AUSTRALIAN Pork™

AUSTRALIAN PORK LIMITED

National Environmental Guidelines for Piggeries

SECOND EDITION (REVISED)

2010

National Environmental Guidelines for Piggeries

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Prepared By FSA Consulting for: Australian Pork Limited
APL Project No 2008/2231

Foreword

The National Environmental Guidelines for Piggeries (2004) delivered, for the first time, a national approach to environmental management of Australian piggeries. It was always intended that the document would be regularly updated to ensure it incorporates the most up-to-date scientific information available. This second edition of the National Environmental Guidelines for Piggeries (National Guidelines) demonstrates the commitment of the pig industry to ensuring that pig production in Australia is environmentally sustainable.

Pig producers in Australia are under increasing pressure to demonstrate that they take every practical step to minimise the impact of their operations on the environment. This is evident from the increasingly stringent regulatory requirements imposed on piggeries. Unfortunately, these requirements vary between states and between councils within states and do not always take into account site-specific or management-specific features, which can markedly influence environmental risks. It is important that industry stakeholders are kept up to date with the latest research and development conducted by the industry. The National Guidelines provide guidance for environmental assessments for developing piggeries and options for existing piggeries to achieve positive environmental outcomes. Australian Pork Limited (APL) has also developed EnviroCheck, which is designed to assess how well existing piggeries comply with the National Guidelines and identify areas where improvements could be made.

The industry's achievement of its environmental goals will not be possible without the support of all relevant stakeholders. APL's initiative in updating the National Guidelines has received considerable support from all industry stakeholders, in particular, state government departments and environmental authorities, the research community and producers from all major pig-producing states. I trust that the second edition of the National Guidelines will receive a similar level of adoption by all these stakeholders to help the industry achieve its environmental goals.

Enzo Allara
Chairman of the Board of Directors
Australian Pork Limited

Acknowledgements

Australian Pork Limited (APL) thanks the principal authors of the second edition of the National Environmental Guidelines for Piggeries, Robyn W Tucker, Eugene J McGahan, Justin L Galloway and Michael F O'Keefe of FSA Consulting.

The significant contribution of Mr Bruce Edgerton formerly of APL in the development of these guidelines is also acknowledged.

The updating of the National Guidelines commenced with a consultative meeting at the Gold Coast on 14 & 15 May 2008 to discuss the findings of all recent Australian piggery environmental research and how these could be included in the second edition. Comments on the 30 April 2009 draft of the National Guidelines were obtained through written feedback. Further consultative meetings were conducted in Melbourne on 27 and 28 July 2009. The time and effort that the following people invested in developing the second edition of these guidelines is acknowledged:

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Abbreviations

APL	Australian Pork Limited
BSES	Bureau of Sugar Experimentation Station
CEC	cation exchange capacity
dS	deciSiemens
EC	electrical conductivity
EKP	exchangeable potassium percentage
EMP	environmental management plan
EMS	environmental management system
ESP	exchangeable sodium percentage
GHG	greenhouse gases
GPS	global positioning system
ha	hectare
kg	kilogram (s)
m	metre
m/s	metre(s) per second
m^3	cubic metre
m^3 /ha	cubic metre per hectare
mg	milligram (s)
mL	millilitre
ML	megalitre
NATA	National Association of Testing Authorities
National Guidelines	National Environmental Guidelines for Piggeries, second edition 2010
N	nitrogen
NO_3 or NO_{3-}	nitrate
OU	odour unit
P	phosphorus
PBC	phosphorus buffer capacity
RDS	rational design standard
SAR	sodium adsorption ratio
SEPS	sedimentation and evaporation pond systems
SPU	standard pig unit
t/ha	tons per hectare
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TS	total solids
VFS	vegetative filter strip
VS	volatile solids
yr	year

Overview

Australian Pork Limited (APL) worked with industry, the community and government to develop the first edition of the National Environmental Guidelines for Piggeries, which was released in 2004. These guidelines provided a general framework for managing the environmental issues associated with piggeries, and were tailored to the circumstances and conditions most commonly encountered.

This second edition of the National Environmental Guidelines for Piggeries (National Guidelines) includes updates based on the latest research findings and changes in acceptable design and management practices.

The document is made up of seven parts:

Chapters 1-20
National Guidelines - provides advice on planning and managing piggeries to minimise the risk of impacts to the environment

Appendix A:
National Odour Guidelines for Piggeries - details methods of assessing the impact of odours

Appendix B:
Environmental risk assessment - details methods for assessing the likelihood that the piggery will have an impact on the environment

Appendix C:
Complaints register - shows an example of a complaints register that can be used to keep track of complaints received and corrective action taken

Appendix D:
Sample analysis - describes methods for collecting samples (e.g. water, soil and by-products) for analysis

Appendix E:
Useful conversions - lists conversions that may be used in implementing the National Guidelines

Glossary:
Definitions used in the National Guidelines

Chapters 1-20

National Guidelines - advice on
planning and managing piggeries to minimise
the risk of impacts to the environment

1 Introduction

Maximising opportunities for industry growth is a strategic objective of Australian Pork Limited (APL). To assist in this regard, APL worked with industry, the community and government to develop the first edition of the National Environmental Guidelines for Piggeries, which was released in 2004. A national approach promotes consistency in proposals for new developments and facility upgrades across the states and territories. It also helps producers to comply with licence and approval conditions and with current regulatory standards. APL is committed to regularly updating the National Environmental Guidelines for Piggeries to ensure they remain technically up to date to reflect changes in science, community expectations and piggery management. This second edition of the National Environmental Guidelines for Piggeries (National Guidelines) provides updated advice on siting, design and management to allow people developing piggeries to minimise the risk of impacts to the environment.

The National Guidelines provide a general framework for managing the environmental issues associated with piggeries, and they have been tailored to the circumstances and conditions most commonly encountered. However, site-specific conditions must still be considered when applying the National Guidelines. Hence, site-specific risk assessment is recommended. Similarly, many of the factors discussed in the National Guidelines are interlinked, and sound management practices must be applied to the suite of considerations, not single issues in isolation, to achieve optimal environmental practice.

The National Guidelines may be used to complement, develop or update existing state piggery guidelines. However, it is important to realise that they may not fully cover or match all requirements in each state and territory. Each state and territory of Australia has its own legislation, codes of practice and guidelines for the development and operation of piggeries, as well as more general requirements for water use, land clearing, composting, waste management and other relevant issues. Applicable local government departments and local government officers can identify relevant planning requirements, legislation, codes of practice and guidelines. The user is responsible for ensuring that a proposal complies with the specific requirements of the relevant state or territory regulatory authorities.

The National Guidelines focus on environmental issues specific to piggeries. Legislative and planning requirements over-ride industry guidelines and codes of practice, including these National Guidelines. Therefore, developers need to be aware that piggery developments may be assessed in a manner or scope outside that contained in the National Guidelines. Operators must also observe their responsibilities under workplace health and safety, animal welfare and other relevant legislation.

2 Planning Principles

The following planning principles can apply to new developments, expansions or changes in material use at piggeries. The first step in planning involves the identification of any land use or zoning issues from local government, and the state government agencies responsible for piggery licensing and approval, water licensing, soil conservation and vegetation clearing. Consultation with the relevant agencies, ideally through a pre-lodgement, on-site meeting, helps to determine if the site is suitable, and the major issues to be addressed in an application. These issues are listed below in a checklist.

The next step is to gather and compile the information. As the National Guidelines provide recommended siting, design and management information, they can be used to assemble the supporting information for a piggery development application. Submission of application forms and supporting information, advertising the development and formal assessment, will follow. For large or complex applications, professional assistance may be necessary.

ISSUES	CHECK
Applicant details	
Site description (including plans) and assessment	
Real property description	
- Land tenure	
- Land area	
- Cadastral plan	
Land zoning, and zoning of the surrounding land	
Climatic data	
- Median annual rainfall	
- Average monthly rainfall	
- Rainfall intensity data (1-in-20-year design storm, 1-in-20-year 24-hour storm)	
- Average monthly evaporation	
- Monthly maximum and minimum temperatures	
- Wind speed and direction	
Soil description for the piggery complex site (including analysis of basic physical properties) and reuse areas (including analysis of basic chemical and physical properties)	
Description of groundwater resources and geology of the site	
- Details of any bores on the subject property	

PLANNING PRINCIPLES (continued)

ISSUES	CHECK
- Analysis of the chemical properties of groundwater for use in piggery	
- Details of any licenses held	
Description of surface water resources on the property or in the vicinity of property	
- Analysis of the chemical properties of surface waters for use in piggery.	
- Details of any licenses held	
Description of the current vegetation of the site and the extent of any proposed clearing	
Identification of any items, sites or places that may have cultural heritage significance	
Description of the proposed piggery operation	
Total pig or standard pig unit (SPU) numbers	
- herd composition	
- numbers and weights of incoming and outgoing stock	
- sources of stock	
Description of housing and layout plans	
Water requirements for drinking, cooling, cleaning and shandying with effluent, and water sources and quality	
Bedding requirements and bedding sources	
Feed requirements, sources and storage areas	
Staff numbers	
Hygiene practices	
Prediction of manure production and mass balance estimate of the nutrient content of solid and liquid by-products	
Design of effluent collection, pre-treatment and treatment system, including plans	
Sizing and proposed management of the reuse areas, including location, area, method, frequency and general management of spreading/irrigation activities	
Description of carcass management or disposal, including plan for mass mortalities	
Calculation of traffic numbers and consideration of access and road safety. There is also a need to negotiate with state or territory and local governments regarding road upgrading and maintenance responsibilities	

PLANNING PRINCIPLES (continued)

ISSUES	CHECK
Environmental impact assessment	
Community amenity impacts - particularly odour, dust, noise, traffic Calculate separation distances to sensitive receptors	
Surface water impacts – quality and availability for other potential users	
Groundwater impacts – quality and availability for other potential users	
Vegetation impacts – effects of clearing on rare and threatened species and communities	
Impacts on items, sites or places of cultural heritage significance	
Impacts to soils of reuse areas	
Summary of design and management features to minimise adverse environmental impacts	
Proposed environmental monitoring and reporting	
Environmental Management Plan (EMP) - An EMP focuses 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 impacts are minimised; and processes for continual review and improvement	
Plans including:	
Topographic plan - showing watercourses and drainage lines; flood lines, protected land; and location of nearby residences	
Recent aerial photograph	
Farm plan – showing current land uses; proposed piggery complex location; proposed carcass composting or burial site; proposed reuse areas; on-farm roads; location of on-farm bores; and location of any soil conservation or drainage works	
Piggery complex layout plan - including location of by-products treatment and storage facilities	
Effluent treatment ponds plan - (if applicable)	
Separation and buffer distances plan - showing location of piggery complex (including feed storage; and by-products storage and treatment facilities) and reuse areas; and distances to sensitive land uses e.g. houses and towns, as well as buffers around sensitive natural resources	

3 Environmental Outcomes

To operate in an ecologically sustainable manner, piggeries need to be sited, sized, designed, constructed and managed to protect many aspects of the environment such as soil, water and biodiversity. Preservation of community amenity and cultural heritage must also be considered.

By-products reuse should maintain or improve the productive qualities of the land used, by considering soil pH, salinity and sodicity, structure and stability, erosion, nutrient levels, organic matter content, microorganisms and hydrological properties. This can be achieved by effective reuse of the nutrients, organic matter and water in piggery by-products.

Groundwater and surface waters should be protected through good siting, design and management of the pig housing, by-products storage and treatment areas, carcass disposal areas, reuse areas and stormwater runoff from reuse areas.

Local residents' comfortable enjoyment of life and property should not be affected by a piggery. The effects of piggery odour, visual impacts, dust, flies, noise and vehicle movements should be considered.

Vegetation clearing and by-products reuse should be managed to protect flora species or communities, and fauna species and habits.

Items, site or places of cultural heritage significance, both to Aboriginal and to other people, should be protected.

This document presents detailed information to achieve these environmental outcomes.

Piggeries should be designed, sited and managed to protect the many aspects of the environment

4 Types of Piggeries

This section defines the different forms of pig production and piggeries, including an outline of the basic differences in design. It also defines a standard pig unit (SPU).

4.1 Pig Production

Pig production can be divided into five main production stages:

- breeding
- gestating or dry sows
- farrowing
- weaning
- growing / finishing.

The breeding section of a pig herd includes the boars, gilts and dry (gestating) sows awaiting either mating or confirmation of pregnancy and gestation. This section of the piggery is where all the pig mating occurs, including artificial insemination.

Generally, boars are housed individually, whereas dry sows may be housed in individual dry sow or gestation stalls and group pens. Sows are often housed in stalls for the first weeks of gestation to confirm pregnancy, and so they can be individually fed and managed. They may then be moved to group pens to complete their gestation period.

The farrowing section of a piggery houses both sows due to farrow (give birth) and sows with their progeny from farrowing to weaning. Each sow and litter is generally housed in an individual pen providing:

- protection from drafts
- a creep area segregated from the main stall by side rails, to protect the piglets from being crushed by the sow and to provide access to creep feed by piglets only
- extra heat in the creep area.

Weaners can be stressed by the change in diet from milk to solid feed, mixing with other pigs and environmental changes, increasing their susceptibility to disease. Newly weaned pigs must be housed in a warm, dry, draft-free environment to counter these abrupt changes.

Growing and finishing pigs require less environmental controls than newly weaned pigs. They are often fed in 'phases', so that the diet is tailored to provide optimal nutrition required for each growth stage.

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
- breeder
- weaner
- grower / finisher.

A farrow-to-finish piggery includes the breeder, weaner and grower / finisher stages. The pigs born at the site are reared until sale age (usually 20-26 weeks of age). Many farrow-to-finish piggeries operate with 'closed herds', where no new animals are introduced, and replacement breeding animals are selected from within the herd and / or from artificial insemination. Other farrow-to-finish piggeries import some or all of their replacement breeding animals from outside herds.

Multi-site piggery systems geographically separate different production stages.

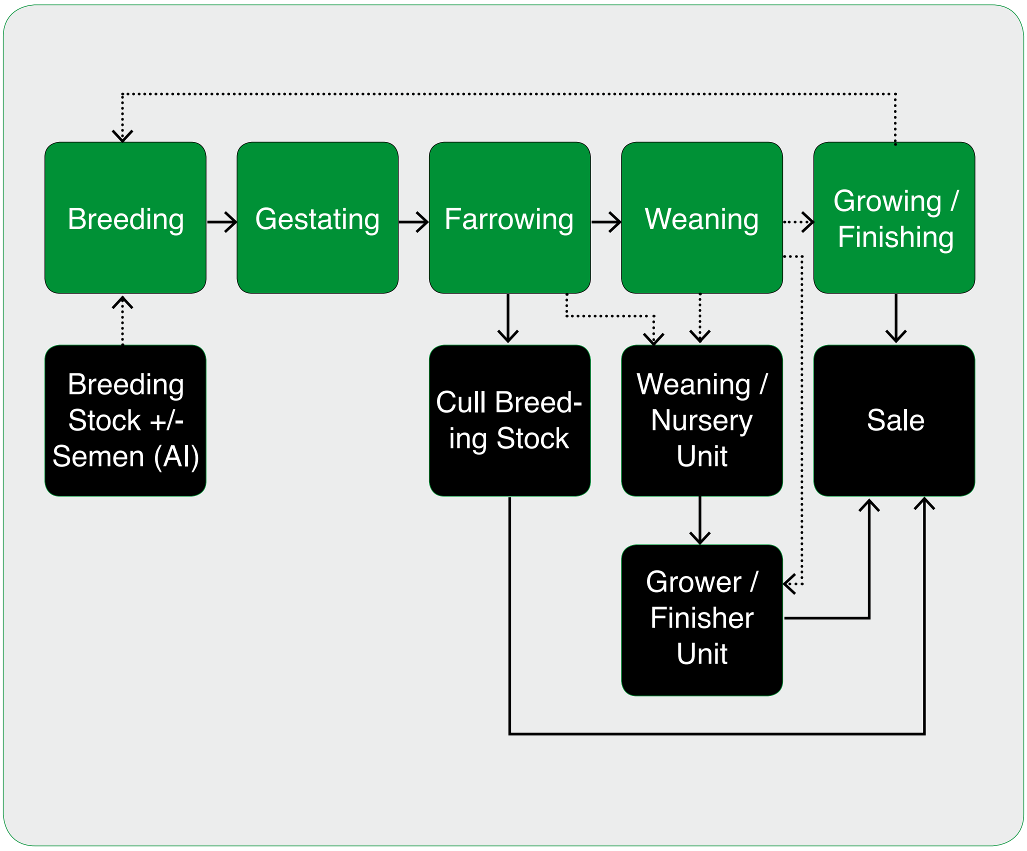
A breeder piggery includes breeding stock, with the progeny being removed from the piggery at, or just after, the weaning phase.

A weaner piggery includes only weaner pigs. These are generally aged from three or four weeks up to eight to ten weeks. Most weaner pigs are raised in a controlled environment (mechanically ventilated) conventional shed or in deep litter housing.

A grower/finisher piggery includes grower (about 10-16 weeks of age) and finisher (from about 16 weeks up to 22-26 weeks of age) pigs. They generally live in conventional sheds or deep litter housing or in a combination of these.

Figure 4.1 summarises the most common pig production systems.

FIGURE 4.1 Pig production systems



4.2 Piggery Definitions

The type of piggery can be defined by the type of accommodation.

In ***extensive pig farming***, the animals rely *primarily* on foraging and grazing, rather than on supplementary feed, to meet most (greater than 50%) of their nutritional requirements. *This type of system is not covered by the National Guidelines.*

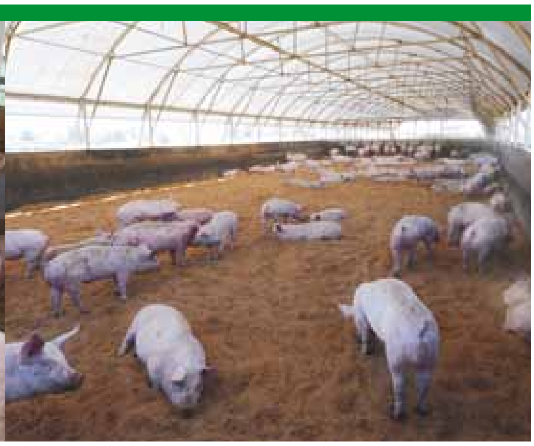
In all ***intensive piggery*** operations, the pigs are fed for the purpose of production, relying primarily on prepared or manufactured feedstuffs or rations to meet their nutritional requirements. These piggery systems are covered by the National Guidelines. These can be split up by accommodation type.

In an ***indoor piggery,*** the pigs are accommodated indoors in either conventional or deep litter housing.

Conventional piggeries 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 or hosing.

Deep litter piggeries typically accommodate pigs 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 pigs is removed, or on a regular basis.

Conventional piggeries



Deep litter piggeries

Outdoor piggeries confine pigs within an outdoor area with housing provided for shelter where they are fed for the purpose of production, relying primarily on prepared or manufactured feedstuffs or rations to meet their nutritional requirements. The two types of ***outdoor piggeries*** recognised by the National Guidelines are: rotational and feedlot.

In ***rotational outdoor piggeries***, the pigs are kept in paddocks, sometimes with arks or other basic huts. The paddocks are rotated with a pasture or cropping phase. During the stocked phase, the pigs are supplied with prepared feed, but can also forage. During the non-pig phase, the area grows pastures or crops that are harvested to remove the nutrients deposited in pig manure during the pig phase.

Feedlot outdoor piggeries continuously accommodate pigs in permanent outdoor pens, sometimes with arks or other basic huts. The pens must be located within a controlled drainage area. This is so all nutrient-rich stormwater runoff from within these areas is controlled and kept separate from stormwater runoff from areas outside the pig pens. The base of the pens must be sealed to minimise nutrient and salt leaching.

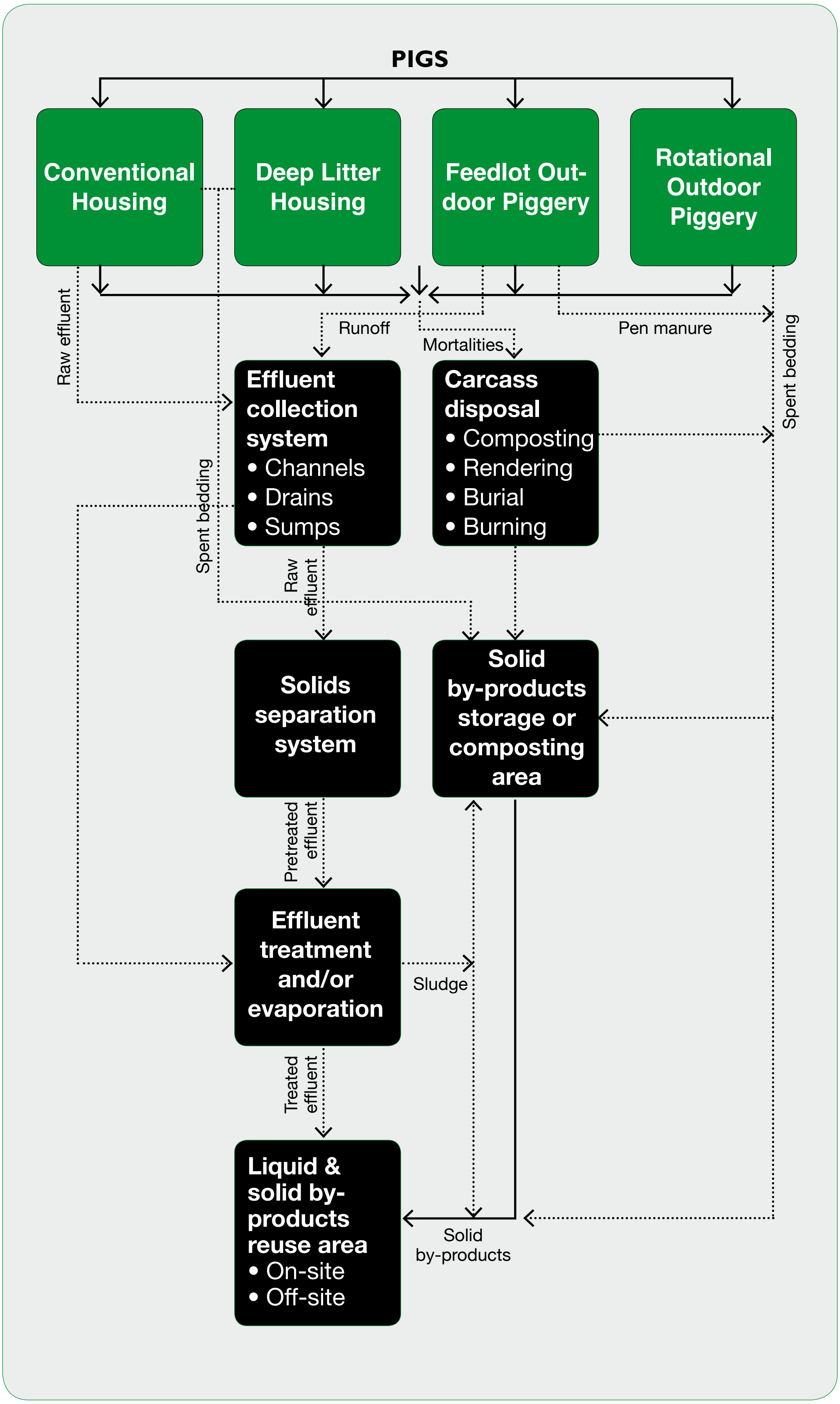
A **piggery complex** includes:

- all buildings or areas where pigs are housed
- adjoining or nearby areas where pigs are yarded, tended, loaded and unloaded
- adjacent areas where piggery by-products are accumulated or treated, pending on-site reuse or transport off-site
- areas where pig-feeding facilities are maintained or areas where feed is prepared, handled or stored (including feedmills).

