site a soil monitoring site that is close to the area of interest. It should have a similar soil type and land use to the reuse area but should not have received piggery effluent or manure

Boar an uncastrated male pig over nine months of age

Breeder piggery a unit where breeding stock are kept, along with sucker pigs

Buffer distance the distances provided between the piggery complex or reuse areas and sensitive natural resources (e.g. bores, watercourses and major water storages) as an important secondary measure for reducing the risk of environmental impact

Bulking mixing of multiple soil samples from a paddock or plot to produce a representative sample

Bund watertight wall designed to prevent liquid escaping as a result of seepage or leaks

Cation exchange capacity (CEC) the total of exchangeable cations that a soil can absorb

Composite sample sample consisting of multiple grab samples that are bulked together to provide a representative sample

Compost the controlled microbiological decomposition of organic materials under aerobic and thermophilic conditions

Contamination the release of a contaminant into the environment in the form of gas, odour, liquid, solid, organism or energy

Controlled drainage area an area that collects contaminated stormwater runoff or effluent and excludes clean rainfall runoff

Conventional piggery these typically house pigs within steel or timber framed sheds with corrugated iron or sandwich panel roofing and walls made from pre-formed concrete panels, concrete blocks, corrugated iron or sandwich panel (or some combination of these), sometimes with shutters or nylon curtains depending on the ventilation system. A fully environmentally controlled shed has enclosed walls with extraction fans and cooling pads providing ventilation and climate control. Conventional sheds have a concrete base, often with concrete under-floor effluent collection pits or channels. The flooring is usually partly or fully slatted, and spilt feed, water, urine and faeces fall through the slats into the underfloor channels or pits. These are regularly flushed or drained to remove effluent from the sheds. Sheds without slatted flooring usually include an open channel dunging area which is cleaned by flushing, hosing or pressure washing

Crate equipment designed for confining pigs for a number of husbandry functions, including weighing, handling for veterinary interventions, farrowing and assisting with other reproductive processes

Creep area a separate area within a farrowing facility in which piglets are protected from crushing, or overlying, by the sow, and which is usually heated to provide a temperature that is more suitable for maintaining the welfare of piglets, while at the same time, maintaining the comfort of the sow

Deep litter piggery a housing system in which pigs are typically accommodated within a series of hooped metal frames covered in a waterproof fabric, similar to the plastic greenhouses used in horticulture. However, skillion-roof sheds and converted conventional housing may also be used. Deep litter housing may be established on a concrete base or a compacted earth floor. Pigs are bedded on straw, sawdust, rice hulls or similar loose material that absorbs manure, eliminating the need to use water for cleaning. The used bedding is generally removed and replaced when the batch of the pigs is removed, or on a regular basis

Desludging removing settled solids from the bottom of an effluent pond

Dry matter the amount of material left after water is removed. Also called total solids

Dry sow a female pig that has been mated and has not yet farrowed

Effluent liquid wastewater stream including manure, waste feed and cleaning water

Effluent sumps pits that store effluent before solids separation, or before is directed to ponds or irrigation

Environmental management plan (EMP) plan focusing on the general management of the whole farm, taking into account the environment and associated risks. It should document design features and management practices, identify risks and mitigation strategies, include ongoing monitoring to ensure risks of impacts are minimised and processes for continual review and improvement

Erosion the wearing away of the land surface by rain or wind, removing soil from one point to another (for example gully, rill or sheet erosion)

Exchangeable sodium percentage (ESP) the percentage of a soil's cation exchange capacity occupied by sodium

Facultative pond a pond or lagoon that uses facultative microorganisms to treat the effluent stream. These are microorganisms that can function in the presence or absence of oxygen from the air. Facultative lagoons are typically 2-3 m deep

Farrow give birth to piglets

Farrowing crate an enclosure closely related to the sow's body size, in which sows are kept individually during and after farrowing, to prevent a sow from overlaying her piglets

Farrowing pen an enclosure for optionally confining individual sows and their litters during and after farrowing. Such pens contain a creep area and a farrowing crate, or other structure, for confinement of the sow

Farrow-to-finish a production system incorporating a breeding herd, plus progeny, through to finished bacon weight (usually 100-110 kg)

Feeder equipment from which feed is dispensed

Feedlot outdoor piggery a piggery where the pigs are continuously accommodated in permanent outdoor enclosures that are not rotated

Finisher pigs generally above 50 kg live-weight, until they are sold or retained for breeding. Usually refers to pigs that are in the final phase of their growth cycle

Flushing systems underfloor channels in conventional sheds that are flushed daily, to twice weekly, with either clean water or effluent recycled from the ponds

Freeboard the height of the pond embankment crest above the design's full storage level. The freeboard protects the bank against wave action and construction inaccuracies

General environmental duty (GED) a responsibility shared by all individuals and businesses for the actions taken that affect the environment whereby any activity that causes or is likely to cause environmental harm cannot be carried out unless all reasonable and practicable measures are taken to prevent or minimise the harm