The **piggery complex** itself does not include any reuse areas, unless it is a rotational outdoor piggery. Figure 4.2 shows a piggery complex and the reuse areas, along with the flow of by-products through both these areas.

Outdoor piggeries

FIGURE 4.2 **Piggery by-products flow diagram**



4.3 Defining Piggery Capacity in Standard Pig Units

A ***Standard Pig Unit (SPU)*** is a unit for defining piggery capacity based on by-products output. The manure and waste feed produced by one SPU, contains the amount of volatile solids (VS) typically produced by an average size grower pig (90 kg VS/yr). SPU multipliers for other pig classes are based on their comparative VS production.

This definition assumes that the pig is fed a typical diet, has typical feed wastage and is not fed with advanced feeding technologies, such as phase feeding. Consequently, there are two methods for specifying the total number of SPUs in a piggery. The first is outlined in Table 4.1, which provides figures that can be used to determine the number of SPUs in different types of piggeries, and example pig and SPU numbers for a 100 sow farrow-to-finish piggery.

TABLE 4.1 SPU conversion factors

Pig Class	Mass Range (kg)	Age Range (weeks)	SPU Factor	Pig Numbers (and SPU) for typical 100-sow farrow-to-finish (26 weeks) piggery
Gilt	100 – 160	24 – 30	1.8	5 (9)
Boar	100 – 300	24 – 128	1.6	5 (8)
Gestating sow	160 – 230	-	1.6	83 (133)
Lactating sow	160 – 230	-	2.5	17 (43)
Sucker	1.4 – 8	0 – 4	0.1	177 (18)
Weaner	8 – 25	4 – 10	0.5	253 (127)
Grower	24 – 55	10 – 16	1.0	249 (249)
Finisher	55 – 100	16 – 24	1.6	330 (528)
Heavy finisher	100 – 130	24 – 30	1.8	82[a] (148)
			TOTAL	**1201 (1263)**

SPU=standard pig unit

[a] For this example, it is assumed that the heavy finishers are sold at 26 weeks of age.

Notes: Refer to 9.1 for manure solids and nutrient output for different classes of pigs.

Another method is to:

- use the standard SPU conversion figures provided in Table 4.1 to estimate the standard SPU capacity of the piggery
- multiply the standard SPU capacity by 90 to estimate the VS production of the piggery (kg of VS/yr)
- estimate the actual VS production/yr of the piggery using an appropriate manure estimation model such as PigBal (Casey *et al* 2000)

- adjust the pig numbers in PigBal (or alternative model) until the VS production matches that calculated using the standard SPU multipliers.

If this method is adopted, the reasons for adjusting feed use and feed wastage must be justified, and practices maintained on an ongoing basis. This method is likely to best suit piggeries with high operating standards. An example is given below.

Example

A pig producer wishes to establish a 100-sow farrow-to-finish (26 weeks) piggery. After calculating the number of pigs in each class, the multipliers given in Table 4.1 are used to determine that a 'standard' piggery would produce 108,000 kg of VS/yr. Feed conversion rates from another piggery using similar diets and feeding systems are available and can be used to accurately estimate feed intakes and wastage. After running the PigBal model for the proposed piggery, it is determined that the piggery is only likely to produce 100,000 kg of VS/yr. The pig numbers in PigBal are adjusted up until the model predicts that the piggery will produce 108,000 kg of VS/yr. Thus, the pig producer is able to establish a 108 sow farrow-to-finish piggery, producing the same VS as a 'standard' 100-sow farrow-to-finish piggery. Conversely, the proposed 100 sow piggery is equivalent in capacity to a standard 93 sow farrow-to-finish unit (i.e. 100/108).

Conventional and deep litter systems can often operate on the same site

5 Site Selection

Environmental advisers can provide guidance on the suitability of a proposed site for a piggery. The main factors to consider include:

- statutory land use planning restrictions
- availability of suitable land area
- suitable road access
- access to power
- availability of a reliable water supply
- access to markets and labour
- climate
- the site's natural resources
- possible effects on community amenity or cultural heritage
- any possible future expansion plans.

Each of these factors is discussed below.

***Environmental outcome:* Protection of natural resources and the community through good piggery siting.**

5.1 Planning Restrictions

When selecting a piggery site, the current and future land zoning of the property and surrounding land should be discussed with the local government authority. This may quickly identify properties that are unsuitable because of land use, zoning or legal constraints. Agricultural advisers can identify state and territory department planning controls.

5.2 Available Land Area

Property size is an important consideration. Ideally, a property should be large enough to contain the piggery complex and any required areas for by-products use. However, it is possible to transport by-products off-site to a third party. Owning land around the piggery complex prevents encroachment by nearby developments. However, owning the required separation distances to sensitive land uses is not a pre-requisite because it is rare to own the large property size needed. Hence, separation distances may go over the property boundary but should not impact on receptors. The shape of the property also affects the buffer effectiveness. For example, a larger buffer along the direction of the prevailing wind may reduce the number of complaints coming from that end of the piggery.

5.3 Suitable Road Access

Roads used by piggeries must be of a suitable standard for trucks. The safety of all road users must be considered when selecting and designing property access points. The farm entry point should provide good visibility in both directions and allow for safe entry and exit by vehicles. Where alternative routes are available, those avoiding nearby houses and other sensitive locations like schools, bus pick-up points, halls and community areas should be considered. Routes involving sealed roads may also generate less dust at nearby houses.

5.4 Access to Power

If mains power will be needed for the functional operation of the piggery, then access to a supply should be considered during selection of the site for a piggery complex.

5.5 Access to Markets

Piggeries need to be able to source labour to operate. They should also be located close to feed supplies and abattoirs to reduce operating costs.

5.6 Climate

Climate affects many environmental aspects of a piggery's operations. Rainfall and evaporation rates affect the availability of surface waters. Options for using effluent also depend on local rainfall and evaporation. In most regions, effluent irrigation is needed for conventional piggeries. Climate also influences the required size of the effluent treatment systems and reuse areas, and the plants that can be grown on these areas. Prospective sites in high rainfall areas will usually require significantly more land for the treatment and reuse of effluent, and potentially have higher capital and operating costs. Climate also affects irrigation opportunity. For example, in winter-dominant rainfall areas, effluent may have to be held in storage for up to six months until the soil dries out sufficiently to allow effluent irrigation. In some areas of Australia, the net annual evaporation may allow piggery effluent to be removed solely by evaporation from suitably lined holding ponds. However, this concentrates salts in the sludge, limiting its suitability for reuse.

5.7 Natural Resources

5.7.1 Topography

Suitable siting reduces the likelihood of future community amenity nuisance issues and saves money during the design and construction of a piggery. Topographical barriers (hills, ridges etc.) between the piggery and sensitive locations are desirable. For some, the sight of a piggery is not aesthetically pleasing. For others, it is a reminder of the presence of a piggery, which may trigger complaints. Undesirable sites are often elevated and cleared, providing a clear line of sight between nearby roads or neighbouring houses and the piggery.

The movement and dispersion of odour from the piggery depends on the topography in the vicinity of the property. Under stable conditions, concentrated odour tends to gravitate down hills, more severely affecting receptors downslope from the source. Odours can also travel significant distances with very little dispersion if the development is in a confined valley. These factors warrant serious consideration when selecting the site for a piggery complex.

The ideal site for housing pigs indoors is relatively flat, to minimise the earthworks for shed pad preparation. If the building site is higher than any effluent treatment or storage system, effluent and leachate can be conveyed into these by gravity. This can eliminate the need for effluent collection sumps and pumping equipment, which may be prone to blockages and breakdowns, as well as incurring ongoing energy costs. Excess soil removed during pond construction can be used to build-up the base of sheds, to allow gravitation of effluent into the pond system.

For outdoor feedlot piggeries, a slope of 2-6% down the pens will optimise drainage, while reducing the erosion risk. The effluent storage pond must be located downslope of the pens.

Site selection principles for rotational outdoor piggeries are the same as for reuse areas. For sites with heavy soils, gently sloping reuse areas are less likely to have water-logging and drainage problems. However, an area that is too steep may promote nutrient loss through soil erosion or stormwater runoff. The ideal slope depends on soil type, land use, vegetative cover, rainfall intensity, agronomic practices and the soil conservation measures that are in place.

5.7.2 Soils

A preliminary investigation should identify the range and distribution of soil types on the property. The suitability of building pads, effluent treatment systems, solid by-products storage, carcass composting pads or burial pits and reuse should be considered. For example, loam to medium clay loam soils are often preferred for reuse areas, as they usually drain well and retain nutrients. Clays and clayey sands and gravels best suit pads for deep litter piggeries, outdoor feedlot piggery pens, effluent ponds, solid by-products storage sites and carcass burial pits, since these soils can be compacted to provide a low permeability base.

Doing a soil survey and chemical and physical analysis early in the planning phase helps to identify:

- the suitability and required size of reuse areas
- the need for imported clay or synthetic liners for deep litter piggery pads, outdoor feedlot piggery pens, effluent treatment systems, solid by-products storage areas and carcass burial pits or composting pads
- the types of erosion controls and management that could be needed during construction and operation.

Soil analysis data for reuse areas also provide a benchmark for assessing future monitoring results.

5.7.3 Water

Water Supply

Water is needed for drinking, shed cleaning and sometimes for summer cooling. It is essential to confirm that enough water of suitable quality is available at a proposed site.

The drinking water requirement varies depending on climate, season and drinker type. Approximately 8 L/SPU/day is required. The needs of a breeding herd may be 50% higher. An additional 10-50% should be allowed for drinking wastage. Emergency water storage of at least one to two days worth of drinking water should be provided. Shed flushing and hosing requirements vary widely, depending on shed type and design, herd composition, water quality, by-products treatment and reuse, and whether treated effluent is recycled for flushing.

Water licensing requirements vary between states and territories, and regions within them. It is essential to confirm that water can legally be used in a piggery. The holding of a water allocation may not guarantee the supply of that volume. Pump testing of bores is recommended.

Water quality influences herd health and performance, effluent pond function and options for by-products reuse. Potential water sources should be analysed to identify suitable supplies. Suggested analysis parameters include total dissolved solids (TDS), bicarbonate, calcium, fluoride, magnesium, nitrate, nitrite, sulphate, hardness, pH and *Escherichia coli (E. coli)*. For surface water supplies, check if the supply is susceptible to blue-green algal blooms. ANZECC and ARMCANZ (2000) provide specific guidance on water quality for stock drinking and irrigation purposes. However, a pig husbandry or veterinary consultant can also advise on drinking water suitability.

Access to a reliable irrigation supply can be helpful in effectively using the nutrients in piggery by-products, since this can promote more consistent and higher crop or pasture yields from the reuse areas. Effluent can also be mixed or "shandied" with fresh water to suit specific crop requirements. The land area needed for reuse can also be minimised, because irrigation increases crop yield and therefore nutrient uptake.

Surface Water Protection

Selecting piggery complex sites and reuse areas that are well separated from watercourses protects surface water quality. Practices that allow nutrients and organic matter to enter surface waters promote algae and aquatic weed growth. When these die, their decay strips oxygen from the water, killing aquatic life and creating offensive odours. High nitrogen levels can cause nitrate and ammonia to accumulate to levels that may be toxic to animals. High phosphorus levels in surface water are linked to the occurrence of potentially toxic blue-green algal blooms.

Flood Risk

Piggery complexes should be sited above the 1 in 100 year flood line, since flooding may cause stock losses, building damage and surface water contamination. Information on land submerged by a 1 in 100-year flood is available from the local government authorities, or state water resources agencies. All-weather access to the piggery complex is also essential for feed delivery and pig transportation. Piggery reuse areas should be above the 1 in 5 year flood level. Where this is not possible, levee banks may be constructed (with appropriate approvals/permits) to protect land from flooding.

Groundwater Protection

Groundwater is also protected through careful selection of sites for piggery complexes and reuse areas. Sites with light soils and shallow groundwater pose a high risk for groundwater contamination. These sites should be avoided, as this may significantly increase the standard of design and management for effluent treatment systems and by-products management and reuse, as well as possibly increasing groundwater monitoring requirements.

Piggery by-products need careful management to prevent nutrient leaching into groundwater. Nitrogen is highly mobile when in the nitrate form and readily leaches. While most soils are capable of safely storing some phosphorus, if excessive levels are applied to soils over prolonged periods, leaching into groundwater may eventually occur. Potassium also readily leaches when oversupplied in the soil.

Ideally, by-products reuse areas should be located on land where groundwater is deep, stored within confined aquifers or well protected by a clay layer. The risk to groundwater from by-products reuse depends upon the protection afforded by soil type (e.g. a deep clay layer may afford good protection, a sandy loam soil provides relatively poor protection); the geology; the type of aquifer (e.g. a confined aquifer versus an alluvial aquifer); and the way by-products are used.

The consequences of nutrient or salt leaching to groundwater depend on the quality of the groundwater (e.g. potable water versus brackish water) and its uses. However, it is important to protect groundwater so that options for current and future use are not restricted.

5.7.4 Flora and Fauna

It is an advantage to have good tree cover between a piggery and receptors or roads as this can visually screen the piggery and promote odour, dust and noise dispersion. Avoid areas of remnant vegetation, wildlife habitats and natural wetlands when selecting a site for a piggery complex or for by-products reuse. Relevant local, state and territory authorities should be consulted to determine specific restrictions on tree clearing.

5.8 Community Amenity

Most conflicts between piggery operators and neighbours relate to odour, but they sometimes relate to noise, dust, flies and rodents, pathogens or visual amenity. Conflicts arising from these issues are often very emotive, and the people involved sometimes experience great personal stress. In the long-term interests of community harmony and farm security, conflicts must be resolved. Good site selection is fundamental to minimising community amenity impacts. However, appropriate layout, design, management and a good communication strategy are also necessary.

The main community amenity issues are discussed in the following sections, and should be considered carefully when selecting a site for a piggery development.

5.8.1 Odour

Odour nuisance is a very complex issue. Careful site selection is imperative in minimising the likelihood of odour nuisance for nearby receptors. However, this should be supported by good design and management. An odour assessment can determine if an unreasonable odour impact is likely at off-site receptors. Each state and territory has its own legislation, codes of practice and guidelines for piggery odour impact assessment. Odour impact assessment is covered in detail in Appendix A, which provides a multi-level evaluation process. While this process represent the best available options for assessing potential odour impacts from the information that is currently available, the relevant approved authority should be contacted for information regarding the content or application of legislation, codes of practice or guidelines in a particular state. ***Early contact with state and territory agencies is recommended to discuss regulatory requirements for any proposed operations or changes to existing operations.***

5.8.2 Noise

Each state and territory has its own regulations or guidelines pertaining to noise. Noise is generated by the piggery itself, associated equipment used on other parts of the farm (e.g. pumps) and traffic accessing the piggery. Where practical, the piggery site and other on-farm noise sources should be well separated from sensitive land uses, to minimise the likelihood of nuisance for nearby receptors. Careful siting and selection of traffic routes can also reduce traffic noise at houses along access routes.

5.8.3 Dust and Smoke

Dust and smoke should be minimised through good siting, design and management. Traffic movements along unsealed roads and spreading of dry manure by-products can generate significant dust. Choosing routes with either sealed roads, or good separation to houses, reduces the risk of amenity impacts. Selecting reuse areas that are well separated from receptors also reduces the risk of nuisance from dust.

5.8.4 Flies, Rodents and Other Vermin

Siting piggeries away from sensitive land uses reduces the risk of nuisance from flies, rodents and other vermin. However, good manure management also has an important role to play.

5.8.5 Pathogens

APL has investigated the pathogens present in pig effluent and the public health risks associated with effluent reuse (Blackall 2005 and Blackall 2001). The research found that the range of pathogens potentially present in Australian piggery effluent is much narrower than the range found in human sewage. Significantly, piggery effluent lacks many of the major pathogens that are of concern when reuse of human sewage is considered (e.g. *Vibrio cholerae* and human pathogenic viruses such as noroviruses). The only pathogens in piggery effluent that need consideration are bacteria, as the only virus likely to be present is rotavirus, and this virus 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 treatment ponds of 13 southeast Queensland piggeries identified low campylobacter counts in 11 final ponds, and low salmonella counts in only three final ponds. Erysipelothrix and rotavirus were not detected in any final pond. The results were evaluated using a quantitative microbial risk assessment approach for a real-life scenario in which piggery effluent was being used to irrigate turf. The study found that relatively small separation distances (e.g. 125 m at wind speeds of 0.5 m/s and 300 m at wind speeds of 2.5 m/s) were needed to minimise any health risks from campylobacter and salmonella in the irrigation aerosols.

5.8.6 Visual Amenity

Piggeries are often perceived negatively by the community, so it is desirable to screen the piggery complex from public view. Take advantage of the topography and vegetation where possible. Vegetation around the complex can significantly improve the visual appeal of a piggery, and can help in dispersing odour, noise and dust. Visual screens and vegetative buffers can be intentionally established and maintained specifically for this purpose.

5.9 Cultural Heritage

Items, sites or places of Aboriginal or European cultural significance should be considered when selecting a site for a piggery complex. If these could be present, consult the appropriate bodies (including the traditional land owners) to determine the most suitable course of action. The issue may be resolved by properly recording, preserving or relocating special objects to allow development to proceed, or, in rare cases, permanently sectioning off parts of the property to prevent any potential detrimental effects.

Native vegetation provide a visual screen and also assist in dispersing odour, dust and noise

5.10 Future Expansion Plans

During the site selection process, any plans for future expansion should be considered. This may include allowing extra area around the piggery complex for additional sheds and by-products treatment systems, and ensuring sufficient land is available for productive and sustainable by-products reuse. Considering these aspects during the site selection stage helps to simplify any future expansion processes.

During the planning stage, it may be worth ensuring that separation distances will allow for future expansions. This might involve investigating the potential for acquisition or rezoning of nearby land to protect or expand the separation distances available.

Deep litter Piggery

6 Separation and Buffer Distances

Good siting, design, construction and management are the most important factors for preventing impacts to sensitive locations and receptors. However, providing adequate separation and buffer distances between piggeries and sensitive locations is an important secondary measure for reducing the risk of environmental degradation, and avoiding conflicts relating to community amenity.

Local authorities may have specific by-laws or other planning requirements that stipulate separation distances and buffers for piggeries. Appropriate planning is needed to maintain these separation distances and buffers between established piggeries and receptors, watercourses and groundwater. **Contact your approved authority early in the planning process to identify any requirements.**

In the absence of specific advice from the approved authority, sections 6.1 and 6.2 provide recommended buffers for surface water and groundwater, and separation distances for community amenity, respectively. *These buffer and separation distances are for new developments and are not applicable to existing piggeries.*

Environmental Outcome: **The community, water resources and vegetation are protected by providing separation distances and buffers that mitigate potential runoff and odour impacts.**

6.1 Buffer Distances from Surface Water and Groundwater

Surface waters should be protected through sound design and management of piggery complexes and reuse areas. Reuse areas should be managed and sized to achieve a nutrient balance or sustainable nutrient storage. Effluent reuse should be carefully timed with irrigation, occurring when the soil is not saturated and rain is not expected, to minimise the risk of nutrients in stormwater runoff. Ideally, by-products should be irrigated or spread just before sowing or when plants are actively growing, to ensure nutrient uptake and to minimise nutrient losses by leaching or runoff.

Buffers provide secondary protection against:

- effluent entry to surface waters through runoff of tailwater from irrigated effluent
- nutrient rich stormwater runoff from reuse areas
- spray drift from irrigation with effluent.

Vegetative cover in the buffer area between the reuse area and any watercourse should be maintained wherever possible, particularly riparian vegetation, to minimise the movement of nutrient rich runoff and eroded soil into surface waters.

The appropriate buffer width depends on the vegetative cover of the buffer area and the presence of other stormwater control devices, such as diversion banks and terminal ponds. Vegetative filter strips (VFS) can very effectively reduce nutrient entry to watercourses. They reduce the nutrient concentration of runoff through particle trapping, and reduce runoff volumes by increasing infiltration. Generally, wider VFSs can effectively trap larger quantities of soil eroded from upslope areas. However, for the same soil loss rate, areas with steeper slopes need a wider VFS than areas with gentler slope. Place VFSs as close as possible to the reuse areas to minimise additional runoff through the filter strip. It is also critical to place the VFS before any convergence of runoff. For further information, refer to Redding and Phillips (2005).

As a safeguard, buffers should be provided between the piggery complex and reuse areas, and groundwater bores and surface waters. The required buffer distance should be assessed on a case-by-case basis with the aim of protecting sensitive waters, while not being overly onerous. For instance, only a relatively small buffer would be needed if there is a well-developed and maintained VFS between a reuse area and a watercourse. Similarly, good irrigation practices, such as direct injection, should only require a small buffer requirement. **Under some state and territory requirements, fixed buffer distances may apply.**

Major stores of potable water and watercourses within drinking water catchments generally need the greatest protection. (A watercourse, is a naturally occurring drainage channel such as a river, stream and creek. It has a clearly defined bed and bank, with intermittent (ephemeral) or continuous (perennial) water flows.) **Also, refer to relevant state or territory acts for legal definitions.**

Piggeries should be 800 m from major water supply storages (including public water supply storages). Restrictions may apply in catchment areas for major water storages owned by water boards or local authorities. The measuring point for the buffer distance from a watercourse, should be the maximum level to which the water surface of a watercourse may reach before overtopping of a bank begins (bank-full discharge level). **Relevant state or territory legislation should be consulted for the applicable legal definition.**

In all cases, the relevant approved authority should be consulted where a piggery is proposed within a declared catchment area or a declared groundwater area. A reduced separation distance may be allowed if it can be demonstrated via a risk assessment that the feature will be protected. For highly sensitive or vulnerable resources, or under some state and territory requirements, the distance may need to be increased.

Table 6.1 provides recommended buffer distances from reuse areas to surface waters, by reuse category. **These can be used in the absence of specific advice from the approved authority.**

The recommended fixed buffer distances surrounding reuse areas are to be used as a guide. A site-specific risk assessment may be used to obtain dispensation for these distances from the approved authority. For example, appropriate vegetative buffers and terminal ponds designed to catch the first 12 mm of runoff from reuse areas may allow for a reduction in the required distance to watercourses.

TABLE 6.1 Buffer distances from reuse area

Reuse category	Distance from major water supply (m)	Distance from watercourse (m)
Effluent that is discharged or projected to a height in excess of 2 m above ground level	800	100
By-products that remain on the soil surface for more than 24 hours (i.e. are not immediately ploughed in)		
Spent bedding that is spread immediately (i.e. not stockpiles / composted) and remains on the soil surface for more than 24 hours		
Flood irrigation systems		
Rotational outdoor piggery pens		
Mechanical spreaders and downward discharge nozzles. The discharged material shall not be projected to a height in excess of 2 m above ground level	800	50
Spent bedding that has been stockpiled before spreading		
Discharge by injection directly into the soil (to a depth of not greater than 0.4 m) and at a rate not exceeding either the hydraulic or nitrogen, phosphorus or potassium limits determined for the local soil types	800	25
Spent bedding / solids that have been composted		
Irrigation of effluent or spreading of spent bedding / solid by-products in combination with immediate incorporation of materials into the soil (<24 hrs)		

Notes: Distances should be measured from the perimeter of the area used for handling or reusing by-products.

6.2 Separation Distances for Community Amenity

An odour assessment can determine if off-site receptors are likely to be protected from odour nuisance. However, the success of a proposed piggery development also relies on community acceptance. Community consultation during the planning stage will often provide enough information to allay community concerns. For community consultation to be effective, it is important to structure the process to suit the individual situation.

On-going two-way communication between piggery operators and receptors (particularly neighbouring residents) reduces the likelihood of complaints, can help in identifying when nuisance occurs and can assist in issue resolution.

Odour modelling uses input data representing a site, and applies simplifying assumptions to estimate the odour dispersion (movement away) from the site over time. Modelling is generally conducted by estimating odour dispersion each hour over a period of one year. These models estimate the level, frequency and duration of the odour at specified points away from the piggery. The modelling requirements and odour impact assessment criteria differ from state to state. Input data include odour sources, odour source dimensions, source odour emission rates, meteorological variables for the site and site surface characteristics. Odour modelling accuracy is limited by the simplifying assumptions inherent in the model used, and by the accuracy of input data, particularly meteorological conditions and odour emission rates. Appendix A provides a multi-level approach for assessing the likely odour impacts of a proposed piggery or piggery expansion. **Appendix A is unsuitable for application to existing piggeries that are not expanding, and is not to be used for this purpose.** Appendix A can be used in the absence of specific advice from the approved authority.

Level 1 assessment uses a standard formula to calculate variable separation distances from piggeries to different types of receptors. Providing adequate separation distance between a piggery and sensitive land uses affords amenity protection. The formula considers the number of SPUs, receptor type, topography, vegetation (surface roughness) and piggery design and operation.

As an addition to the Level 1 assessment, a Level 1.5 assessment can be used. This involves the calculation of a wind speed reduction factor. Further details are provided in Appendix A.

Fixed separation distances are also provided to ensure appropriate buffers between the piggery and features such as roads and property boundaries. Both the variable and fixed separation distance to receptors (town, residential and rural) must be calculated, and the greater distance of the two applied. Relevant local government planning schemes may have definitions of the location and extent of each receptor type. Fixed separation distances are given in Appendix A.

Separation distances from reuse areas to relevant receptors and features are also provided in Appendix A. By-products reuse areas are considered separately from piggeries because they are infrequently used and may be spread across a farm. Furthermore, piggery operators have a significant degree of control over the timing of by-products application in these areas. These distances are in addition to separation zones for the piggery complex and are determined separately.

Level 2 and Level 3 assessments involve odour modelling. These assessment methods may be used in the absence of required methods in any state. Full details of Level 2 and Level 3 assessments are provided in Appendix A.

For further details of the methodology behind Level 1, Level 2 and Level 3 assessments, refer to Nicholas and McGahan (2003). For further details of the methodology behind Level 1.5 assessments, refer to Torringer and Purton (2008).

7 Cleaner Production

Using resources more efficiently, reducing the amount of by-products generated and carefully reusing by-products can reduce costs and the risk of impacts to the environment. Cleaner production involves continuously applying an integrated, preventative strategy to all processes, to increase overall efficiency and reduce risks to the environment (including humans).

Environmental Outcome: **Efficient use of resource, minimal waste production and reuse and recycling of by-products where appropriate.**

7.1 Efficient Resource Use

The major input to any piggery is feed. Reducing wastage improves feed conversion efficiency, and reduces the quantity of by-products for treatment and the potential for subsequent odour and other environmental impacts. Feed wastage can be minimised by providing the pigs with fresh feed, matching feed delivered to the amount required, and using well-designed feeders and sound feeding practices. Closely matching diet composition to animal nutritional requirements, and using additives including enzymes (e.g. phytase) to increase nutrient availability, also improves feed conversion efficiency. Industry benchmarks for feed conversion efficiency provide a guide to performance.

Implementing sound shed design principles significantly reduces power use and consequently heating and cooling costs. Well-insulated sheds require less energy for heating and cooling, and orienting sheds east-west reduces heat from the sun. Natural ventilation reduces cooling costs and deep litter housing uses less power.

Water is needed for drinking, cleaning and perhaps cooling. Water use varies widely between piggeries, and this increasingly scarce resource should be used efficiently. It is important to supply cool drinking water in hot weather. Wastage is generally lower for well-designed bowl drinkers (for sows) and bite nipples than for push nipples. Leaking nipples should be adjusted or replaced. Sheds with sandwich panel walls and fully slatted floors are more easily cleaned than those with brick or iron walls, reducing the amount of water used for cleaning. Sweeping conventional shed laneways also reduces the amount of cleaning water required.

Recycling treated effluent for flushing reduces the overall water usage, but may increase struvite formation in pipelines. Struvite is a crystalline compound that precipitates out of effluent (and sometimes out of bore water), blocking pipes and equipment. The use of deep litter sheds significantly reduces cleaning water requirements. Significant amounts of water can be lost through leaking pipelines and these need ongoing maintenance. Overall, continuous monitoring of water use can identify excess use and enable rapid rectification of leaks.

7.2 Waste Hierarchy

Waste avoidance should be a priority, followed by reuse and recycling. Disposal should be a last resort.

7.3 Minimising By-products Generation

The main piggery by-products are effluent, used bedding from deep litter housing and mortalities. Effluent mainly comprises wastewater from shed cleaning and cooling (conventional housing), runoff from feedlot outdoor piggeries, drinking water spills and leaks, manure and waste feed.

Section 7.1 outlines methods for efficiently using water. Optimising feed conversion efficiency reduces manure production. Methods for improving feed conversion are given in section 7.1. Feed wastage can be minimised by using well-designed feeders and sound feeding practices.

7.4 By-products Reuse

Piggery by-products may be used as a fertiliser resource or as an energy source for power generation or heating.

The solid and liquid by-products of piggeries contain significant quantities of the nutrients and organic matter that promote plant growth. By-products can be spread without treatment, but composting is one way of value-adding to make the product more stable, less odorous and more marketable to a wider range of users. The nutrient content and availability of by-products varies, so inorganic fertilisers may also need to be applied in conjunction to meet plant requirements.

Methane in the biogas produced by digesting piggery by-products can be captured for heating, electricity generation or both. The methane can provide power for on-farm facilities or can be sold to electricity suppliers. It can be captured by covering, or partly covering, an anaerobic effluent treatment pond, or with a digester. Spent bedding from deep litter systems can be used in conjunction with a covered lagoon. Management of rain water caught by the pond cover, and pond desludging, need careful consideration. Analysis of costs and benefits is worthwhile. Because current methane digesters are expensive and technically demanding, they will only be viable for a small percentage of producers; economies of scale are important. For further information, refer to section 20.3.

Reducing wastage improves feed conversion efficiency and the potential for odour and other environmental impacts

8 Pig Housing – Design and Management

Environmental Outcome: Pig housing that is designed, constructed and managed for optimal hygiene to prevent adverse impacts to the environment and community amenity.

Expert advice should be sought on structural design and internal layout of piggery buildings. Design should consider the type of building foundations that suit the soil type, the number of pigs to be housed, pen layout, the piggery site, local climatic conditions, orientation, shading, insulation and ventilation (both natural and mechanical).

There are two common forms of indoor piggeries – conventional sheds that produce liquid effluent, and deep litter sheds that produce spent bedding containing manure.

Conventional sheds suit all classes of pigs. Shed environment, nutrition and husbandry can be tightly controlled, but these sheds are relatively expensive to build. Some operating costs are relatively high (e.g. labour and power). The sheds may also need large quantities of water to be cleaned. Ponds or other treatment systems coupled with reuse areas or evaporation ponds, are usually needed to manage the liquid effluent produced.

Deep litter sheds best suit weaners, growers/finishers and dry sows. Weaners and growers/finishers generally move through these sheds in batches ('all-in, all-out'), with spent bedding cleaned out only at the end of each batch. They may be relatively inexpensive to build and may provide welfare benefits, but bedding may be difficult and expensive to buy during drought years, particularly for the finisher pigs and dry sows as they require more bedding. The spent bedding also requires management. However, much is to be learned about optimising pig performance in this housing type. Further information on deep litter sheds is also available in Payne (2000).

There are two common forms of outdoor piggeries – rotational outdoor piggeries and feedlot outdoor piggeries. Rotational outdoor piggeries accommodate pigs in paddocks. In feedlot outdoor piggeries, the pigs are kept in pens.

Sections 8.1 and 8.2 and Tables 8.1-8.4 detail design considerations for conventional sheds and deep litter sheds. Requirements for outdoor piggeries are covered in section 8.3 and Table 8.5. It is important to confirm the recommendations of the most current edition of the Code of Practice for the Welfare of Animals Pigs and applicable state regulations.

For all types of piggeries, good management is crucial in minimising the likelihood of amenity and environmental impacts. Regular and frequent cleaning of accommodation and feed storage areas; prompt waste feed removal; immediate removal and management of mortalities; and good by-products management are imperative in minimising odour generation, insect and vermin breeding and environmental impacts. The likelihood of noise nuisance can be reduced by careful timing of noisy activities like feed milling, hand feeding, operation of ventilation systems and truck movements. These should be restricted to daylight hours where practical. In hot weather, early morning stock loading may be needed to protect animal welfare, but neighbours usually understand if they are advised in advance. Appropriate mufflers and noise attenuation equipment should be fitted to machinery. Considerate driving styles also help to reduce traffic noise at houses along access routes.

TABLE 8.1 Summary of design considerations for piggery sheds

Design Component	Considerations
Shed orientation	Buildings should be oriented with their long axis east-west to minimise heat load.
General design and materials	New sheds should be constructed from materials with good thermal properties that maintain shed temperature in the required range, with minimal mechanical heating or cooling. The flooring and drainage system should exclude the ingress of clean stormwater runoff and prevent the discharge of effluent, solid by-products or contaminated waters to adjacent areas. Floors must be concreted for conventional sheds or have low permeability for deep litter sheds (preferably being concreted, otherwise soil compacted for a design permeability of 1×10^{-9} m/s for a minimum depth of 300 mm comprising two layers each 150 mm thick) to prevent seepage of effluent into soils and groundwater. See http://www2.dpi.qld.gov.au/environment/13764.html (Skerman 2005a) for guidance on how to achieve this design permeability. Buildings should be located above the 1-in-100-year flood level.
Feeding system design	Automatic feeding systems should present feed to all animals simultaneously to reduce the level of noise at feeding times. Ad libitum or continuous feeding systems also reduce feed wastage.
Ventilation	Adequate ventilation removes piggery gases, dust and odour, controls air temperature and relative humidity, removes excess heat and moisture, dilutes and removes airborne disease organisms and maintains oxygen levels. Naturally ventilated sheds should be separated by a distance of five times their height to maximise ventilation.

TABLE 8.1 (continued)

Design Component	Considerations
Air quality	The dustier the piggery, the more odorous it will be. Piggery dust may be reduced through adequate ventilation, routine shed cleaning, using pelletised feed, reducing feed-borne dust by adding fat/tallow to diets (making the feed greasy so it will not generate dust), eliminating floor feeding, installing automated feeding equipment, and use of oil sprays.
Visual impact	The material types and colours used for structures combine with landscaping to influence visual impact. Careful choices can produce structures that blend with the surroundings.
External landscaping	Strategic tree planting around the piggery complex can significantly reduce visual impacts of the piggery, and may improve odour and dust dispersion.

8.1 Conventional Sheds

Shed stocking densities affect pig performance and also the cleanliness and odour production of sheds.

For minimum space allowances for adult pigs and growing pigs, i.e. weaners, growers and finishers housed indoors in conventional sheds refer to Appendix 3 of the Model Code of Practice for the Welfare of Animals: Pigs.

Conventional sheds need regular sweeping and hosing to keep lanes, pens and handling areas clean. The design and management of effluent collection systems associated with conventional sheds are discussed in detail in Section 10.

8.2 Deep Litter Sheds

Floors in deep litter sheds are covered with straw, sawdust, rice hulls or other bedding materials that absorb spilt drinking water and manure. Impermeable flooring makes cleaning easier and prevents nutrient leaching into groundwater. Regular bedding top-up is needed to maintain dry, low odour conditions within sheds. On average, some 0.5-1 kg/pig/day of straw is needed. The bedding should be thoroughly cleaned out and replaced before allowing each new batch of pigs into litter-based sheds. Extending the floor pad at least a metre beyond the shed end allows for bedding to be contained at cleanout. Deep litter sheds with concrete floors are sometimes hosed after bedding removal. This is generally the only liquid effluent stream from these sheds. Like other effluent streams, this needs to be captured and managed.

Stocking rates need careful management to control odour generation. For recommended minimum space allowances for adult pigs and growing pigs, i.e. weaners, growers and finishers in deep litter systems refer to Appendix 3 of the Model Code of Practice for the Welfare of Animals: Pigs.

8.3 Rotational Outdoor Piggeries

Rotational outdoor piggeries accommodate pigs in paddocks, sometimes with simple communal shelters for dry sows, kennels for weaners and individual arks or huts for lactating sows. Wallows should be provided. Since these should not leach nutrients, they need to be positioned on a suitable (not sandy) soil type. Pigs must not be able to access watercourses.

For rotational outdoor piggeries, it is important to minimise uncontrolled nutrient movements. Hence, strategies to minimise soil erosion and runoff of nutrient-rich stormwater need to be implemented. Paddock management must include regular spelling from pig production, with a plant growth and harvest phase to strip the nutrients added by pig production. There also needs to be a physical barrier (e.g. a bank) and / or good resilient vegetative cover around the perimeter of the piggery to minimise nutrient transport and for visual screening. Indigenous species should be selected for planted vegetative buffers. Local nurseries or Land Care groups can assist with plant selection.

For recommended space allowances for outdoor systems and shelters refer to Appendix 3 of the Model Code of Practice for the Welfare of Animals: Pigs.

8.4 Feedlot Outdoor Piggeries

Feedlot outdoor piggeries accommodate pigs in pens, sometimes with simple communal shelters for dry sows, kennels for weaners and individual arks or huts for lactating sows.

Feedlot outdoor piggeries need to be located within a controlled drainage area with runoff collected in a holding pond. This pond should be designed so overtopping does not occur more than once every 10 years. Runoff coefficients of 0.8 for the pens, roads and laneways, and 0.4 for grassed areas should be used in calculating the holding pond volume.

The feedlot outdoor piggery pad must have a compacted base to prevent nutrient leaching. This should have a design permeability of 1×10^{-9} m/s for a depth of 300 mm comprising two layers each compacted to 150 mm. For guidance on how to achieve this design permeability, see http://www2.dpi.qld.gov.au/environment/13764.html (Skerman 2005a). Wallows should be provided and these need to be designed to prevent nutrient leaching.

The piggery can be visually screened from nearby sensitive land uses using tree plantings. Indigenous species should be selected for planted vegetative buffers. Local nurseries or Land Care groups can assist with plant selection.

9 Estimating the Nutrient Content of Piggery By-Products

The nutrients and salts in piggery by-products need quantification to enable good management. This is an essential first step towards calculating by-products treatment requirements and reuse area sizing.

When planning a piggery development, the nutrient content of by-products is best estimated using mass balance principles. Manure quantification and the fate of nutrients, including the split between effluent and solids, can be estimated using predictive mass balance models (e.g. PigBal, MEDLI® and the Piggery Assessment Spreadsheet). These models are discussed in this section.

For existing piggery units, the nutrient content of by-products is best quantified using testing combined with quantity data. This method is detailed in section 14.1.3. Models like WastLoad can use this type of data to provide a reuse area nutrient mass balance.

***Environmental Outcome:* Measuring the amount and quality of by-products, enabling appropriate treatment and sustainable reuse.**

9.1 Estimating Volatile Solids

Section 4.3 provides the methods for estimating the SPU capacity of a piggery. The manure and waste feed produced by one SPU contains approximately 90 kg of VS/yr. Hence, multiplying the SPU capacity of the piggery by 90 kg of VS provides the estimated VS output of the entire piggery each year. The PigBal model also estimates VS production.

9.2 Estimating Nutrients and Salts– Mass Balance Principles

This section provides details to estimate the quantity of nutrients and salts in piggery by-products using mass balance principles.

9.2.1 Mass Balance Principles for Piggeries

A mass balance estimates the quantity of nutrients and salts in by-products through the difference between inputs (generally pigs, feed, water and bedding (if used)) and outputs (pigs and nitrogen volatilisation in sheds). It may also estimate nitrogen losses via ammonia volatilisation and how nutrients are split between effluent and sludge in effluent treatment ponds (if applicable), or from solid by-products stockpiles (if applicable). Each of these elements is important in accurately estimating the nutrient load available for use.

Nutrients and salts excreted by pigs can be estimated using predictive models, such as PigBal and MEDLI® (see Sections 9.2.2 and 9.2.3) that are based on diet digestibility and mass balance principles. Mass balance principles consider different diets, feed use, feed wastage, water quality and use, bedding quality and use, and other factors affecting the composition and quantity of by-products produced.

9.2.2 PigBal Model

PigBal 3.1 is an Excel® spreadsheet that estimates the mass of solids, nitrogen, phosphorus, potassium and salt in piggery by-products using diet digestibility and mass balance theory (Casey *et al* 2000). Table 9.1 provides PigBal estimates for the typical quantities of solids and nutrients in the manure and waste feed of different classes of pig housed in conventional sheds, based on typical diets. For pigs housed on deep litter, the nutrients added by the bedding may need to be considered (particularly potassium if straw is used). Typical nutrient composition data for bedding materials are provided in Table 9.2.

TABLE 9.1 Predicted solids and nutrient output for each class of pig (kg/hd/yr)

Pig Class	Total solids	Volatile solids	Ash	Nitrogen	Phosphorus	Potassium
Gilts	197	162	35	12.0	4.6	4.0
Boars	186	151	35	15.0	5.3	3.8
Gestating Sows	186	151	35	13.9	5.2	3.7
Lactating Sows	310	215	95	27.1	8.8	9.8
Suckers	11.2	11.0	0.2	2.3	0.4	0.1
Sow and Litter	422	325	97	50.0	13.0	11.0
Weaner pigs	54	47	7	3.9	1.1	1.1
Grower pigs	108	90	18	9.2	3.0	2.4
Finisher pigs	181	149	32	15.8	5.1	4.1

Notes: Refer to Table 4.1 for approximate animal numbers in each pig class per 100-sow production unit.

TABLE 9.2 Typical solid and nutrient content of clean bedding materials

	Content (% dry matter)			
Bedding materials	Total Solids	Nitrogen	Phosphorus	Potassium
Hardwood Sawdust[a]	90	0.22	0.01	0.05
Softwood Sawdust/Shavings[a]	90	0.14	0.01	0.03
Rice Hulls[b]	92	0.53	0.08	1.32
Barley Straw[b]	91	0.69	0.07	2.37
Wheat Straw[b]	89	0.58	0.41	0.51

[a] based on unpublished data from Department of Primary Industries and Fisheries - Queensland

[b] based on data from National Research Council (1984)

9.2.3 MEDLI® Model

MEDLI® is a Windows® based computer model for designing and analysing effluent treatment systems and reuse of effluent in land irrigation. It was developed jointly by the CRC for Waste Management and Pollution Control, Department of Primary Industries and Fisheries, Queensland, and the Department of Natural Resources, Mines and Energy, Queensland (1995). MEDLI uses the same principles as PigBal (mass balance and diet digestibility) to predict the effluent stream from the sheds. It follows the effluent stream of a piggery through pre-treatment, treatment and reuse.

9.2.4 Wastload Model

Developed in South Australia, Wastload is an Excel® spreadsheet-based model designed to calculate sustainable by-products spreading rates. Inputs include soil properties, effluent and shandying water composition, land use and harvested yields. Outputs include potential loading rates for nitrogen, phosphorus and potassium, the sustainable effluent and/or solids application rate and salt dynamics (Clarke 2003).

9.2.5 Piggery Assessment Spreadsheet

The Department of Primary Industries and Fisheries, Queensland, originally developed the 'Piggery Assessment Spreadsheet' (Skerman 2003) for use by their regulatory officers in assessing applications for new and expanding piggeries under the relevant state legislation. To enhance its value in the pig industry, the assessment spreadsheet has recently been revised and updated to a more user-friendly form, making it more useful to many producers, consultants and industry advisers. The spreadsheet uses piggery by-products estimates derived from PigBal to automate the calculations required in preparing applications, and assists in documenting proposed piggery design characteristics and management practices. It partitions the by-products between the liquid effluent, separated solids, pond sludge and deep litter, and performs nutrient mass balances on the effluent and solid by-products land application to areas to assess their long-term sustainability. It also calculates pond volumes required for the storage and treatment of effluent.