Gestation the period when a sow is pregnant

Gilt a young female pig, selected for reproductive purposes, before she has been mated

Grab sample a single sample collected at a particular time and place that represents the composition of the material being sampled

Groundwater all water below the land surface that is free to move under the influence of gravity

Group housing a type of loose housing in which multiple pigs are kept in the same pen or area **Grower pigs** pigs generally with live weights of 20-60 kg

Growing pigs weaners, growers and finishers

Indoor piggery piggery system in which the pigs are accommodated indoors in either conventional or deep litter sheds

Lactating sow a sow that has given birth and is producing milk to feed her piglets

Leaching process where soluble nutrients (e.g. nitrogen) are carried by water down through the soil profile

Loose housing housing that provides the pig with freedom of movement. It can be individual or group housing but the pigs must be able to turn around and extend their limbs

Manure faeces plus urine. For the purpose of these guidelines, manure may also refer to solids separated from the effluent stream, effluent pond sludge and spent bedding

Mortalities compost the microbiological decomposition of mortalities under aerobic and controlled conditions

Multi-site piggery system a production system where there is physical separation of the breeder, weaner and grower pigs. Typically piglets are weaned at 3-4 weeks of age and are transferred to a weaner unit. Weaner pigs are then transferred to a grower unit at 8-12 weeks of age for growing and finishing

Nutrient a food essential for a cell, organism or plant growth. Phosphorus, nitrogen and potassium are essential for plant growth. In excess they are potentially serious pollutants, encouraging unwanted growth of algae and aquatic plants in water. Nitrate-nitrogen poses a direct threat to human health. Phosphorus is considered the major element responsible for potential algal blooms

Nutrient accounting a technique used to quantify nutrient inputs, storage and outputs at a farm or paddock scale using a mass balance approach

Organic carbon a chemical compound making up organic matter. As organic matter is difficult to measure, it is estimated by multiplying the amount of organic carbon by 1.75

Organic matter living or dead plant and animal material

Outdoor piggery system in which the pigs are kept outdoors but are confined within an area with housing provided for shelter and fed for the purpose of production, relying primarily on prepared or manufactured feedstuffs or rations to meet their nutritional requirements

Overtopping overflow or spill from dam or pond

Pathogens microorganisms that can cause infections or disease

Pen an enclosure for confining pigs in which they can turn around, which may be used for housing pigs in groups, housing boars individually, management purposes, such as mating or farrowing, or for confining pigs individually

pH a measure of the acidity or alkalinity of a product. The pH scale ranges from 1 to 14. A pH of seven is neutral, a pH below seven is acidic and a pH above seven is alkaline

PigBal a validated model for estimating the quantity and composition of effluent and manure streams from piggeries and for sizing effluent treatment ponds

Piggery system in which the pigs are confined within a structure and fed for the purpose of production, relying primarily on prepared or manufactured feedstuffs or rations to meet their nutritional requirements

Piggery complex this includes all buildings where pigs are housed, adjoining or nearby areas where pigs are yarded, tended, loaded and unloaded; areas where manure from the piggery accumulates or is treated pending use or removal; and facilities for preparing, handling and storing feed. This does not include the reuse areas

Piglet a pig up to the time it is weaned from the sow

Piezometer a non-pumping well, generally of small diameter, that is used to measure the elevation of the water table and for collecting samples for water quality analysis. It generally has only a short well screen through which water can enter

Pollution direct or indirect alteration of the environment causing contamination or degradation

Pull-plug systems underfloor pits in conventional sheds that store effluent until it is released, using gravity release pipes in the centre of the pits

Rational Design Standard (RDS) a pond sizing method base on volatile solids (VS) loading rate

Receptor person or site that receives, and is sensitive to, community amenity impacts, including a residential dwelling, school, hospital, office or public recreational area

Recharge the replenishment of a groundwater body by gravity movement of surplus soil water that percolates through the soil profile

Reuse the act of spreading or irrigating manure or effluent on land for the purpose of utilising the nutrients and water they contain for crop or pasture growth

Reuse area an area where effluent or manure are spread for the purpose of utilising the nutrients and water they contain for crop or pasture growth

Riparian vegetation plants growing on any land that adjoins, or directly influences, a body of water. It includes the vegetation on land immediately beside creeks and rivers (including the bank), gullies that sometimes run with water, areas surrounding lakes and wetlands, and river floodplains that interact with the river during flood

Rotational outdoor piggery an outdoor piggery where the pigs are kept in paddocks that are used in rotation with a crop, forage or pasture phase. During the stocked phase, the pigs are supplied with prepared feed, but can also forage

Run-down screen a screen comprising of finely spaced stainless steel bars held on an incline by a steel frame. When effluent is poured onto the screen, the liquid and fine solids pass through, while the larger solids are retained on the screen

Runoff all surface water flow, both over the ground surface as overland flow and in streams as channel flow. It may originate from excess precipitation that can't infiltrate the soil, or as the outflow of groundwater along lines where the water able intersects the earth's surface