9.2.6 Fate of Nutrients - Conventional Piggeries

Significant ammonia losses in the sheds and ponds reduce the amount of nitrogen available to be used. Ammonia volatilisation losses within piggery sheds account for approximately 10% of excreted nitrogen. Anecdotally, some 15-30% of nitrogen entering a piggery effluent pond deposits to sludge. Volatilisation of ammonia nitrogen from the pond surface may remove 40% to 70% of the effluent nitrogen. Cumulative total losses for the entire system might range from 54% to 89%.

Phosphorus is not lost from the pond system through chemical or biological transformations. However, about 90% of the phosphorus entering the pond system may accumulate in the sludge of a conventional anaerobic pond.

There is little loss of potassium and other salts to sludge. Since potassium is very soluble, the liquid component of sludge has a similar potassium concentration to the pond effluent. Around 10% of the potassium added to the pond is likely to be present in sludge.

The salt content of the effluent stream depends on the salt content of the feed and water used in the piggery. The salt content of the treated effluent also depends on the quantity of effluent removed for use (recycling and irrigation), the climate, and the surface area of the effluent treatment ponds. Conductivity of pond effluent ranges from 2.2 dS/m to 14.7 dS/m (Table 14.1, see treatment ponds). Salinity of piggery sludge ranges from 6.3 dS/m to 16.5 dS/m (Table 14.2, see section 14).

There is little quantitative data on heavy metal excretion by pigs. However, Table 14.1 and Table 14.2 show concentrations of copper, zinc and selenium in piggery effluent and solids.

9.2.7 Fate of Nutrients - Deep Litter Piggeries

Spent litter from deep litter sheds includes nutrients from the manure and bedding. Significant ammonia losses would be expected in the sheds (approximately 10-20%) and from stored spent litter. However, phosphorus and potassium losses should be minimal. Rates of nitrogen loss through volatilisation after litter clean-out depend on material handling. Composting results in more nitrogen losses than stockpiling. However, when compost is spread, nitrogen loss rates are lower, and the net amount of nitrogen added to the soil can be similar to that of spread stockpiled litter.

Significant dry matter losses occur during the storage/treatment of deep litter. The more intensively the material is treated (e.g. turned and water during composting), the more rapid the dry matter and nitrogen losses. This has the effect of increasing the phosphorus concentration of the material and reducing the nitrogen to phosphorus ratio. However, the nitrogen in composted material is more stable and smaller losses will occur during reuse.

9.2.8 Fate of Nutrients - Outdoor Piggeries

Significant nitrogen losses from the manure deposited in rotational outdoor piggeries is expected. Low levels of nutrient leaching could also occur.

A significant percentage of the manure nitrogen deposited in feedlot outdoor piggeries will be lost through ammonia volatilisation. Since outdoor feedlot piggeries have compacted bases, losses of other nutrients and salts should be minimal. The deposited manure will need to be regularly removed from the pad. Nutrient losses from harvested manure and compost are discussed in sections 13.2 and 13.3, respectively. The ponds will collect nutrient-rich stormwater runoff from the feedlot outdoor piggery pad. Some nutrients in the pond effluent will be deposited as sludge, others will remain in the effluent.

10 Effluent Collection Systems

Raw effluent is conveyed from conventional sheds to treatment facilities by a collection system that generally includes pits or channels, drains and/ or sumps. These facilities must be large enough for the expected effluent volume and flow rate. Effluent should ideally flow by gravity (rather than being pumped, which requires energy and maintenance) and along open channels (rather than through pipes that can block). For outdoor feedlot piggeries, runoff needs to be collected by a drainage system.

***Environmental Outcome:* Effluent is collected and moved from conventional sheds and outdoor feedlot piggeries, to treatment facilities or reuse areas, with minimal odour generation and no releases to surface water or groundwater.**

10.1 Design Principles

Effluent collection systems should be designed and constructed to stop stormwater runoff from coming in, and effluent from exiting. They must be impervious to prevent seepage and the possibility of groundwater contamination. They should also be self-cleaning or be regularly cleaned to reduce manure build-up and to minimise the risk of excessive odour and fly and mosquito breeding. Consider future expansions in piggery capacity when designing and locating the effluent collection system.

The effluent collection system should be managed by ensuring that:

- excess manure is not left in the effluent collection and transport system after flushing or emptying
- there is no overtopping or leakage from pits, drains and sumps
- there is regular emptying or cleaning to minimise odour, adverse effects on pig health impacts and fly breeding.

10.2 Collection Systems

10.2.1 Flushing Channels

Flushing systems consist of underfloor channels in conventional sheds that are flushed daily, to twice weekly, with either clean water or treated effluent recycled from the ponds. The drain width, drain length, flush volume, flush rate and flushing frequency need to be carefully matched to ensure effective removal of accumulated manure and cleaning of pits and drains. The maximum recommended flush length is 50 m, and box drains with a 1% slope are preferred. Alternatively, level box drains with a 50 mm lip at one end to retain some water in the base of the drain, can be used. For drains up to 40 m long, the minimum recommended flushing water volume is 700-1000 L/m of drain width/flush. A water velocity of 0.9 m/s, an initial flow depth of 75 mm and a flush duration of at least 10 seconds will effectively dislodge and transport solids.

10.2.2 Pull Plug Systems

'Pull-plug' systems store effluent in underfloor pits in conventional sheds that are drained at least fortnightly, using the gravity release pipes in the centre of the pits. Following complete drainage, the pit is partially refilled with either clean water or recycled effluent to prevent deposited manure from sticking to the pit floor. Pull-plugs systems are suitable for sheds with negative pressure ventilation systems. Each shed may be divided into a number of cells serviced by individual pull-plug systems.

10.2.3 Static Pits

Static pits are common in older-style conventional sheds. They comprise underfloor pits that store effluent for up to several weeks before it is released via a sluice gate at the end of the shed. These systems do not always adequately clean underfloor pits. They need recharging with 50 mm of water to reduce ammonia releases, and prevent manure and waste feed from sticking to the base.

10.2.4 Open Flush Gutters

Some older conventional sheds collect effluent in open flush gutters or vee drains running along solid flooring within, or beside, the pens. The gutters rely on pig movements dislodging the manure, which in turn reduces the amount of cleaning water required. However, both the pens and the pigs remain dirtier than in other systems. This increases the potential for odour and for rapid disease transmission along the shed via the cleaning water that runs through, or beside, each pen.

10.2.5 Drains

Drains or pipes are also needed to move effluent from other systems to sumps or treatment ponds. Drains are preferred to pipes, which are more likely to block because they are more difficult to inspect and to clean. There is no significant difference in odour between open drains and pipes, as the effluent is only in these conduits for a short time.

Drains should be made of smooth concrete, fibreglass or other impervious material in spoon or vee channel sections. They should have at least a 0.5% slope to ensure minimum solids retention and ease of cleaning and drying between uses. Enclosed drains or pipes should have a 1% slope and be flushed with enough fluid to be self-cleaning. Pipe drains should be laid on a constant grade with minimal bends and joins.

Feedlot outdoor piggeries require sealed drains at the base of pens to convey runoff to the retention pond. These will need adequate slope (0.5-1.5%) to prevent significant settling of solids in the drains. The drains will also need regular maintenance to ensure that they are free of deposited solids and vegetation.

10.2.6 Dry Scraping Systems

Dry scraping systems consist of blades on cables that drag manure and wastewater from effluent channels under conventional sheds. Since flushing water is not added to the manure, the amount of effluent that is treated is greatly reduced. However, the effluent has a very high concentration of solids. Ammonia within sheds may also be significantly higher than in other effluent collection systems. Dry scraping systems work best in climates with very low rainfalls and high evaporation rates, since an odour-controlling crust readily forms over the effluent discharged to a pond or basin.

10.2.7 Effluent Sumps

Sumps store effluent before pre-treatment, or before it is directed to ponds or irrigation. They must be made from strong, corrosion resistant and impermeable materials, such as concrete, fibreglass, stainless steel, poly-lined steel or enamelled steel.

When sizing sumps, it is important to consider the shed flushing frequency, flushing volume, pumping frequency, pumping capacity, possibilities for equipment failure and stormwater entry. Contingency plans are needed in the event of equipment failure.

Mechanical stirrers or high velocity pumps are generally used to ensure that solids are kept in suspension to prevent settling, and to enable pumping of the resulting slurry. The type and size of the agitator needed depends on the effluent properties and the size and shape of the collection tank. Diaphragm pumps cause less solids break-up than impeller pumps, enabling maximum solids recovery. If the mixing speed is too high, odour may increase.

10.3 Collection Systems Management

All components of the effluent collection system need regular inspections for solids accumulation, leakage and deterioration. This includes:

- inspection of drains and sumps daily, or as required, depending on the flushing frequency
- inspection of pits at least weekly, and daily cleaning of flushing systems in conventional sheds (ideally)
- emptying of each static pit in conventional sheds at least weekly, with each pit being emptied in rotation to promote uniform loading of the effluent treatment system.

11 Solids Separation Systems

Solids separation systems separate larger solids from liquid effluent before the effluent is treated, recycled and used. Removing large solids enables effluent to be conveyed using conventional equipment (e.g. centrifugal pumps) and increases the flexibility of reuse options. Solids removal also reduces the effluent's organic matter, and consequently the capacity required for effluent treatment. Nutrients and minerals in the separated solids are also removed from the liquid effluent.

The solids separation system and the solids storage area should be located within a low permeability, controlled drainage area. The design permeability standard is 1×10^{-9} m/s for a depth of 300 mm comprising two 150 mm deep layers. For guidance and technical direction on pad preparation requirements see: http://www2.dpi.qld.gov.au/environment/13764.html (Skerman 2005a). Impervious drains or pipes should convey all runoff, separated liquid and leachate from the separated solids to adequately sized storages.

Environmental Outcome: **Solids separation systems designed and constructed to optimise solids removal and management, while minimising impacts on community amenity (odour and vermin), surface water and groundwater.**

11.1 Options for Solids Separation

Methods for separating solids from liquids include gravitational settling, screens, presses and centrifugal separation.

11.1.1 Gravitational Settling

In gravitational settling, the effluent is held in a basin or tank so that the solids settle. The remaining liquid is then released or removed from the top of the storage unit. A sedimentation and evaporation pond system (SEPS) uses long earthen channels to remove solids by gravitational settling and to store and treat the effluent. Since SEPS provide both solids separation and treatment in a single system, they are detailed in section 12.4. Another gravity separation process is dissolved air flotation (DAF), which uses air or gas bubbles to remove solids.

11.1.2 Screens

Screens separate solids from liquid on the basis of particle size and shape. Types include static rundown screens, vibrating screens and rotating screens.

11.1.3 Presses

Screw or belt presses force the effluent against a filter, which retains the solids and allows the liquid to pass through. As solids build-up on the filter matrix, more of the finer particles are recovered.

11.1.4 Centrifugal Forces

Centrifugal forces can be used to separate out solids. Examples are hydrocyclones and horizontal centrifuges. The tangential flow separator tank of a hydrocyclone acts like a cyclone, using lime or other additives to assist solids removal.

The performance of most mechanical solids separation systems improves when there are more than 3% solids in the total volume. However, the effluent from most flushed sheds has a total solids concentration of only about 1%. Thickening can be achieved through gravity settling and/or adding coagulants or flocculants.

Tables 11.1-11.3 summarise the efficiency of various solids separation methods. For further information, see Watts *et al* (2002), McGahan *et al* (2004) and Skerman (2006).

TABLE 11.1 **Summary of performance of a range of solids separation systems**

Separation system	Indicative capital costs[a]	Indicative operating costs[b]	Solids dryness	Maintenance and supervision	Degree of operator training	Pre-treatment needed	Removal Efficiency (% of total solids) 1.2% TS	Removal Efficiency (% of total solids) 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+ polymer	70	70
Tangential flow Separators	High	High	Low-medium	Medium	Medium	Screw press	50	50

TS = total solids

[a] Capital costs – see Table 11.2 [b] Operating costs – see Table 11.3

Notes: 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 wastewater treated.

Based on Watts et al (2002).

TABLE 11.2 **Capital cost classifications for different types of solids separators**

	200-sow farrow-to-finish unit (2002 $)	2000-sow farrow-to-finish unit (2002 $)
Low	< 5,000	< 20,000
Low-medium	5,000-20,000	20,000-35,000
Medium	20,000-40,000	35,000-75,000
Medium-high	40,000-60,000	75,000-150,000
High	60,000-256,000	150,000-404,500

TABLE 11.3 **Operating cost classifications for different types of solids separators**

	200-sow farrow-to-finish unit (2002 $/ML)		2000-sow farrow-to-finish unit (2002 $/ML)	
	Total solids 3.1%	Total solids 1.2%	Total solids 3.1%	Total solids 1.2%
Low	130-350	80-170	80-150	40-70
Low-medium	350-550	170-330	150-200	70-100
Medium	550-1000	330-760	200-300	100-270
High	1000-4070	760-1510	300-990	270-460

Notes: Operating costs vary widely depending on a range of factors, particularly the total solid (TS) content of the effluent and the size of the operation. 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 wastewater treated.

11.2 Management of Solids Separators

Solids separation systems need regular checking and cleaning to maintain optimum performance. For example, screens should be scrubbed with a wire brush and washed occasionally with a high-pressure hose. The out-loading bay (if present) should be kept clean of excess solids.

Separated solids need careful management to minimise odour, fly breeding and surface water or groundwater contamination. For management of separated solids, see section 13.

12 Effluent Treatment Systems

Effluent treatment systems aim mainly to reduce organic matter (volatile solids) in liquid effluent. They may also reduce the nitrogen content of effluent, mainly through ammonia volatilisation losses, and produce a stabilised sludge. This section deals mainly with effluent ponds. However, alternative systems are available, the most appropriate treatment system for each site should be assessed and used.

Factors to consider are:

- effluent characteristics
- volume of effluent
- size and type of piggery
- end use of by-products
- availability of land for by-products use
- sensitivity of neighbouring environment (including proximity to potential receptors)
- climate
- topography
- soil characteristics
- groundwater vulnerability
- nutrient mass balance
- water balance
- future expansion plans
- state or territory regulatory requirements
- cost
- reliability
- maintenance requirement
- ease of use and labour requirements.

Treatment ponds are an integral part of effluent treatment at most piggeries that have conventional sheds. They are more convenient, simple to manage and robust than most other treatment systems. The effluent produced is unsuitable for discharge to waterways and is usually utilised by land spreading or irrigation, providing a rich source of nutrients for the soil. Because treatment ponds are inherently dangerous, occupational health and safety considerations must be integrated into their design and management.

Environmental Outcome: **Effluent treatment systems that are designed, constructed and managed to effectively reduce the volatile solids in effluent, without causing odour nuisance or adverse impacts on water resources.**

12.1 Design of Effluent Treatment Ponds

12.1.1 General Principles

When planning the location for effluent treatment ponds, consider:

- topography including slope (for drainage)
- depth to groundwater (the depth to the water table from the excavated base elevation should exceed 2 m at all times)
- soil type
- space for possible future expansion of piggery and ponds
- access for desludging and maintenance
- proximity to neighbours and public areas and prevailing winds
- **the requirements of the local authority and other relevant approved authorities.**

The pond's shape should assist content mixing. Round, square and rectangular ponds are all effective. However, ponds with sections isolated from the main volume have a reduced effective treatment capacity. Inlets and outlets should be positioned to prevent effluent short-circuiting, thus maximising retention time and treatment efficiency. Inlet pipes or channels should discharge into the pond beyond the toe of the pond wall, preferably at a number of points in large ponds. Consider ease of unblocking of inlet pipes when deciding on inlet position and height.

Ease of desludging should be considered when deciding on the pond's dimensions. Smaller or narrower ponds may be more easily desludged, although this may need to occur more frequently.

Pond banks need to be designed to allow safe access for desludging and maintenance. Bank tops 2.5-4 m wide and external batters or ramps not exceeding 1:3, allow safe access by vehicles. For slopes that are to be mown, batter grades no steeper that 1:3 (vertical:horizontal) are required. Internal batters should be designed to maintain the pond integrity based on a soil stability assessment. Below the water level, internal batters should not exceed 1:2 (vertical:horizontal). Ideally, there should be no vegetation on the internal pond batters. Further details on desludging are provided in section 12.2.

Adequate soil compaction and correct moisture content are required to produce a design permeability of 1×10^{-9} m/s for a depth of 300 mm for ponds up to 2 m deep, or 450 mm for deeper ponds (compacted layers should not exceed 150 mm each). Guidance and technical direction regarding clay lining and compaction of effluent ponds can be obtained from http://www.dpi.qld.gov.au/4789_14274.htm (Skerman *et al* 2005). Ponds constructed using soils containing less than 20% clay will require sealing with liners made from imported clay, polyvinyl chloride or high density polyethylene. The floor of effluent treatment ponds should always be at least 2 m above the water table. An assessment of the risk of potential impacts to groundwater and surface water can be used to guide decisions on the type of liner and standard of construction. The structural integrity of the liner should be regularly checked and maintained as needed.

Providing at least 500 mm freeboard allows the pond banks to contain wave action and prevents overtopping due to imperfections in the crest level. Freeboard should not be used for effluent storage. Consequently, the final pond in a series should be equipped with a spillway to avoid pond banks being eroded and breached during spill events that may accompany extreme wet conditions. The water from the spillway or from pond overtopping should not enter any waterway or leave the property boundary.

The pond system must be able to contain effluent flowing in, plus rainfall and runoff during extended periods of wet weather, so that overtopping does not occur on average more than once every 10 years. Entry of clean stormwater runoff should be minimised by using diversion banks. The ponds should only collect contaminated stormwater runoff, which should be minimised. The overtopping potential of a treatment pond system is most accurately assessed using a water balance model (for example, MEDLI) and long-term local climate data.

12.1.2 Primary Anaerobic Ponds

Most primary effluent treatment ponds are anaerobic or lacking dissolved or free oxygen. Anaerobic bacteria within these ponds convert VS firstly to volatile organic acids, and then to low-odour methane and carbon dioxide. The second stage is pH dependent. Very high VS loading rates produce high concentrations of volatile organic acids that inhibit the methane formers, causing the release of odorous volatile organic acids. Good design and management is important. Where the VS loading rate is too high, either because the effective treatment capacity of the pond is too low, or because large amounts of VS are added infrequently, incomplete anaerobic digestion may produce strong odours. However, properly functioning anaerobic ponds can reduce the VS content of effluent by up to 70%. Further information on VS loading rates and pond odour emissions is provided in Hudson *et al* (2004). In addition, heavily loaded ponds may develop a crust that reduces odour releases. A by-product of anaerobic digestion is a stabilised sludge that accumulates at the bottom of the pond at a rate proportional to the amount of total solids treated.

Effluent from a piggery is generally captured in a series of ponds

When designing anaerobic ponds, there are three main aims. They are:

- to keep odour emissions acceptably low
- to allocate enough space for sludge storage between desludging
- to ensure that effluent and sludge from the pond can be removed and used as needed.

Primary anaerobic ponds are typically 2-5 m deep. Deeper ponds generally have a smaller surface area for a given volume, which reduces the odour-emitting surface. However, they may be more difficult to desludge depending on their other dimensions and available equipment. The required capacity of a primary anaerobic pond depends mainly upon the design VS loading rate, the piggery size and the amount of maintenance the operator is prepared to undertake. Any anaerobic pond will require periodic desludging to maintain effective treatment capacity.

Larger anaerobic ponds generally:

- require infrequent desludging (e.g. once every five to ten years)
- function effectively with relatively low to moderate ongoing odour emissions. However, once accumulating sludge begins to encroach on the designed treatment capacity, the pond function may deteriorate, resulting in increased odour emissions over the relatively large surface area of the pond
- can occupy a significant land area
- may be expensive to build, line and cover (if required)
- can be difficult to desludge because of their size and / or depth.

Table 12.1 provides sizing details for large anaerobic ponds in three broad climatic zones, with different desludging frequencies, with or without pre-treatment of the effluent stream.

By comparison, smaller anaerobic ponds generally:

- are cheaper to build, line and cover (if required)
- are more easily desludged
- allow for more regular and effective utilisation of the valuable nutrient and soil amendment of piggery solids
- have lower odour emissions due to a significantly reduced pond surface area and crusting of the pond surface. This may provide potential for the establishment or expansion of piggeries at sites limited by separation distances to sensitive receptors
- require more frequent desludging than large anaerobic ponds.

Table 12.2 shows maximum suggested loading rates for anaerobic ponds under Australian conditions. It is suggested that anaerobic ponds should have a maximum VS loading rate of 750 g VS/m^3/day in a hot climate, 600 g VS/m^3/day in a warm climate and 450 g VS/m^3/day in a cool climate. Effluent discharged from anaerobic ponds with these loading rates should be stored in a holding pond, or ponds prior to recirculation as shed flushing water or reuse. Because they need more frequent desludging, ponds with relatively high VS loading rates should be narrow, with the main constraint generally being the width of the machinery used to construct the pond (typically 3 m). This will result in very long ponds for large piggeries, and multiple parallel ponds may be preferable. For more information, see Skerman *et al* (2008).

Providing parallel anaerobic ponds that can be used independently of one another enables the temporary decommissioning of a pond for desludging. Where ponds are used in parallel to process the effluent from a piggery, their capacities can be regarded as additive in assessing whether the required capacity is present. Ponds are often used in series (one after the other) to produce effluent with a lower concentration of organic matter for recycling through the piggery's flushing system. However, where ponds operate in series, only the capacity of the first pond should be considered when assessing the primary treatment capacity. This is because the first pond receives the entire organic loading and most of the sludge will accumulate there.

TABLE 12.1 Suggested large anaerobic pond capacities for different climates, desludging frequencies and pre-treatment options

Climate	Desludging Frequency	Effluent Treatment & Desludging Frequency (m^3/SPU)	
		No pre-treatment	Pre-treatment[a]
Cool[b]	Annually	4.6	3.5
	5 yearly	6.0	4.6
	10 yearly	7.7	5.9
Warm[c]	Annually	3.5	2.7
	5 yearly	4.9	3.8
	10 yearly	6.6	5.1
Hot[d]	Annually	2.9	2.2
	5 yearly	4.3	3.3
	10 yearly	6.0	4.6

SPU = standard pig unit

[a] Assumes a screen that removes 20% of the TS and 25% of the VS (e.g. a stationary run-down screen).

[b] Based on a treatment capacity loading rate of 60 g VS/m^3/day. Examples of localities with cool climates are Armidale New South Wales, southern and central Victoria, southern South Australia, and Tasmania.

[c] Based on a treatment capacity loading rate of 80 g VS/m^3 /day. Examples of localities with warm climates are most of inland New South Wales, South-East Queensland, South Australia and southern Western Australia.

[d] Based on a treatment capacity loading rate of 100 g VS m^3 /day. Examples of localities with hot climates are central to northern Queensland, Moree and Goondiwindi.

TABLE 12.2 Suggested maximum anaerobic pond loading rates for different climates

Climate	Suggested Capacity (m^3/SPU)
Cool[a]	0.55
Warm[b]	0.41
Hot[c]	0.33

Based on Skerman *et al* (2008).

[a] The recommended maximum volatile solids loading rate for treatment capacity in a cool climate is 450 g VS/m^3 pond capacity/day. Examples of localities with cool climates are Armidale in New South Wales, southern and central Victoria, southern South Australia, and Tasmania.

[b] The recommended maximum volatile solids loading rate for treatment capacity in a warm climate is 600 g VS/m^3 pond capacity/day. Examples of localities with warm climates are most of inland New South Wales, South-East Queensland, South Australia and southern Western Australia.

[c] The recommended maximum volatile solids loading rate for treatment capacity in a hot climate is 750 g VS m^3 pond capacity/day. Examples of localities with hot climates are central to northern Queensland, Moree and Goondiwindi.

12.1.3 Facultative Ponds

Facultative ponds are aerobic near the surface and anaerobic at greater depths. They sometimes provide second-stage treatment following the anaerobic pond, improving effluent suitability for use in shed flushing or on land.

Facultative ponds are generally shallower than anaerobic ponds (2-3 m) and have a greater surface area to volume ratio. To keep the upper layer aerobic, a lower organic matter load is needed than for an anaerobic pond. The combination of anaerobic and facultative ponds produces better effluent quality.

12.1.4 Aerobic Ponds

Aerobic ponds may provide polishing treatment, the final treatment stage before effluent is reused. Aerobic ponds digest organic matter using bacteria that need an abundant supply of oxygen. The oxygen in these ponds is supplied from the atmosphere and from algae in the water. Aerobic ponds are shallow (less than 1 m deep). They require low organic matter loading rates to prevent them from becoming facultative or anaerobic. Piggery effluent is usually too concentrated to allow for true oxygen-rich conditions, without mechanical aeration.

12.1.5 Wet Weather Ponds and Evaporation Ponds

Wet weather ponds provide emergency wet weather effluent storage. In cold climates, they also provide winter effluent storage for the months when rainfall exceeds evaporation. They may also store effluent before use, although effluent may be drawn from other ponds in the system for these purposes.

Evaporation ponds provide storage before the effluent is 'disposed' by evaporation. Solids remaining in the base of dry evaporation ponds need periodic removal. These may be difficult to deal with due to high salinity.

Wet weather ponds and evaporation ponds need to be sized so overtopping happens no more than once every 10 years. In environmentally sensitive locations, it may be appropriate to design ponds that overtop at a lower frequency. Wet weather ponds may also need to store up to several months worth of effluent.

12.2 Management of Effluent Treatment Ponds

The outer banks of effluent treatment ponds should be grassed to prevent weed infestation, cracking and erosion. The grass cover should be kept short to facilitate regular inspections for signs of deterioration. Trees, shrubs and woody weeds should not be allowed to establish on pond banks as these can damage the integrity of the pond.

Anaerobic ponds use bacteria to degrade the manure. It takes some time for new ponds to develop suitable bacterial populations. Partially filling new ponds with water prior to start-up is recommended. The addition of effluent from another piggery with the same ownership and health status can be helpful in establishing bacteria. Sourcing pond culture from the pond of an unrelated piggery is not recommended due to biosecurity risks. Substances that may inhibit microbial activity, such as foreign material (afterbirth, veterinary equipment, plastic bags etc.), toxic chemicals and oxidising agents, should be prevented from entering the effluent treatment pond.

The pH of pond effluent should be in the 6.8-8.0 range. pH should be monitored to ensure it is within a range that is ideal for maintaining a suitable bacterial population in the pond. Ponds may need to be diluted with fresh water to keep the salinity at an acceptable level. Also, the use of high-salinity effluent on land can cause salt accumulation in the soil, with detrimental effects on plant growth. There should be no floating islands of vegetation. The presence of purple sulphur bacteria often indicates sound pond function.

The performance of anaerobic treatment ponds can be gauged mainly from their VS reduction rate. The need for desludging should be investigated if the VS reduction in the primary anaerobic pond falls below 50% or the VS concentration of the treated effluent exceeds 1%. However, VS removal can fall below these levels for other reasons, for example, disruption to the pond bacteria by chemicals or a pH imbalance. Difficulties in obtaining representative samples may also introduce error. Hence, these limits should be regarded as a trigger for a more detailed investigation of the situation, possibly by collecting and analysing more samples or by plunging a 0.3 m wide "T" into various sites within the pond to ascertain sludge depth.

Removing and drying sludge is a slow process. Before desludging, consider the size of the pond, removal of liquid before desludging, the amount of sludge for removal, proximity to neighbours, seasonal conditions, prevailing winds, how long the extracted sludge will be stored for, where it will be stored (if it is not spread immediately), how it will be reused and how the effluent flow will be managed if a pond needs to be decommissioned during desludging. Ponds can be desludged using vacuum tankers, sludge pumps on the pond bank, sludge pumps on floating pontoons, long-reach excavators, swamp dozers and other methods. The most suitable system will depend upon site constraints and design, though the sludge pump located on the pond bank is generally the most cost-effective option. When sludge is stored for drying before reuse, the storage site will need to be properly compacted and bunded to prevent leachate from entering groundwater and surface waters (see section 13) for further information on storage design). Further details on in-situ desludging and sludge drying are provided in GHD (2008b).

Pond management usually involves removal of some of the water for use in irrigation. This also removes salts, helping to maintain salinity at an acceptable level.

No matter how well an effluent treatment pond system is designed and managed, breakdowns, power shortages, blockages, entry of foreign substances and overflows can create problems. Contingency plans need to be developed to cater for these situations.

12.3 Pond Covers

Pond covers may either be permeable or impermeable.

A permeable pond cover is a porous barrier that floats on the pond surface. Permeable pond covers can reduce the odour emission rates from anaerobic treatment ponds by up to 90%. Supported polypropylene geofabric with a shade cloth overlay, shade cloth and supported straw, all provide suitable covers. The polyprolylene geofabric has a longer life span than straw, providing it is protected from UV damage by a shade cloth overlay. Shade cloth covers also show potential and are lower cost. Straw covers need replacement as the cover deteriorates (annually or as required), need more weed management and can create pumping problems. However, the long-term performance and life of the covers, and potential disadvantages, are yet to be verified. For further details, refer to Hudson (2005).

An impermeable pond cover does not allow the entry or exit of gases or liquids. Hence, impermeable covers can significantly reduce gaseous emissions. The captured biogas can be flared or used to produce heat or electricity. Because these covers don't allow rainfall landing on the cover to pass through, water management needs to be considered at the design stage. Sludge recirculation is needed to optimise biogas yields and also needs to be considered in the design.

Pond covers can provide multiple benefits by reducing odour, reducing greenhouses gases and providing the potential for bioenergy

Access to the pond for desludging must be considered when designing a pond cover. Some covered ponds are fitted with a network of pipes over the floor to allow for desludging without removal of the cover (Birchall *et al* 2008). Partial or floating covers should be designed to allow access for desluding.

It may also be worth referring to the website of the New Zealand National Institute of Water and Atmospheric Research: www.niwa.co.nz.

12.4 Sedimentation and Evaporation Pond Systems (SEPS)

A SEPS is an alternative to a primary anaerobic pond. These consist of long, narrow, earthen channels built as embankments along the land contour. Usually two or three channels are built in parallel down the slope. At any time, one channel is in active use while the other one or two channels are drying and / or being cleaned. The piggery effluent is pumped or drained into one end of the active channel, and is continuously drained or siphoned off at the other end of the channel into treatment or holding pond(s). The active channel is used continuously for six to twelve months. During this time, the manure solids settle out of the effluent into the base of the channel. At the end of the active period, the remaining liquid is drained or siphoned from the channel, leaving wet sludge. This dries by evaporation over the summer period. Dried solids are then easily removed using a front-end loader or excavator and stockpiled ahead of composting, reuse or sale. If the site constraints permit, leaving space between each channel will allow for temporary stockpiling of dry solids above the channels until it can be moved to a storage area or spread. Runoff from these areas should be directed back into the system.

Each SEPS must be able to store at least 12 months wet piggery solids, which requires a capacity of 0.5 m^3/SPU. If three channels are used in parallel, each channel should be sized to store six months of wet solids, which requires a capacity of 0.25 m^3/SPU. The VS loading rate to a channel providing 0.25 m^3/SPU is about 1000 g/m^3/day. The need for desludging should be investigated if the VS reduction in a channel falls below 50% or the VS concentration of the treated effluent exceeds 1%. However, VS removal can fall below these levels for other reasons, for example, disruption to treatment bacteria by chemicals or a pH imbalance. Difficulties in obtaining representative samples may also introduce error. Hence, these limits are only a trigger for a more detailed investigation of the situation, possibly by collecting and analysing more samples.

Each channel is typically 6 m wide at the base, with 3:1 internal batters and a maximum water depth of 0.7-1.0 m plus freeboard of 0.5 m. The base and sides of the channels must be compacted for a design permeability of 1×10^{-9} m/s for a depth of 300 mm. For guidance regarding clay lining and compaction to achieve this design permeability, see: http://www.dpi.qld.gov.au/4789_14274.htm (Skerman *et al* 2005). The base must also be trafficable to allow for cleaning. In low rainfall environments, the base of channels that are not in active use can dry and crack. Hence, these should be regularly inspected to ensure that the integrity of the base is maintained.

A SEPS overcomes the difficulties and high costs involved in desludging large, deep anaerobic ponds. They can be constructed at a new piggery or may be integrated into an existing treatment system where site constraints permit.

Further information on SEPS is provided in Payne *et al* (2008); Kruger, Payne, Moore and Morgan (2008); Kruger, Moore, Morgan and Payne (2008); and Hayes *et al* (2007).

12.5 Other Effluent Treatment Systems

Other methods for treating effluent include one or more of the following:

- artificial aeration
- activated sludge
- rotating biological contactors
- trickling filters
- constructed wetlands
- biodigesters.

Some of these are discussed in more detail in references such as Kruger *et al* (1995) and Ryan and Payne (1989). They are not discussed here as they fit into one or more of the following categories:

- they are in the experimental stage
- they have not yet been proven in Australian piggeries
- they are better suited for less concentrated effluent than is produced by piggeries
- they are more suited to polishing low-nutrient effluent
- they often require large capital expenditure and/or running costs (e.g. they require expert personnel for good operation)
- they are relatively technologically complex and expensive to install and operate
- they were primarily designed for treatment to municipal sewage that is released to watercourses rather than being applied to land (where the nutrients and organic matter can be used effectively to promote plant growth).

SEP's are an alternative to primary ponds. A number of earthern channels allows the solids to be captured and dried for a more easier desludging

12 EFFLUENT TREATMENT SYSTEM

13 Solid By-products Storage and Treatment Areas

Carcasses, spent bedding, separated solids and pond sludge may be stored, composted or treated before use. Carcass composting is addressed in Section 15.1.

Environmental Outcome: **Solid by-products storage and treatment areas designed, constructed and managed to minimise odour nuisance and adverse impacts on surface and groundwaters.**

13.1 General Design Principles for Solid By-products Storage and Composting Areas

Solid by-products should only be stored or composted within bunded areas that are either concreted or have a design permeability of 1 X 10^{-9} m/s for a depth of 300 mm, comprising two layers each compacted to 150 mm. For guidance on achieving this design permeability, see: http://www2.dpi.qld.gov.au/environment/13764.html (Skerman 2005a). The depth to the water table from the excavated base elevation should exceed 2 m at all times. Drainage water or leachate from the solid by-products storage area should be directed into effluent treatment ponds or other collection pond. Storage areas should be located where they are unlikely to cause complaints about odour. The size of the area needed to store or treat solid by-products is highly variable, depending on the size of the piggery, the type of by-product, the type of machinery used to handle the material, the material handling method, and the dimensions of piles or windrows. Sufficient space needs to be provided for general and contingency situations. Providing a storage area that can last for six months, fits in with cropping cycles.

13.2 Storing Solid By-products

Wet solid by-products may heat up and spontaneously combust. When blended with the solids, high carbon materials, such as straw, sawdust or rice hulls, help to absorb some of the liquid, and raise the carbon to nitrogen ratio promoting composting. Regularly turning wet solids also helps to promote drying, manage heat build-up and produce a manageable product.

Drying pond sludge is a slow process. Transferring the sludge to drying bays may achieve a relatively dry material (e.g. 60% TS) more quickly. The bays can vary in complexity from simple bunded pads adjacent to an anaerobic pond, through to dedicated sludge drying bays with a sand layer over slotted pipes, or with geotextile fabric or shade cloth walls to promote drainage. For more information, see GHD (2008b).

13.3 Composting Spent Bedding, Sludge and Separated Solids

Piggery by-products can be composted into a marketable soil amendment. Composted solids are more stable, easily handled and can be spread more evenly than the raw constituents, and the nutrients are more available for uptake by plants.

While composting can proceed to a degree in a simple stockpiling situation, more intense management (turning and watering) accelerates the composting process and provides other benefits like weed seed and pathogen destruction. Turning may generate more odours and nitrogen losses compared to static pile storage, but it significantly reduces the potential for odour when the compost is spread. It is recommended that compost for retail sale should meet the Australian Standards for compost. Three Australian Standards relate to products containing composts:

- AS4454 – Composts, Soil Conditioners and Mulches (2003)
- AS3743 – Potting Mixes (Standards Australia 2002a)
- AS4419 – Soils for Landscaping and Garden Use (Standards Australia 2002b).

Following the Standards will facilitate the sustainable recycling of organic materials and guarantee that the products are consistent in quality and safe to use. Australian Standard AS 4454-2003 details the practices required to consistently produce high quality composts, soil conditioners and mulches.

By-products can be composted into a marketable product

Composting is generally undertaken using windrows. Windrows are typically 1.5-3 m high, 2-3m wide at the base and up to 1 m wide at the top. Sufficient space must be allowed for access to the piles or windrows, for turning and watering.

The rate of composting is influenced by the amount of moisture, carbon to nitrogen ratio, aeration, and temperature. Moisture content of 40-65% provides enough water for microbial breakdown, while avoiding the anaerobic conditions that cause odour. Since a carbon to nitrogen ratio of 15-40:1 optimises microbial growth, straw, sawdust or other high carbon materials often need to be added to sludge and separated solids. To keep the pile aerobic, oxygen can be supplied through the addition of bulky, high carbon agents (e.g. straw or sawdust), or by pile turning. The ideal temperature range during the active phase is 55-65°C, so that weed seeds and pathogens are destroyed while the required microbial population survives. Providing the other conditions are achieved, the pile temperature will normally rise to the optimal range.

Under optimal conditions, a composting cycle is typically twelve weeks. Active composting takes around eight weeks, and up to twice as long if management has been less intense. Active composting is completed when wetting the pile does not raise the temperature to 55-65°C. A four-week 'curing' period is required to further decompose some compounds and large particles in the compost (this is in addition to the eight week composting cycle). The finished product can then be spread on-site (see Section 14) or transported off-site for use or further refinement.

For more information, see Nicholas *et al* (2006), McGahan *et al* (2007) and the Australian Pork Limited (2007a) factsheet 'Composting for By-Product Management'.

14 Reuse Areas

Reuse areas are land areas where by-products are spread for the purpose of using the nutrients and water they contain for crop or pasture growth. The effluent and solid by-products of piggeries contain valuable plant nutrients and carbon that can be spread on farming land to improve soil fertility, structure, health and microbial activity. These nutrients should be incorporated into a crop, hay or silage production system to achieve a balance between the amount of nutrients applied and the amount removed, or to optimise soil nutrient levels as determined by soil testing. Since enclosures used for rotational outdoor piggeries are also areas where by-products are deposited, the same design principles apply.

Environmental Outcome: **Reuse areas designed and managed to benefit from the properties of by-products while avoiding soil degradation.**

14.1 Methods for Using Effluent and Solid By-products

Piggery effluent and solid by-products are typically distributed onto land by irrigation or spreading. In outdoor rotational piggeries, the nutrients are spread by pigs depositing their manure, and the by-products can be used both on-farm and off-farm. In both cases, the piggery owner has a duty of care to ensure the by-products are used sustainably. In some states, the piggery operator is legally responsible for the sustainable off-site use of piggery by-products. Hence, it is recommended that piggery operators have a written agreement with any off-site users, defining the type and quantity of by-products involved, and estimating the nutrient content of the by-products.

14.1.1 Selecting a Suitable By-products Reuse Area

Ideally, a by-products reuse area should:

- be suitable for pasture or crop production
- comprise well-structured, non-rocky, non-saline and non-sodic loam to medium clay soil
- not be located adjacent to a watercourse, waterway, wetland, channel, drain etc.
- not be prone to water logging
- not flood more than once every five years
- have slopes that promote infiltration, rather than runoff and erosion
- be located at least 2 m above the shallowest water table
- be well separated from neighbouring residences and other sensitive areas.

Areas that do not have these properties may require better design and more intense management to minimise the risk of environmental impacts.

14.1.2 Land Area Needed for By-Products Reuse

Piggery by-products are rich in nutrients. To best use these nutrients, it is necessary to determine or estimate the:

- quantity of nutrients and salts in effluent and solid by-products (refer to sections 9.2 and 14.1.3)
- expected uptake of nutrients by harvest of plants growing on reuse areas
- nutrient status of the soil
- expected nutrient (nitrogen) losses from volatilisation.

14.1.3 Concentration of Nutrients and Salts in Piggery By-products

Table 14.1 and Table 14.2 show typical data for the composition of piggery effluent and sludge respectively, from conventional piggeries. Data in Table 14.1 are measured from the final pond, which would most often be used for drawing effluent for irrigation. Table 14.3 provides data for spent bedding from deep litter piggeries. The wide variation in results reflects the range of design, management, diets, water use and climate. Thus 'typical' or 'average' composition data from pond effluent (irrigation water) and pond sludge cannot be provided. Testing effluent and pond sludge will provide better data for determining appropriate reuse rates for a particular farm.

TABLE 14.1 Characteristics of piggery pond irrigation effluent

Element	Units	Effluent at work[a]	DEEDI data[b]	
			average	range
Dry Matter	mg/L	3623	7900	1100-44300
Volatile Solids	mg/L	1809	1640	480-5290
pH		8.0	8.0	7.0-8.7
Total Nitrogen or {TKN}	mg/L	{384}	584	158-955
Ammonium Nitrogen	mg/L	249	144	25-243
Total Phosphorus	mg/L	44	69.7	19.3-175.1
Ortho-Phosphorus	mg/L	28.5	16.3	2.4 – 77.9
Potassium	mg/L	-	491	128-784
Sulphur	mg/L	22 (9 – 50)	-	-
Sulphate	mg/L	26	47.6	13.3-87.2
Copper	mg/L	-	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
Conductivity	dS/m	-	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.

TABLE 14.2 Characteristics of in situ piggery pond sludge

Element	Effluent at Work[a]	DEEDI data[b]	
		average	range
Dry matter	-	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	-	-
Carbon	-	28.1%	22.5-37.1%
Total Nitrogen or {TKN}	{2617}mg/L	3.41%	2.84-4.02%
Ammonium Nitrogen	1156 mg/L	2582 mg/kg	1472-4422 mg/kg
Total Phosphorus	1696 mg/L	4.69%	2.83-5.9%
Ortho-Phosphorus	1082 mg/L	-	-
Potassium	-	0.75%	0.27-1.33%
Sulphur	-	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	-	-
Conductivity	8.5 dS/m	-	

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.

14 REUSE AREAS

TABLE 14.3 **Nutrient content of spent bedding from deep litter piggeries**

	Unit	Straw	Rice Hulls	Sawdust
Moisture	% wb	41.6 (18 - 64)	36 (21 - 53)	40.8 (21 - 50)
pH		6.8 (5.7 - 8.5)	7.1 (7 - 7.3)	6.3 (6.2 - 6.3)
Total Nitrogen or {TKN}	% db	0.8 (0.2 - 1.3)	0.7 (0.1 - 1.6)	0.9 (0.6 - 1.3)
Ammonium Nitrogen	% db	0.5 (0 - 1.2)	0.3 (0.1 - 0.5)	0.6 (0.4 - 1)
Total Phosphorus	% db	1.1 (0.2 - 2.5)	0.9 (0.6 - 1.3)	1 (0.4 - 1.3)
Ortho-Phosphorus	% db	0.4 (0.2 - 0.6)	0.4 (0.3 - 0.6)	0.4 (0.2 - 0.5)
Potassium	% db	1.8 (0.6 - 2.8)	1.8 (1.2 - 2.1)	1.8 (1.6 - 1.9)
Sulphur	% db	0.4 (0.1 - 0.7)	0.4 (0.3 - 0.5)	0.5 (0.4 - 0.5)
Copper	% db	0 (0 - 0.1)	0 (0 - 0)	0 (0 - 0)
Iron	% db	1.3 (0.1 - 3.2)	1 (0.7 - 1.6)	1.1 (0.5 - 1.6)
Manganese	% db	0.1 (0 - 0.8)	0.2 (0 - 0.8)	0.3 (0 - 0.8)
Zinc	% db	0.2 (0 - 0.4)	0.1 (0 - 0.3)	0.1 (0.1 - 0.2)
Calcium	% db	1.9 (0.4 - 3.1)	1.4 (1 - 2.1)	2.4 (2.1 - 2.7)
Magnesium	% db	0.7 (0 - 1.8)	0.4 (0 - 0.6)	0.4 (0 - 0.7)
Sodium	% db	0.4 (0.1 - 0.7)	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)
Conductivity	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
Source: Black (2000); and Nicholas et al 2006.

For an operating piggery, the quantity of by-products and the concentration of nutrients can be used to estimate the mass of any element. This is usually the best method to determine rates of applying the by-product, provided that representative samples are collected, and the mass or volume applied is accurately known.

A method for estimating the nutrient load using mass balance principles is provided in Section 9.2. This method is the most suitable for proposed developments.

14.1.4 Application Rates

The mass of nutrients applied by irrigation or spreading depends on the application rate and the nutrient content of the by-products. It is important to periodically analyse by-products to enable a good estimate of the mass of nutrients applied. The results should be matched to the expected nutrient uptake by crops, plus nitrogen volatilisation losses and phosphorus storage.