Salinity electrical conductivity (EC) is the generally accepted measure of salinity (i.e. of the concentration of salts in solution). The salts that occur in significant amounts are the chlorides, sulphates and bicarbonates of sodium, potassium, calcium and magnesium. In water these salts dissociate into charged ions, and the electrical conductivity of the solution is proportional to the concentration of these ions, providing a convenient means of measuring salinity. Salinity is usually expressed as deciSiemens per metre (dS/m) or its equivalent, milisiemens per centimetre (mS/cm)

Screw press a cylindrical screen with a screw-conveyor in the centre. The conveyor presses the solids against a screen to remove moisture. The conveyor also moves solids from one end of the press to the other, to a collection area

Sedimentation the process of settling entrained solids from an effluent stream through the influence of gravity. A sedimentation system may be a pond, basin or terrace that discharges to a holding pond or evaporation system

Separation distances the distances provided between the piggery complex and sensitive receptors (e.g. residences, recreational areas, towns etc.) as an important secondary measure for reducing the risk of amenity impacts

Sedimentation and Evaporation Pond System (SEPS) an effluent management system consisting of 2 or 3 long, narrow, shallow, trafficable earthen channels, designed to settle out solids and store effluent. Each channel is designed to receive effluent for a six to 12 month period. At the end of this time, another channel is activated and the liquid is drained or siphoned from the first channel, allowing the settled solids to dry and be removed

Shandying diluting effluent with clean water, usually for irrigation

Sludge the accumulated solids separated from effluent during treatment and storage

Sodium absorption ratio (SAR) a measure of the sodicity of water. It is the relative proportion of sodium ions to calcium plus magnesium ions. It is important because excess sodium in irrigation waters may adversely affect soil structure and permeability. A higher SAR value equates to a higher sodium content and higher potential for soil problems

Sodicity an excess of exchangeable sodium causing dispersion to occur

Solids separation systems for separating larger solids from liquid effluent before the effluent is treated, recycled and used **Sow** an adult female pig, which has had one or more litters

Spent bedding a mixture of bedding and manure that is removed from deep litter shelters at clean-out

Stall an enclosure, closely related to the pig's body size, in which sows are kept individually. The Australian pork industry is committed to gestation stall free (GSF) housing. Sows are kept in loose housing from 5 days after mating until one week before they are ready to give birth. This can be in individual pens or group housing providing each sow has freedom of movement, meaning she can turn around and extend her limbs. In some cases, bedding may be provided. Generally, boars are housed individually

Standard pig unit (SPU) pig equivalent to a grower pig (average weight 40 kg) based on volatile solids production in manure

Static pits underfloor pits in conventional sheds that store effluent for up to several weeks before it is released via a sluice gate at the end of the shed

Stormwater surface runoff from rain and storms

Surface waters dams, impoundments, rivers, creeks and all watercourses

Sucker or suckling piglet a piglet between birth and weaning (i.e. and unweaned pig)

Swill prohibited pig feed that is illegal to feed in Australia as it poses a disease risk. It includes food scraps, bakery waste, restaurant waste, untreated used cooking oils or other food waste that contains or has come into contact with meat or meat products

Terminal pond a pond located below the pig paddocks that is sized and located to catch at least the first 12 mm of runoff from a paddock which may have a higher nutrient concentration than runoff received later in a large storm

Topography the shape of the ground surface as depicted by the presence of hills, mountains or plains; that is, a detailed description or representation of the features, both natural and artificial, of an area, such as are required for a topographic map

Total dissolved solids (TDS) the inorganic salts (major ions) and organic matter and nutrients that are dissolved in water, used as a measure of salinity

Total solids (TS) dry matter content of a compound

Volatile solids (VS) the quantity of total solids burnt or driven off when a material is heated to 600°C for 1 hour. Volatile solids is a measure of the biodegradable organic solids content of a material. One standard pig unit (SPU) is equivalent to a grower pig based on volatile solids production in manure

Watbal a water balance model used to size the wet weather storage capacity of effluent ponds

Watercourse a naturally occurring drainage channel that includes rivers, streams and creeks. It has a clearly defined bed and bank, with intermittent (ephemeral) or continuous (perennial) water flows. Legal definitions can be found in relevant state or territory acts

Weaner a pig after it has been weaned from the sow until it is approximately 30 kg in liveweight. Weaners are typically aged from 3-4 weeks to 8-12 weeks

Weaning the act of permanently separating piglets from the sow

Weaner unit a production system including only weaner pigs. Pigs are transferred to the unit after weaning (usually 2-4 weeks) and are transferred from the unit when they reach the grower stage (usually about 8-12 weeks, typically up to 30 kg)

Wet basis the amount of a component in a material expressed as a concentration or percentage of the total weight (dry matter plus water)

Z-filter a continuous filtering and dewatering system that can be used to separate solids from effluent

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National Environmental Guidelines for Indoor Piggeries (NEGIP) 2025