Nitrogen volatilisation rates for irrigation depend on the application method, the proportion of ammonium nitrogen, and whether irrigation occurs during the day or at night. For effluent irrigation, spray methods may allow 20% of the nitrogen to be lost by volatilisation. Less nitrogen (approximately 10%) is lost when surface flow methods are used. Nitrogen volatilisation rates when solids are applied to land depend on the amount of pre-treatment (e.g. composting) and whether the solids are immediately incorporated.

From an environmental perspective, the high nutrient concentration of piggery effluent, rather than the hydraulic load, usually determines the irrigation rate.

Specialist consultants and agronomists can assist in determining appropriate application rates based on soil properties, plant requirements and by-product nutrient concentrations.

14.1.5 Expected Nutrient Removal by Plant Harvest

The type of crop grown on the reuse area determines the amount of nutrients removed through harvest, depending on the crop's dry matter yield and nutrient content. Table 14.4 shows typical dry matter nutrient contents and expected yield ranges for a variety of pasture, silage, hay, grain and horticultural crops. The yields presented are for typical cropping soils.

TABLE 14.4 Nutrient content and anticipated dry matter yield of various crops

Crop	Dry matter nutrient content (kg/t)			Normal yield range[a] (dry matter t/ha)	Normal Nutrient Removal Range (kg/ha)		
	Nitrogen	Phosphorus	Potassium		Nitrogen	Phosphorus	Potassium
Grazed Pasture[b]	20	3	15		7.1 - 19.0	0.9 – 2.2	0.1 – 0.6
Dry Land Pasture (cut)	20	3	15	1 – 4	20 - 80	3 - 12	15 – 60
Irrigated Pasture (cut)	20	3	15	8 – 20	160 - 400	24 - 60	120 - 300
Lucerne Hay (cut)	31	3	25	5 - 15	155 - 465	15 - 45	125 - 375
Maize Silage	22	3	20	10 - 25	220 - 550	30 - 75	200 - 500
Forage Sorghum	22	3	24	10 - 20	220 - 440	30 - 60	240 - 480
Winter Cereal Hay	20	3	16	10 - 20	200 - 400	30 - 60	160 - 320

TABLE 14.4 (continued)

Crop	Dry matter nutrient content (kg/t)			Normal yield range[a] (dry matter t/ha)	Normal Nutrient Removal Range (kg/ha)		
	Nitrogen	Phosphorus	Potassium		Nitrogen	Phosphorus	Potassium
Seed Barley	19	3	4	2 - 5	38 - 95	6 – 15	8 - 20
Seed Wheat	19	4	5	2 - 5	38 - 95	8 - 20	10 - 25
Triticale	19	4	6	1.5 - 3	29 - 57	6 - 12	9 - 18
Rice	14	3	4	4 - 8	56 - 112	12 - 24	16 - 32
Seed Oats	15	3	4	1 - 5	15 - 75	3 - 15	4 - 20
Grain Sorghum	20	3	3	2 - 8	40 - 160	6 - 24	6 - 24
Grain Maize	20	3	4	2 - 8	40 - 160	6 - 24	8 - 32
Chickpea	40	4	4	0.5 - 2	20 - 80	2 - 8	2 - 8
Cowpea	30	4	20	0.5 - 2	15 - 60	2 - 8	10 - 40
Faba Bean	40	4	12	1 - 3	40 - 120	4 - 12	12 - 36
Lupins	45	3	8	0.5 - 2	22.5 - 90	1.5 - 6	4 - 16
Navy Bean	40	6	12	0.5 - 2	20 - 80	3 - 12	6 - 24
Pigeon Peas	26	3	9	0.5 - 2	13 - 52	1.5 - 6	4.5 - 18
Cotton	20	4	8	2 - 5	40 - 100	8 - 20	16 - 40

[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.

Sources: Reuter and Robinson (1997) and National Research Council (1984).

Grazed 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 ten times more area than systems using a removal process (e.g. cut and cart).

14.1.6 Calculating Sustainable Application Rates

It is good agronomic practice to know the nutrient status of reuse areas. It is good environmental practice to know both the application rates and the nutrient removal and storage rates through crop harvest, soil phosphorus storage, nitrogen volatilisation and other acceptable losses. This information is essential to manage the area in a productive and sustainable manner.

Mass balance is one recommended method for deciding the appropriate by-products application rate. A balance is needed between nutrient additions (by effluent, solid by-products and/or inorganic fertiliser applications) and removals (by crop harvest and acceptable losses - nitrogen volatilisation and salt leaching - or soil storage where soils are nutrient deficient). Soil and by-products testing can also be used to determine sustainable reuse rates.

The mass balance could be a desktop study (e.g. PigBal, MEDLI or Wastload) or could use physical measurements coupled with a desk top study. For example, the expected nutrient removal by cropping, and the analysis of effluent or solids would determine application rates.

In simple terms, a system is sustainable if nutrient removal by crop harvest or grazing matches the addition of nutrients. Other factors, such as expected losses and soil storage, may be considered to modify this definition for use of piggery by-products. A suggested mass balance equation for reuse areas is:

crop uptake + expected losses + soil storage = amount applied

To solve this equation, it is necessary to quantify expected losses and the capacity for phosphorus storage, and consider the management practices and the sites natural resources.

Expected losses may include nitrogen volatilisation during and after application, and leaching – provided it does not exceed an acceptable level or degrade the groundwater source.

Soils have a varying capacity to adsorb and store phosphorus, from large amounts in ferosols (kraznozems) to very small amounts in sandy soils. If using phosphorus storage, consider it to be a temporary measure along with good agronomic practices, such as spreading solids every few years, and building up soil nutrient concentrations. Soils have a finite capacity to bind phosphorus. Bound phosphorus will eventually be released and become available for leaching or movement into runoff if it not taken up and removed in plant harvests. There are a number of methods to find the storage capacity of soils, including one in Redding (2003).

If phosphorus is applied in amounts exceeding removal rates, the following criteria apply:

- the soils must be able to store phosphorus via methods such as those described in Redding (2003)
- the soils should be used for crop and pasture production after application of by-products, to ensure that the applied phosphorus is removed before leaching or movement into runoff occurs
- the soil profile should have a depth of at least 0.5 m.

For further information on land application of effluent phosphorus, see Redding and Phillips (2005).

Because piggery by-products are not balanced fertilisers, it is not possible to match the quantity of nutrients applied to the quantity removed for all elements. Hence, the by-products application rate will generally be controlled by the nutrient that requires the lowest application rate to achieve a match with nutrient removal. Nutrient availability also needs considered. Not all the nutrients in effluent and solids are available immediately for plant uptake and some may not become available for several years. For this reason, there may be merit in applying a mass of phosphorus several times greater than plant uptake every few years, rather than annually applying the amount required for plant uptake (e.g. applying three times the amount of phosphorus required every three years). Extra caution is needed to ensure by-products are applied at times when there is a low risk of runoff. However, the more mobile nitrogen should not be applied in excess of the annual requirement.

It is also important to ensure there will be enough available nutrients to meet crop demand. It may be necessary to add nutrients from a different source (e.g. fertiliser or other organic sources) to meet plant requirements for all nutrients. From an environmental sustainability perspective, organic fertilisers may be superior to inorganic fertilisers, because not all of the nutrients are in a readily available form and at their most mobile (e.g. nitrate-nitrogen) immediately after application. They become available as the plant requires them and are therefore less prone to loss from the system. For further information on calculating appropriate effluent application rates to control phosphorus availability, see Redding *et al* (2003). For further information on management of potassium in irrigated piggery effluent, see Smiles and Smith (2003).

Extensive grazing does not effectively remove nutrients. If this system is used, nutrients should be applied only at levels that improve soil's nutrient status. Otherwise, very low application rates should be used.

Further guidance on application rates for spent bedding is provided in Black (2000) and Nicholas *et al* (2006). Further information on optimum application rates for pond sludge is provided in Rodd *et al* (2007). Various nutrient balance calculators for piggeries are assessed in Hogan and Bedros (2007).

14.2 Outdoor Rotational Piggeries

Dry sows, lactating sows, grower pigs and finisher pigs in outdoor rotational units spread their manure by urinating and defecating about the paddocks. Because they may favour particular areas for dunging, nutrients may not be evenly spread. This poses an increased risk of nutrient overloading, leaching or runoff. A sustainable rate of spreading nutrients depends on maintaining an adequate stocking density and paddock rotation system. It is also important to minimise erosion.

Section 9.2.2 provides the approximate mass of nitrogen and phosphorus in the manure of different classes of pigs. Based on the generic data given in Table 9.1, the annual mass of nitrogen, phosphorus and potassium added by dry sows is likely to be about 13.9 kg/pig, 5.2 kg/pig and 3.7 kg/pig respectively.

The appropriate nitrogen, phosphorus and potassium application rates depend on the land use of the area, the rotational pattern (e.g. two years of pigs, two years of plant harvest) and the phosphorus sorption of the soil. For any given outdoor rotational piggery, the appropriate nitrogen, phosphorous and potassium rates need to be determined. These are then used to determine stocking density corresponding to the applicable nitrogen phosphorus, and potassium application rates. The lowest of the three calculated stocking densities should be used.

14.3 Benefits of Reusing By-products

Benefits of responsible by-products use include:

- increased soil organic matter
- enhanced soil structure
- improved rainfall infiltration
- improved water-holding capacity of soil
- enhanced soil fertility through increased cation exchange, capacity and nutrient retention
- reduced erosion rates
- increased plant yields
- reduced organic fertiliser costs.

14.4 Potential Impacts of Poor By-product Reuse Practices

Poor reuse of by-products can have an adverse effect on the air, soil, groundwater and surface water.

In the air, potential impacts are:

- odour nuisance
- dust generation.

To minimise the risk of these impacts, avoid spray irrigating under still conditions or at night. High-pressure spray irrigators are unsuitable for effluent irrigation because they produce small droplets. The resulting aerosol drift can convey odour over long distances. Avoid spreading very dry solids, particularly under windy conditions.

In soils, potential impacts are:

- sodicity and increased soil dispersion, which is associated with structural decline, increased erosion risk, reduced water infiltration rate, reduced workability and reduced soil permeability
- increased soil salinity, which can affect which crops may be grown or crop yields
- waterlogging, if very high hydraulic loads are used
- elevated nitrate levels, which can cause toxic levels of nitrate in forage or reduced forage palatability
- high phosphorus concentration in runoff once the surface soil becomes saturated with phosphorus.

Potential impacts to groundwater include:

- elevated nitrogen or phosphorus levels
- where nutrient leaches through the soil before it can be used by plants
- increased salinity.

Potential impacts to surface water include:

- algal blooms triggered by eutrophication, which can result from nutrients entering stormwater runoff or erosion of nutrient-rich soil to streams
- nutrients entering surface water in situations where contaminated groundwater surfaces in the vicinity of streams.

Potential impacts to animal health include:

- metabolic disorders (e.g. hypomagnesia) resulting from cation imbalances in the soil
- pathogen transfer if cattle graze pastures immediately after spreading.

These potential adverse impacts highlight the importance of careful use of by-products.

14.5 Recommended By-product Reuse Practices

Good by-products reuse practices minimise nutrient exports from reuse areas. The nutrients in by-products need spreading at productive and sustainable rates. Application methods must promote even and controlled distribution. By-products must be spread at suitable times. Regular monitoring of the nutrient and pH levels in the soils of reuse areas is essential in determining if reuse rates need to be adjusted.

Weather is an important factor in reusing by-products. By considering the prevailing wind direction before spreading, odour impact can be reduced. Only irrigating effluent when the soil is unsaturated, and it is not raining or forecast to rain with 24 hours, reduces the risk of runoff during or soon after application. High-pressure spray guns are unsuitable for effluent irrigation, as they very finely disperse the effluent, allowing significantly greater drift than low-pressure systems.

Irrigation should not cause water logging or excess drainage below the plant root zone. Water balance modelling can be used to decide the appropriate short-term irrigation rate. If the nutrients in effluent are applied at sustainable rates (i.e. using smaller amounts of effluent frequently rather than using large volumes occasionally), waterlogging is not a problem. This method also helps to maximise nutrient uptake and minimise loss from leaching.

Where possible, by-products should be applied just before sowing, or when plants are actively growing, to maximise nutrient uptake and to minimise nutrient losses by leaching. By-products incorporation into the soil may reduce nitrogen losses through volatilisation. A higher standard of management may be needed to prevent the transport of nutrients from solid by-products spread on bare soil. Redding (2001) provides further information on determining effluent application rates to better manage phosphorus availability.

Surface irrigation methods only suit sites with an even grade, and must be designed and equipped to achieve uniform effluent applications. This often requires measures such as laser grading and the provision of properly designed flow control systems. These methods are unsuitable for sandy or sandy-loam soils, since effluent passes through these soils too quickly. They are also unsuitable for duplex soils with sandy or sandy-loam topsoil, since effluent passes through this layer more quickly than through the heavier subsoil, and then moves laterally over the subsoil layer. A higher standard of management will be needed if effluent is irrigated on steep slopes (>10%) or highly erodible land.

14.6 Secondary Control Measures and Reducing Loss of Nutrients

Sound spreading or irrigation practices minimise nutrient exports from reuse areas. These practices include using appropriate application rates and systems, and applying by-products at appropriate times (e.g. when plants are actively growing and taking up nutrients). Secondary control measures further reduce nutrient loss when the above practices are insufficient, and may include:

- putting VFSs downhill of the reuse areas
- putting terminal ponds downhill of the reuse areas
- installing contour banks on sloping land
- maintaining continuous ground cover
- incorporating solid by-products into the soil.

These measures effectively reduce soil erosion and filter nutrients from runoff. However, control measures such as VFSs and terminal ponds should not be used as a 'quick-fix' for poor practices. They provide secondary environmental protection to complement sustainable use practices, based on mass balance principles and/or monitoring.

14.6.1 Vegetative Filter Strips

VFSs are strips of dense grass between reuse areas and protected areas. Section 6.1 provides design details for these.

14.6.2 Terminal Ponds

Terminal ponds located at the bottom of reuse areas should catch the first 12 mm of runoff from a paddock, which may have a higher nutrient concentration than runoff received later in a large storm. The principle is to trap a significant proportion of the dissolved and suspended nutrients in the runoff from the by-products use area. The stored runoff can then be re-irrigated. During storms producing greater than 12 mm of runoff, terminal ponds overflow through a properly designed spillway. However, they can still reduce nutrient export by slowing the flow velocity to enable some settling of suspended soil and organic matter particles. It is important to either irrigate or recycle runoff collected in terminal ponds back to the irrigation storage as soon as possible, to provide storage capacity for the collection of subsequent runoff.

In the past, terminal ponds were used as to protect surface waters as a substitute for sound methods of by-product use. Except for flood irrigation systems (which require a terminal pond as part of good design), this does not reflect best management practice, as it only provides secondary environmental protection.

14.6.3 Graded Banks

Banks constructed along height contours on sloping areas reduce the velocity of runoff and hence erosion. They capture and redirect runoff from smaller areas of a paddock, preventing runoff from concentrating into larger streams that erode large volumes of soil. While these may effectively prevent the loss of nutrients attached to soil, they do not prevent the loss of nutrients dissolved in runoff.

14.6.4 Groundcover

Maintaining continuous groundcover, either through a pasture based system or through conservation tillage practices, promotes infiltration of rainfall and reduces runoff, water velocity and soil movement. Again, this reduces nutrient removal due to soil erosion, but may not remove some dissolved nutrients.

14.6.5 Incorporation of Solid By-products

Incorporating solid by-products reduces the nutrient concentration at the soil surface. This may reduce nutrient losses by erosion or via stormwater runoff.

15 Carcass Management

From an environmental perspective, rendering and composting are the preferred methods for carcass disposal (including disposal of stillborn piglets and afterbirth). Suitable alternatives may include incineration and burial. Irrespective of the method chosen, dead pigs should be immediately removed from the access of other pigs, and disposed of within 24 hours of death.

Poor carcass management practices may contaminate groundwater and surface water, cause odour, spread infectious diseases, and attract vermin. Further details on all carcass management methods are provided in Ausvetplan (2007).

***Environmental Outcome:* Carcass management practices that prevent groundwater and surface water contamination, odour nuisance, spread of infectious diseases and vermin breeding.**

15.1 Carcass Composting

Well-managed carcass composting is an environmentally acceptable method, and has the advantage of producing a soil amendment.

Carcass composting should be undertaken within bunded areas with a base with a design permeability of 1×10^{-9} m/s for a depth of 300 mm comprising two 150 mm deep layers. For guidance and technical direction regarding earth pad preparation requirements see: http://www2.dpi.qld.gov.au/environment/13764.html (Skerman 2005a). The depth to the water table from base ground level should exceed 2 m at all times. Any leachate or stormwater runoff caught within the composting area should be directed into the effluent treatment ponds or other collection ponds.

Carcasses are generally composted in a series of bays, although windrows can be used. The bays can be excavated into the ground (similar to silage bunks), or formed using large hay bales on a prepared pad.

Sawdust is generally the best medium for composting carcasses, as it produces the ideal carbon to nitrogen ratio. However, used litter is also suitable. Before adding carcasses, at least 300 mm of sawdust (or alternative carbon source) should be spread over base of the bay to ensure that the first layer of carcasses is surrounded by high-carbon material and to absorb leachate. Carcasses should then be layered over the floor of the bay, with 300 mm of sawdust covering each layer. Good sawdust coverage assists composting by adding a carbon source, and is essential for controlling odours, avoiding attracting pest insects and deterring feral animals from disturbing the pile. Large carcasses need slitting before placing them in the compost pile to reduce the gasses that cause bloating, thus preventing bloated carcasses rising out of the pit. When a carcass bay is full, a new one should be started. The carcasses in the full bay are then allowed to decompose for around three months.

When the compost is used as a fertiliser, it should be spread evenly onto land at environmentally sustainable rates. To minimise the risk of grazing livestock contracting botulism, salmonellosis or mastitis, they should be excluded from these areas for at least three weeks after the compost is spread. Providing the compost is used sensibly, there is an insignificant risk of BSE transmission to grazing stock in Australia.

For further information, see McGahan *et al* (2007) and the Australian Pork Limited (2007b) factsheet 'Composting for By-Product Management – Carcass Composting for Mortality Management'.

15.2 Rendering

Rendering is an excellent carcasses management method because there is little risk of adverse environmental impacts. Rendered carcasses can also provide saleable meat and bone meal. However, this method is only economically viable if there is a nearby rendering plant willing to receive the carcasses.

A bunded area with a low permeability floor must be provided for storing carcasses before dispatch. The floor may be concrete or soil compacted for a design permeability of $1X10^{-9}$ m/s for a minimum depth of 300 mm, comprising two layers each 150 mm thick.

Guidance regarding earth pad preparation requirements can be obtained from: http://www2.dpi.qld.gov.au/environment/13764.html (Skerman 2005a). This area needs to be well separated from live pigs.

An agreement with the receiving company is needed to ensure regular (preferably daily) receipt of carcasses. Similarly, a contingency plan is needed in the event of a failure to dispatch carcasses.

15.3 Burial

Burial is a common method of disposing carcasses. However, it should only be used where rendering or composting is not feasible. It is not the preferred method because:

- the carcasses decompose slowly and need covering to avoid odour problems and scavenging by feral animals
- burial pits fill quickly and continually need replacement
- nutrients and bacteria can leach into and contaminate groundwater, particularly if there is shallow groundwater and inappropriate sealing of the bottom of the pits
- stormwater runoff from pits can contaminate surface water
- land can become contaminated.

To avoid these problems:

- large carcasses should be split to minimise bloating
- the pit bases should be at least 2 m above the water table at all times
- pits should be situated on low permeability soils and / or low risk sites
- carcasses need to be well covered with soil, or other suitable material, each day to avoid scavenging by feral animals and to prevent odour

- further clay should be compacted over filled pits
- earth should be mounded over filled pits to promote shedding of stormwater. The mounds should be grassed over, but trees should not be planted at the site as the roots allow water to move through the pit.

An alternative to an earthen pit is an enclosed burial pit, constructed from concrete or high-density polyethylene or fibreglass and fitted with a watertight lid.

Some state government agencies only allow burial under specific conditions, for example, disease outbreaks or mass mortalities.

15.4 Burning or Incineration

While biologically the safest carcass management method, incineration is generally not ideal because:

- it needs to be performed efficiently and effectively to ensure that it is complete, and to avoid complaints about odour and particulates (smoke)
- it is not energy efficient and generates greenhouse gases
- it is expensive
- regulations of some state and territory government departments responsible for environmental protection and local council by-laws do not permit it.

Generally, the requirements are similar to those for clinical waste. The incinerators are either complex multi-chamber units or pyrolysis process types. They typically have a final chamber that operates at 1000°C with a residence time of at least one second to incinerate the odorous gases that may result from the ignition of the carcass. The fuel and operating practices needed to ensure that combustion does not result in offensive odour, mean that this is a specialised activity.

Burning of carcasses in open fires is unacceptable, as it creates smoke and odour and is unlikely to maintain a sufficiently high temperature consistently. It is also a biosecurity hazard due to the potential for thermal updraughts to disperse biological matter. Correct burning or incineration is rarely feasible on-farm.

15.5 Mass Carcass Disposal

Effective responses to emergency disease outbreaks require effective planning. The options available for disposal of mass mortalities depend on the cause of death and resource issues, including soil type and depth to groundwater. However, all piggery operators should identify a disposal site and have a contingency plan for managing the high death rates that may occur as part of a disease outbreak. State government veterinary officers have the main responsibility and resources to combat an exotic disease incursion or endemic disease outbreak. They should be contacted immediately if a disease outbreak is suspected. The relevant state government department should be consulted regarding selection of a disposal method and site. AUSVETPLAN (2007) provides very useful information for managing disposal of a large number of carcasses.

If mass carcass disposal is needed, burial is often the preferred method as it is quick, cheap, relatively easily organised and environmentally clean, if properly done. If burial is to be used, a suitable site is needed. It should be readily accessible, be well separated from sensitive areas (watercourses, bores, neighbours and public land) and be of a soil type that does not drain readily. The pits should be as deep as possible, while ensuring that the base is at least 2 m above the water table. For pit stability, the pit sides should be battered (angled) outwards from the base. The pit width should not exceed the width of the equipment that will be used to fill the pit, since it is difficult to evenly distribute carcasses in wider pits. The carcasses must be well covered with soil, with further soil mounded over the pit which:

- promotes water shedding
- helps to prevent carcasses rising out of the pit as they bloat
- filters odours
- absorbs fluids released through decomposition
- reduces the likelihood of feral animals exposing carcasses.

The burial area should be grassed over after filling. Trees should not be planted, as the roots allow for movement of water (and nutrients) through the pit. Ongoing monitoring of mass burial sites may be needed.

For some diseases, incineration may be the preferred method. The relevant agriculture or environment department may be able to supply a suitable mobile incinerator.

Composting is an option for some diseases, or if the deaths result from environmental conditions (e.g. heat stress). Composting of mass carcasses uses the same principles as described in section 15.1, with long windrows being used instead of small bays. Windrows should be 1-2 m wide at the base and contain only one layer of pigs. All carcasses need to be covered with a minimum of 300 mm of sawdust or alternate carbon source for controlling odour emissions and deterring feral animals. When the temperature in the pile drops (after about 8-16 weeks) the windrow should be turned and recapped.

In some instance, disposal to land fill may be mandated by a state veterinary officer.

16 Environmental Risk Assessment

The purpose of an environmental risk assessment is to identify any actual, or likely impacts that a piggery or proposed piggery development may pose to the environment. This provides the basis for reducing impacts (or risks of impacts) through design, management or monitoring.

Environmental Outcome: **Identification of the actual or potential environmental impacts that a piggery or piggery development may pose to the environment.**

16.1 The Environmental Risk Assessment Process

An environmental risk assessment for a piggery should consider the vulnerability of site resources, the nutrient mass balance of the whole farm, and the design and management of the piggery. The assessment should then use sustainability indicators to decide if adverse environmental impacts are likely. The outcomes of the process are risk appraisals for:

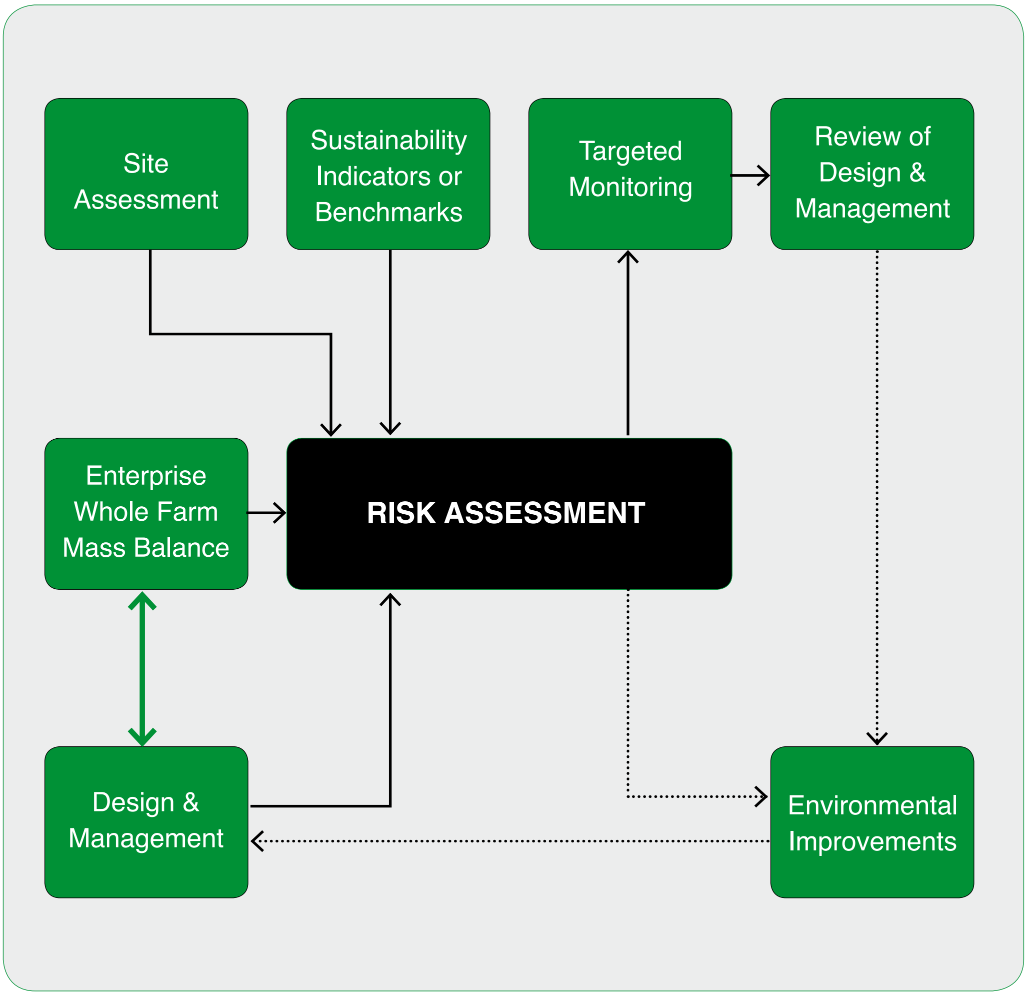
- soils of by-product reuse areas
- groundwater quality and availability
- surface water quality and availability
- community amenity
- targeted environmental monitoring to measure sustainability
- plans for any required design or management improvements.

The stages in an environmental risk assessment are summarised in Figure 16.1. Training in piggery environmental risk assessment is provided through the APL 'Environmental Management Plans for Piggeries' workshop. An example risk assessment process for piggeries is provided in Appendix B. Other methods are also possible.

The risk that a piggery poses to the environment depends upon the vulnerability of the natural resources or amenity, and on the standard of design or management of the operation. For instance, good design and management can protect a vulnerable resource, but with lower design and management standards, an environmental impact is more likely. A high standard of management is no substitute for poor site selection, and serious implications can arise if high management standards are not maintained. Hence, if there are too many high-risk items for a piggery development, the site may be unsuitable.

The environmental risk assessment process included in this section provides a tool for identifying environment areas where changes in the design and management of existing and proposed piggeries may be required. It is a subjective self-assessment tool only, and should never be used as a regulatory instrument.

FIGURE 16.1 **Stages in environmental risk assessment and risk management**



16.2 Vulnerability Ratings - Natural Resources

The first step in an environmental risk assessment is to rate the vulnerability of each of the major natural resources or amenities associated with the piggery, including:

- soils of reuse areas (if reusing by-products on-farm)
- groundwater quality and availability
- surface water quality and availability
- community amenity.

Information to assist in deciding vulnerability of resources and amenity is supplied in Appendix B. Since it is not possible to represent all situations that will occur on all farms, some discretion should be used when evaluating the site vulnerability using these tables. Documenting the reasons for the vulnerability ratings assigned, enables more ready identification of required environmental improvement, or monitoring, later in the risk assessment process.

16.3 Risk Ratings - Piggery Design and Operation

The second step of the environmental risk assessment is to rate the risk of each of the major design and operation features of the piggery, including:

- pig housing
- nutrient content of manure
- the effluent collection system
- the solids separation system
- the effluent treatment system
- solid by-products storage / treatment
- carcass management
- design and management of reuse areas
- chemical storage and use.

Not all of the factors will be applicable to all enterprises. For example, not all piggeries will have a solids separation system. Where factors are irrelevant for a given situation, they do not require evaluation.

To assist in deciding the risk, guidance information for rating design and operational performance is supplied in Appendix B. Since it is not possible to represent all situations that will occur on all farms, it is necessary to use some discretion when evaluating the risk using these tables. Documenting the reasons for the risk ratings selected, enables more ready identification of required environmental improvement, or monitoring, later in the risk assessment process.

16.4 Overall Risk Rating

The third step in evaluating the likelihood of an environmental impact is assessment of the combined effect of resource vulnerability and the design and operation risk. The two- dimensional matrix supplied in Appendix B can be used for this step.

The overall risk can be used to help decide the action to be taken. A low overall rating would not trigger any action. A medium overall rating may trigger some action. A high overall rating would trigger some action. Actions may take the form of environmental improvements or monitoring. It is necessary to examine the design and / or operation of the piggery to decide the most appropriate action. Examining the reasons for vulnerability and risk ratings listed in the applicable tables in Appendix B can assist in this matter. These National Guidelines specify appropriate design and management options. Section 17 provides recommendations for risk-based monitoring.

17 Monitoring and Assessment of Sustainability

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 impacts.

It is extremely difficult to develop tools for determining and demonstrating sustainability, and indicators of sustainability, that cover all situations. The tools for determining sustainability will probably overstate the likely environmental risk in some cases. Consequently, where a significant level of environmental risk or impact is identified, it is critical to confirm that this result is accurate through further investigation or action.

Environmental Outcome: **Identification of environmental impacts through ongoing monitoring, evaluation of results and assessment of the effectiveness of management strategies.**

17.1 Complaints

17.1.1 Community Liaison

Open communication lines between neighbours, piggery operators and regulators can help to confirm complaints, and then identify and fix problems to minimise the impact of a piggery on community amenity. Establishing and maintaining lines of communication from the beginning is better than dealing with complaints as they occur. Good community liaison may include:

- informing neighbours in advance of any events or problems that may cause an unavoidable increase in odour, dust or noise, including practices to mitigate the problem and the expected duration of the problem

Regular monitoring can assist in maximising productivity whilst minimising impacts on the surrounding community and environment

- participation and cooperation in dispute resolution
- gathering relevant evidence, and identifying and implementing strategies to remedy the problem
- informing the complainant of the outcome of any investigations and any actions taken to avoid future associated problems, and seeking feedback to ascertain if the problem has been resolved.

17.1.2 Handling Complaints

The number 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. Many community amenity impacts are closely related to weather conditions, so consider daily weather monitoring if complaints are ongoing. It can also help in assessing the validity of 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.

17.1.3 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 C.

17.2 Soils

A risk assessment can be used to determine the likelihood of adverse impacts to soils. 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 monitored at least every three years. However, nitrate-nitrogen levels should be monitored annually, as nitrogen in this form moves quickly through the soil.

Where there is a medium risk of soil impacts, and at least three years of monitoring data shows the system is sustainable, it is suggested that soils from reuse areas should be sampled and analysed at least every two years, with annual nitrate-nitrogen monitoring. Effluent and solids utilised on-site should be analysed annually.

Where there is a high risk of soil impacts, annual soil monitoring is imperative. Effluent and solids utilised on-site should also be analysed annually.

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 recommended soil monitoring parameters are given in Table 17.1. Analysis results should be compared with the sustainability indicator limits given in section 17.5.4. Where soil analysis results exceed these limits, further investigation is triggered to identify whether by-products reuse is sustainable. Table 17.2 and 17.3 provide the recommended monitoring parameters for effluent and solids, respectively.

TABLE 17.1 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 $EC_{1:5}$ and convert to EC_{se})$^{+}$	0-0.1 m 0.3-0.6 m OR base of root zone	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
Available phosphorus (Colwell or Olsen or Bray or BSES), lactate, calcium chloride or other	0-0.1 m 0.3-0.6 m OR base of root zone[b]	Measure of phosphorus available for plant uptake
Phosphorus sorption capacity or phosphorus sorption index	0 –0.6 m OR 0 – base of root zone[c]	Measure of the soils ability to safely store phosphorus - essential if applying more than plant uptake
Potassium	0-0.1 m 0.3-0.6 m OR base of root zone	Measure of potassium available for plant uptake
Organic carbon	0-0.1 m	Influences soil stability, and consequently, soil erosion
Exchangeable cations and CEC (Calcium, sodium, potassium, magnesium).	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

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

[a] EC_{se} levels in the top soil layers are not intended to be a direct sustainability indicator, but will provide useful agronomic information and provide a guide to soil salt movements.

[b] Only check available P levels annually at 0.3-0.6 m (or base of root zone) if a sandy soil, otherwise every three years.

[c] Measurement of P sorption capacity to 0.6 m (or base of root zone) is desirable before use and every three years after initial application.

Notes: 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.

TABLE 17.2 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	Measure of effluent salinity
SAR	Measure of effluent sodicity

TKN = total Kjeldahl nitrogen; SAR = sodium absorption ratio

TABLE 17.3 Recommended solid by-products 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

TKN = total Kjeldahl nitrogen

Sustainability can be demonstrated through a mass balance, including nutrient content of by-products from the piggery, and nutrient removal through harvest of plant or animal products from the reuse areas. Inputs should be conservative to provide a margin of error. The mass of nutrients added to each reuse area can be calculated by multiplying the measured quantity of effluent or solids applied by its nutrient content. Conversely, the mass of nutrients removed is calculated by multiplying the measured yield of crop or animal products (e.g. weight gain, milk, wool) by the nutrient content of the product grown. For the system to be sustainable, the mass of nutrients removed from each area should equal that added to each area, plus sustainable phosphorus storage. Accepted design tools, such as PigBal, MEDLI or Wastload can be used to determine a mass balance.

Alternatively, sustainability can be demonstrated through physical measurements of nutrient levels in the soil.

17.3 Surface Water

Surface water monitoring is rarely relevant to piggeries because they are not a direct discharge industry, and because by-products are generally applied to land as part of a farming system input. However, in specific high-risk situations, a risk assessment may identify the need for surface water monitoring. This may involve sampling and analysis of watercourses and other water bodies or effluent spills, irrigation runoff or stormwater runoff. This type of monitoring requires sophisticated equipment and trained operators to achieve meaningful results.

Operators should protect surface waters through good design and management. Secondary measures such as buffers, VFSs or terminal ponds can provide additional protection. Effluent spills that may contaminate surface waters can be avoided by regularly checking the water level of effluent treatment ponds and irrigating as necessary. Sound management of by-products reuse rates, coupled with ongoing soil monitoring, also helps to prevent surface water contamination through soil erosion or nutrients carried in runoff.

17.4 Groundwater

Groundwater quality monitoring is essential for facilities posing a high risk to groundwater, such as those that have inadequate sealing of floors, drains, ponds or by-products storage areas. For reuse areas, soil monitoring usually provides an earlier detection system, enabling correction. However, groundwater monitoring may be warranted to detect nutrient leaching from piggery facilities at vulnerable sites, or where there is a significant risk of leaching.

Ideally, groundwater monitoring would include sampling and analysis from bores up-gradient and down-gradient from the piggery and / or reuse areas. Electrical conductivity and nitrate-nitrogen levels should be determined. On very sandy soils, total phosphorus should also be measured. Monitoring is not required if the facility poses a lower risk to groundwater, such as those that have good sealing of areas used to transport, treat or store by-products.

Knowledge of the hydrogeology of the site is important when planning a groundwater monitoring program. The formation, depth, direction of flow and connectivity of groundwater aquifers underlying the site, determine whether there is any value in monitoring groundwater in the first place. They also provide an indication of where any piezometers should be located to provide meaningful data. Groundwater monitoring programs should be designed by a certified hydrogeologist.

Appendix D provides detailed sampling protocols and methodology for surface water, groundwater, soils, effluent, solid by-products and plants.

17.5 Sustainability Indicators

This section includes the sustainability indicators that provide the best practical and objective measures of sustainability. In most cases, they should provide a good tool for sustainability assessment. However, non-compliance with the standards associated with the indicators does not necessarily mean the system is unsustainable. In such instances, piggery operators should examine the situation more closely to determine whether alternative indicators are more appropriate to demonstrate sustainability.

17.5.1 Community Amenity Impacts

The rate of complaints received cannot be used as a sustainability indicator, as it is an imprecise measure of community amenity impact. However, any complaint should be taken seriously by the piggery operator, and should be recorded and properly investigated. An example complaints register form is in Appendix C.

17.5.2 Surface Water Impacts

Since surface water quality monitoring is generally not a relevant measure of sustainability, no indicators are suggested. However, piggery operators could regularly inspect surface waters for algal blooms (such as blue green algae) that are associated with raised phosphorus and nitrogen levels. **Any blooms should be reported to the relevant approved authority. Affected water should not be used as a pig drinking water source.**

Use of surface water should not exceed any allocations set by appropriate government 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.

17.5.3 Groundwater Impacts

In many piggeries, groundwater monitoring is of little practical value because of the particular hydrogeology of the site. However, at sites with suitable hydrogeological conditions, where groundwater monitoring results are likely to be relevant and meaningful, a piggery may be considered sustainable if water sampled from bores down-gradient of the piggery does not indicate contamination by piggery by-products. Contamination may be indicated if electrical conductivity, nitrate-nitrogen and total phosphorus levels are higher than in the water sampled from up-gradient bores. However, it is often difficult to conclusively identify the source of contamination, and careful interpretation of groundwater monitoring results is needed, since other on-farm and off-farm activities not associated with the piggery may influence results.

17.5.4 Soils of Reuse Areas

This section and tables 17.4-17.9 provide suggested trigger values to assist in deciding if nutrients and salts are being applied sustainably to the soils in reuse areas. However, soil properties vary widely and these suggested trigger values are not always the most appropriate measures of sustainability. For this reason, they should be regarded as triggers only for further investigation, such as comparison against background data. The ideal site from which to collect background data would be close to the area of interest, and would have similar soil and land use to the reuse area, but would not have received piggery effluent or solid by-products. However, areas that have received heavy fertiliser applications, or have been degraded over time, may also have different properties compared to their background state. 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 sites of by-products use. Comparison with historical data and trend analysis may also be useful.

Nitrogen

Nitrate-nitrogen is extremely mobile and readily leached. Consequently, high nitrate-nitrogen levels in the subsoil pose a risk to groundwater.

Subsoil nitrate-nitrogen concentrations exceeding a soil solution concentration of 10 mg NO_3N/L may limit the future uses of any receiving aquifer. This concentration is based on drinking water standards contained in the *Australian Drinking Water Guidelines* (National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand 2004). These guidelines state that the nitrate concentration should not exceed 50 mg/L in water used for human consumption, including bottle-fed babies (A nitrate-nitrogen concentration of 10 mg/L approximates a nitrate concentration of 50 mg/L). However, up to 100 mg/L nitrate (or about 25 mg/L nitrate-nitrogen) can be used by adults and children over three months of age (National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand 2004). 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 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 (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand 2000)
- 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)
- baseline nitrate-nitrogen levels in the soil below the active root zone.

The root zone depth depends on the crop type, soil depth, climate and 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 leaching.

For different soil types, Skerman (2000) calculated nitrate-nitrogen concentrations equivalent to 10 mg/L of nitrate-N in soil solution (see Table 17.4). This trigger value applies at a depth of 0.6 cm, 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 17.4. 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 17.4 is 4.5 mg/kg. Hence, depending on soil type, nitrate-nitrogen concentrations ranging from 1.2 mg/kg NO_3N to 4.5 mg/kg NO_3N at the base of the root zone would trigger further investigation. This concentration in the root zone is considered very low for crop production.

TABLE 17.4 Nitrate-nitrogen concentrations corresponding to a soil solution nitrate-nitrogen concentration of 10 mg/L at field capacity

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. A nitrate-nitrogen limit of 10 mg/L below the active root zone is a trigger for further investigation or action. Compare the results with those for background sites. Alternatively, comparison with historical data and trend analysis may be useful. If the nitrate-nitrogen concentration below the active root zone shows signs of build-up over time, review the use of by-products. Comparing nitrate-nitrogen monitoring results against baseline data provides a measure of the nitrogen sustainability of an area.

Other matters to consider when determining the nitrogen sustainability, include the risk of nitrate moving off-site in surface water and groundwater, the quality of the groundwater, and the amount of deep drainage through the soils. These need evaluation as part of the risk assessment of the reuse area.

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 and/or when applied phosphorus is not being removed from a reuse area.

Tables 17.5-17.8 give acceptable values for phosphorus concentrations in surface soil for various extractable phosphorus tests. These values can provide guidance on concentrations that will meet plant requirements, without resulting in significant leaching. Generally, a bicarbonate extraction is the most appropriate (Colwell or Olsen, tables 17.5 and 17.6 respectively), but for very acid soil an acid extraction (Bray or BSES, tables 17.7 and 17.8 respectively) may be better. It should be noted that these limits are commonly exceeded in normal agricultural soils. Thus, they should be used as triggers for further investigation (such as comparison against results from background sites) if there are doubts about sustainability. Alternatively, comparison with historical data and trend analysis may be useful.

TABLE 17.5 Suggested trigger levels for investigation for phosphorus in topsoil

Clay Content	pH	Colwell phosphorus (mg/kg)
< 30%	< 7	31
< 30%	> 7	59
> 30%	< 7	75
> 30%	> 7	85

Notes:

1. These levels do not apply to some soils, (e.g. black vertosols), or to high-productivity systems.
2. Under highly productive agricultural systems, these levels are commonly exceeded. Hence, they should be regarded only as trigger values for further investigation or action.

Source: Skerman (2000)

TABLE 17.6 Rankings for Olsen phosphorus in topsoil (mg/kg)

Very Low	Moderate	High
<12	12-25	>25

Notes:

1. The ranking of high (>25 mg/kg) could be considered a trigger level for further investigation or action.
2. Under highly productive agricultural systems, these levels are commonly exceeded. Hence, they should be regarded only as trigger values for further investigation or action.

The New South Wales (NSW) Department of Infrastructure Planning and Natural Resources, Soil and Land Information System database ranks various chemical test results for NSW soil tests, including Bray P (Table 17.7). The high ranking of 20-25 mg/kg Bray P in the surface soil is a guideline trigger for further investigation or action. This further investigation could include comparison against analysis results for a background site.

TABLE 17.7 Rankings for bray phosphorus (mg/kg)

Very Low	Low	Moderate	High	Very High
<5	5-10	10-20	20-25	>25

Notes: Under highly productive agricultural systems, the 'high' and 'very high' levels are commonly exceeded. Hence, they should be regarded only as trigger values for further investigation or action.

Redding (pers. comm., 2002) developed limits of available phosphorus in the surface soil for the BSES method, based on the same principles as the limits for Colwell (mean + one standard deviation), depending on the level of clay. These are shown in Table 17.8. These numbers are derived from a relatively small data-set and may need refining when more data is available.

TABLE 17.8 BSES phosphorus (mg/kg) guideline levels

Clay Content	Average	Standard deviation	Guideline
< 30%	17	14	31
> 30%	59	72	131

Notes: Under highly productive agricultural systems, these levels are commonly exceeded. Hence, they should be regarded only as trigger values for further investigation or action.

To investigate any possibility of phosphorous leaching, particularly with sandy soils, measurement of available phosphorous 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. Both good agronomic practices and good use of by-products are needed (see Section 14.1.6).

Burkitt *et al* (2002) developed a test to improve the accuracy of phosphorus fertiliser recommendations. The phosphorus buffer capacity (PBC) can be estimated by measuring the amount of phosphorus (mg P/kg) sorbed following the addition of one or two known concentrations of phosphorus (mg/L). It can also be calculated from the Freundlich parameters (a and b):

$$\textbf{PBC (mg P/kg)} = a\,(0.35^{b} - 0.25^{b})$$

Table 17.9 shows the likely range of PBC for various phosphorus sorption capacities from the study of Burkitt *et al* (2002).

TABLE 17.9 Phosphorus sorption capacity classifications for phosphorus buffer capacity

Classification	Phosphorus buffer capacity (mg p/kg)
Very low	< 5
Low	5–10
Moderate	10–15
High	15–25
Very High	> 25

Potassium

Potassium is often calculated to be the limiting nutrient for many cropping systems that use piggery effluent. Since salinity would generally cause environmental problems before potassium on its own, it is rarely 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. Also, high exchangeable potassium levels, relative to exchangeable magnesium levels, may induce hypomagnesia (grass tetany) in grazing ruminants. Hence, it is recommended that by-products should only be spread at very low rates on grazed pastures.

Salts

Reuse areas should not show increases in soil salinity that will adversely impact on the productivity of the land over the long term. Pronounced increases in soil salinity may result from additions of effluent or solid by-products, particularly in the topsoil layer. However, 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 and it will take longer for salt removal to occur. Soils with an electrical conductivity (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, a trigger for further investigation or action is considered to be any EC_{se} increase of 2.5 dS/m, compared with similar soil sampled from background sites *and* any result that places the salinity rating at 'medium' or higher. Soil EC_{se} should be determined at a depth of 0.5-0.6 m (or base of root zone). Alternatively, comparison with historical data and trend analysis may be useful.

Soil sampling should occur at the end of the main growing season. EC_{se} 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 (Na^+) and chloride (Cl) 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 Na^+ and Cl^- concentrations of the soil should be less than 150% of background levels.

Sodicity

Sodicity is important in effluent-use-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 is recommended where the soil ESP exceeds 6%, and strongly recommended where it exceeds 9%.

Applying calcium to the soil in the form of high-quality gypsum or lime helps to displace sodium ions from the clay particles, making them available for leaching below the root zone. Consequently, an ESP level of 6% warrants gypsum or lime application to amend the sodium imbalance. This is strongly recommended where the ESP has risen to 9%. For neutral to acidic sodic soils (ESP = 6-15%), apply 2.5 t/ha of lime. Lime is less effective for alkaline soils, so a gypsum application rate of 5 t/ha is recommended for sodic alkaline soils. For highly sodic soils (ESP exceeding 15%), apply gypsum at 5 t/ha. For highly sodic, alkaline soils, consider planting acidifying legumes. If highly sodic alkaline soils are fully irrigated, gypsum application rates of up to 10 t/ha may be more appropriate (Rengasamy and Bourne 1997).

Soil 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, or 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.

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

18 Environmental Management Plans

Environmental Outcome: **A system enabling the piggery to be managed in an environmentally sustainable manner, including processes for continual review and improvement.**

An Environmental Management Plan (EMP) focuses 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 impacts are minimised; and processes for continual review and improvement. While an EMP is not always mandatory, it is strongly recommended for all piggeries, and provides the evidence that the operator is committed to pig production in an environmentally sustainable manner. An EMP provides a system for documenting:

- the environmental risks of a piggery (through an assessment of resource vulnerability, the standard of design and management, and the interaction of these two areas)
- how these risks will be minimised (by design or management)
- measurement of the effectiveness of these strategies (by monitoring)
- how monitoring results will be reported
- actions that promote good environmental management and reduce risk.

The EMP allows for dynamic, adaptive management and should focus on continuous improvement. It allows variations from the guidelines, and includes the monitoring and feedback loops that provide assurances that environmental impact can be detected and resolved. Proactive and genuine handling of complaints is an integral component of the monitoring and feedback loops.

An EMP typically includes:

- identification and contact details
- a brief description of the piggery
- a commitment that the piggery will be operated in an environmentally sustainable manner
- identification of applicable consents, approvals and/or licences to operate the piggery
- details of the natural and social resources of the property and the surrounding area
- description of the design and management of the piggery
- identification of the environmentally vulnerable areas on-farm or in the surrounding area, and any required mitigation strategies
- identification of the resources to be monitored
- a listing of contingency plans or emergency strategies

- details of any environmental training already undertaken by staff, and any areas where training would be beneficial
- identification of the need for periodic review of the EMP to ensure that any changes in regulatory requirements, the operation of the piggery, the environment, the design or management of the piggery, and associated changes in environmental risk, are reflected in the plan.

Environmentally vulnerable areas would be identified by examination of natural and social resources, and looking at how the design and management of the piggery interact with these resources. Identification of an environmental risk may trigger regular monitoring of the natural resource involved. Alternatively, it may prompt changes in the design or management of the piggery to reduce environmental risk. Any proposed changes could form part of a separate program of environmental improvement.

APL has funded the development of several pig industry environmental training packages, including a workshop that piggery operators can use to develop their own EMP (although other EMP formats are acceptable). Further information about APL environmental training materials can be obtained by telephoning 1800 789 099.

An EMP can be developed into an Environmental Management System (EMS) by developing action plans and incorporating simple auditing, like an EnviroCheck assessment. An environmental expert uses the APL EnviroCheck tool to assess how well an existing piggery complies with the National Guidelines, and identify areas where improvements could be made. APL has developed the Environmentally Sustainable Piggeries EMS templates to assist piggery operators wishing to develop an EMS, although other formats are also available. For further details, refer to Australian Pork Ltd (2007c).

19 Chemical Storage and Handling

***Environmental Outcome:* Chemicals are stored and used in ways that protect the community, air, water resources and soils.**

Each state has its own legislation and mandatory requirements for chemical storage and handling. Factors to consider in reducing environmental problems include:

- minimising the storage and use of chemicals
- storage and handling disinfectants and other chemicals, to avoid spills
- impermeable flooring and bunding of chemical storage areas
- storing and using chemicals, veterinary chemicals and fuels in accordance with workplace health and safety codes of practice
- using agricultural chemicals, drugs, antibiotics, vaccines and disinfectants that are registered for the intended purpose
- selecting chemicals with a low toxicity and low water contamination potential, where possible
- having an emergency response plan and spill kit in place in case of a chemical spill
- having Material Safety Data Sheets for all chemicals stored and used
- avoiding spray drift when using farm chemicals, by using well-maintained equipment and avoiding application during windy weather
- maintaining records of pesticide use
- training staff in the safe use and handling of chemicals, including veterinary chemicals and baits
- ensuring fly and rodent bait stations are sited so that they cannot be accessed by pigs. Ensuring bait stations are placed where flies and / or rodents are usually active; at the correct intervals; and with adequate levels of bait
- disposing of empty drums or packaging in accordance with the manufacturer's instructions
- disposal of sharps to ensure staff safety (sharps should never be allowed to enter the effluent system)
- using accredited chemical contractors
- removal and disposal of material containing asbestos must be undertaken by licensed contractors in accordance with the National Occupational Health and Safety Commission's Code of Practice for the Safe Removal of Asbestos (National Occupational Health and Safety Commission 2005)
- following specific management and routine monitoring requirements for on-site underground petroleum storage systems (UPSS). In particular, a leak detection system that includes daily monitoring of fuel levels.

For further information on safe storage and handling of agricultural and veterinary chemicals, see Standards Australia (2001).

20 Gaseous Emissions – Reporting and Regulation

Piggeries emit gases that contribute to environmental concerns, particularly the greenhouse gases (GHG's) carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other gases such as ammonia (NH_3). For this reason, piggery operators may need to report gaseous emissions to the National Greenhouse and Reporting System (NGERS) and the National Pollutant Inventory (NPI).

The agricultural sector was responsible for 16% or 90.1 Mt CO_2-e of Australia's total GHG emissions in the 2006 inventory (DCC 2008a). The pig industry is a relatively small contributor to the overall NGGI, contributing 1.6 Mt CO_2-e per year, or 1.8% of the agricultural sector's emissions in 2005 (Garnaut 2008). Manure management accounts for 1.37 Mt CO_2-e of these emissions (DCC 2008b), which comprise mainly of methane and nitrous oxide from the anaerobic treatment of piggery manure.

20.1 National Greenhouse and Energy Reporting System

Facilities that exceed set thresholds for greenhouse gas emissions, and energy consumption and production, must register and report these through the NGERS.

NGERS divides GHG emissions into:

scope 1: direct GHG emissions that occur from sources owned or controlled by a business or facility

scope 2: indirect GHG emissions associated with the off-site generation of the electricity, heating/cooling or steam purchased for consumption by a business or facility

scope 3: other indirect GHG emissions generated because of a facilities activity, but physically produced by another business or facility.

Any facility which produces 25 kt of CO_2-e/yr, or more, of scope 1 or 2 emissions, or which consumes or produces more than 100 TJ/yr of energy, must report its emissions or energy consumption or production to the Department of Climate Change. Corporate groups have higher thresholds, which will progressively decrease each year from 125 kt to 50 kt of CO_2-e/yr and 500 TJ to 200 TJ/yr of energy by 2011-2012. The NGERS does not include agricultural emissions such as CH_4 and N_2O released from piggeries at this stage. However, any facility or corporation, which exceeds the thresholds through use of fossil fuels, must report the associated GHG emissions and energy use or consumption (DCC 2008d).

Further information on registering and reporting through NGERS is available at: http://www.climatechange.gov.au/en/government/initiatives/national-greenhouse-energy-reporting/tools-resources.aspx. Access to the NGERS calculator is also available from this website.

20.2 National Pollutant Inventory Reporting

Piggeries face NPI reporting responsibilities if they emit over 10 t/yr ammonia, or for emissions to air associated with fuel and or waste combustion exceeding 400 t/yr, or 1 t/hr at any time in the reporting year (DEWHA 2009). In 2007, the Department of the Environment and Water Resources released an updated emission estimation technical manual for pig farming, containing new emission factors for deep litter piggeries. A conventional piggery with a capacity of 1100-1200 SPUs is likely to trigger responsibilities for reporting ammonia.

A deep litter piggery that stockpiles spent bedding on-farm, triggers reporting responsibilities at a capacity of about 2000 SPU. Whereas, a deep litter piggery that does not stockpile spent bedding, would trigger reporting responsibilities at a capacity of about 7100 SPU.

NPI emissions are reported to the NPI office in the applicable state or territory. To access the current technical manual, which includes a simplified reporting form, visit the NPI website:http://www.npi.gov.au/publications/emission-estimation-technique/pork.html (Department of the Environment and Water Resources 2007).

20.3 Mitigation and Opportunities

Further research is needed to identify strategies that piggery operators can use to reduce their GHG emissions. However, APL is investigating the potential of the following:

- Strategies that improve feed conversion. As well as reducing GHGs, this improves the financial performance of the piggery

A permeable pond cover captures biogas from the effluent pond

- Pre-treatment of effluent streams to remove solids prior to pond treatment
- Covering effluent treatment ponds with impermeable covers. The captured biogas can be burnt in: an engine to produce electricity and heat, a boiler to produce heat, or a flare to convert methane to carbon dioxide
- Capturing and utilising biogas produced from the digestion of spent bedding from deep litter piggeries, with liquid effluent from conventional piggeries. For further details see GHD (2008a)
- Irrigating effluent directly ex-sheds. This can significantly reduce GHG emissions compared with traditional anaerobic pond treatment. However, this may not always be feasible because of the potential for increased impacts to waterways
- Permeable pond covers.

Further work is needed to develop effective methods for covering existing anaerobic ponds, whilst also addressing sludge management (both operating and desludging phases), and low cost alternatives to biogas capture (e.g. digestion of spent bedding).

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Appendix A.

National Odour Guidelines for Piggeries

A1 Introduction

Odour has been identified as the principal community amenity concern in relation to piggery developments. The Australian pig industry has recognised the need to improve its level of environmental performance to comply with rising community expectations. A consistent regulatory approach that provides the latest and best technical information, will facilitate new development proposals, upgrades to facilities, and compliance with licence and approval conditions, and current regulatory standards for operating piggeries in each state. The industry is driving this change by embracing environmentally sustainable practices, and promoting self-regulation, through active participation in the development and adoption of these *National Odour Guidelines for Piggeries*.

These guidelines are based primarily on existing state piggery guidelines and codes of practice, but include ideas from other industries relevant to piggery odour assessment. They represent the best available options for assessing potential odour impacts, from the information that is currently available. However, the relevant approved authority should be contacted for information regarding the content or application of legislation, codes of practice or guidelines in a particular state. **Early contact with state and territory agencies is recommended to discuss regulatory requirements for any proposed operations or changes to existing operations.**

In the absence of specific advice from the approved authority, these guidelines provide recommended methods to determine separation distances for community amenity.

These separation distances are for new developments and expansions, and are not applicable to existing piggeries.

A2 State Legislation and Guidelines

Each state of Australia has different legislation, codes of practice and guidelines that are relevant to odour impact assessment for piggeries. These guidelines have been developed to conform as much as possible to regulatory requirements around Australia. However, regulatory requirements differ on some issues between states and territories, and regulatory requirements are periodically revised. Consequently, these odour guidelines do not conform to all regulatory requirements in every state and territory. Where there are differences, relevant state and territory requirements will override the odour guideline criteria and methodology. Relevant acts and documents for each state are listed below.

A2.1 New South Wales

Protection of the Environment Operations Act 1997.

Environmental Planning and Assessment Act 1979 (as amended).

Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in New South Wales - NSW Department of Environment and Conservation, August 2005.

Assessment and Management of Odour from Stationary Sources in NSW – NSW Department of Environment and Conservation, November 2006.

Technical Notes – Assessment and Management of Odour from Stationary Sources in NSW – NSW Department of Environment and Conservation, November 2006.

Note that the *Policy – Assessment and Management of Odour from Stationary Sources in NSW* provides odour assessment criteria and an odour assessment methodology to be used in NSW. It also provides a process for development of industry-specific odour criteria and variations to the preferred methodology. Before commencing an odour impact assessment in NSW, a proponent should contact the NSW Department of Environment and Conservation to discuss any changes to the odour criteria and / or preferred assessment methodology.

A2.2 Queensland

Environmental Protection Act (1994). Environmental protection policies are subordinate legislation that set standards and criteria for particular environmental problems. One policy addresses the management of air.

Environmental Code of Practice for Queensland Piggeries – Department of Primary Industries and Fisheries, Queensland, 2000.

Separation Guidelines for Queensland Piggeries. – Department of Primary Industries and Fisheries, Queensland, 2001.

A2.3 Victoria

Environment Protection Act 1970.

State Environment Protection Policy (Air Quality Management).

Code of Practice Piggeries: An Environmental Code of Practice – Department of Planning and Housing and Department of Food and Agriculture, 1992.

Note that this code of practice is currently being reviewed and updated. A new code is due for release in 2010.

A2.4 South Australia

Environment Protection Act 1993.

Guidelines for Separation Distances – Environment Protection Authority, South Australia, 2007.

Odour Assessment Using Odour Source Modelling – Environment Protection Authority, South Australia, 2003.

A2.5 Western Australia

Environmental Protection Act 1986.

Environmental Guidelines for New and Existing Piggeries – Agriculture Western Australia, 2000.

Odour Methodology Guidelines – Department of Environmental Protection, Western Australia, 2002.

Interim Guidance on odour as a relevant environmental factor

http://www.epa.wa.gov.au/docs/1028_GS47_Interim.pdf

A2.6 Tasmania

The *Environmental Management and Pollution Control Amendment (Environment Protection Authority) Act 2007.*

The Environmental Management and Pollution Control (Environment Protection Authority) (Consequential Amendments) Act 2007.

A3 Odour Assessment Process

An odour assessment aims to establish whether an odour will have an unreasonable impact at off-site receptors. An unreasonable odour impact is assumed to occur when separation distances between a piggery and a receptor are less than those calculated using the methods set out here. A receptor is a location where people are likely to live, or to spend large amounts of time, including residences, schools, hospitals, offices or public recreational areas. These guidelines mostly limit odour at a receptor to below the level most people would regard as objectionable. This document provides assessment criteria that will achieve this for most sites; however, each site should be considered individually. Three levels of assessment are outlined in these guidelines:

- Level 1 uses a standard empirical formula and is suitable for all piggeries. Level 1.5 incorporates a wind frequency reduction factor into the formula is also available
- Level 2 involves modelling using the most appropriate model, a meteorological data file representative of the site and adopted 'standard' emission rates
- Level 3 involves modelling using the most appropriate model, a meteorological data file representative of the site and non-standard odour emission rates, or an odour concentration / odour intensity relationship.

Since the simple impact assessment methods (Level 1 and Level 1.5) are less accurate than the site-representative assessment (Level 2), or site-specific assessment (Level 3), the separation distances calculated using the simple methods are more conservative.

The levels listed in these guidelines are suitable for assessing the potential for odour impacts from a proposed or expanding facility. They are not useful for assessing the odour impact from an existing facility, and should never be used to determine if a facility should continue to operate, or to determine whether any odour impacts being experienced warrant further action or are acceptable. They are not suitable for investigating odour complaints.

These guidelines assume that all piggery odour sources are accurately represented as either area sources (e.g. ponds) or volume sources (e.g. piggery sheds). As a result, different modelling protocols may be required at some piggery sites, particularly those that include:

- point or line sources
- receptors in the near-field (separation up to 10 x the largest source dimension)
- complex terrain or meteorological conditions.

In these cases, advice regarding appropriate modelling protocols should be obtained from the relevant approved authority.

A3.1 Level 1

Level 1 uses a standard empirical formula and is a simple, cheap and quick method that offers high levels of protection for community amenity. Hence, the formula is relatively conservative and it could be used as a first screen for a proposed development. It gives the largest separation distances of all three levels. If the Level 1 assessment proves unsatisfactory (such as when a piggery of a given size and design does not meet the Level 1 assessment requirements), odour modelling may be required, using the more detailed Level 2 or Level 3 assessment methods to demonstrate that the risk of impact on the surrounding environment is acceptable.

A3.2 Level 1.5

Level 1.5 uses the standard empirical formula approach (Level 1), with the addition of a wind frequency reduction factor for the proposed site, using available wind speed and direction data that is representative of the site. This intermediate factor is designed to improve the prediction of impacts, without the need for using a detailed modelling approach. If the Level 1.5 assessment proves unsatisfactory, odour modelling using the more detailed Level 2 or Level 3 assessment methods may be required to demonstrate that the risk of impact on the surrounding environment is acceptable.

A3.3 Level 2

Level 2 involves odour modelling with 'standard' recommended emission data. This method more closely matches the actual site configuration, but still offers high levels of protection for community amenity. This assessment applies to situations where:

- piggery design or management is substantially different to the standard design used for the Level 1 and Level 1.5 assessments
- meteorological data that represents the site are available
- receptor locations are not accurately represented by the Level 1 and Level 1.5 assessment (for example, prevailing winds may increase / decrease potential impacts at certain receptors).

The emission data used should be based on best available data. The APL odour research database contains recommended emissions based on regular review and updating of information (3-5 yearly). The meteorological file should be representative of the site.

Assessment under Level 2 uses AUSPLUME in situations where it is expected to perform adequately. However, in areas of complex terrain or meteorological conditions, the use of other accepted dispersion models may be warranted.

A3.4 Level 3

Level 3 involves a comprehensive risk assessment, including site-specific (or site-representative) odour emission data or a developed odour concentration / odour intensity relationship for the odour sources. This assessment applies:

- to situations where innovative or unusual piggery design or management processes are implemented on-site
- where particular odour reduction strategies are used.

The risk assessment process may also include a time-series assessment of the odour impact. This assessment would need to investigate the concentration, frequency and duration of odour impacts at individual receptors.

The modelling incorporates the use of site-specific or site representative emission data, based on system measurements collected to appropriate standards. As with the Level 2 assessment, the modelling also requires the use of at least one year's worth of reliable meteorological data representative of the site. The odour modelling results need to comply with the odour impact objective, or an appropriately designed odour intensity study.

The use of an odour intensity study is not a required part of Level 3 assessment, but is included as an option available for sites that are using innovative designs, or management that changes the nature of the odours released. An odour intensity study may provide a better method for assessing odours with non-irritating character (e.g well-managed compost).

Assessment under this level uses AUSPLUME in situations where it is expected to perform adequately. However, in areas of complex terrain or meteorological conditions, the use of other accepted dispersion models may be warranted.

A3.5 Piggery Definitions

Australian piggeries can be categorised as follows:

- Conventional piggeries
- Deep litter piggeries
- A combination of conventional sheds and deep litter sheds
- Rotational outdoor piggeries
- Feedlot outdoor piggeries.

Definitions for these types of piggeries are provided in section 4.2 of the National Environmental Guidelines for Piggeries.

Rotational outdoor piggeries are not required to meet site-specific separation distances, but should meet the minimum separation distances set out in Table A.9. These piggeries pose a low chance of causing a substantial off-site odour impact, provided they are designed and managed according to sustainable nutrient loading rate criteria.

The application of these odour guidelines to feedlot outdoor piggeries is described below.

- Level 1 and Level 1.5 assessments for feedlot outdoor piggeries require an appropriate S1 factor (piggery design factor – see Section A5.4). However, odour emission rates from feedlot outdoor piggeries in Australia have not been reported, so it is not currently possible to develop S1 factors. **Consequently, factors for a Level 1 and Level 1.5 assessments for a feedlot outdoor piggery would need to be negotiated with the relevant approval authority.**

A3 ODOUR ASSESSMENT PROCESS

- Level 2 assessments for feedlot outdoor piggeries require 'standard' odour emission rates for these piggeries. **Little information is available regarding odour emission rates from feedlot outdoor piggeries in Australia, so emission rates used in a Level 2 assessment for such a piggery would need to be negotiated with the relevant approval authority.**
- Level 3 assessments for feedlot outdoor piggeries are done according to these guidelines.

Like the *National Environmental Guidelines for Piggeries*, these odour guidelines do not apply to extensive pig farming, in which the animals rely primarily on foraging and grazing, rather than on supplementary feed, to meet most (greater than 50%) of their nutritional requirements.

A covered pond reduces odours and greenhouse gases

A4 Modelling Protocols and Parameters

Before doing an assessment, the data and methods to be used in the assessment should be discussed with the relevant approved authority. It is important to note that these guidelines apply to an odour impact assessment for piggery facilities, and do not provide a health risk assessment.

A4.1 Model Used

AUSPLUME is currently the accepted emissions model around Australia, but other models are available that more accurately represent the dispersion process, particularly in complex terrain or when there are multiple odour sources not in close proximity. The major disadvantage of these models is that they require more comprehensive meteorological data than AUSPLUME. An APL-commissioned report provides guidance in the selection and use of odour dispersion models (Pacific Air and Environment, 2003b).

If modelling piggeries that are in complex terrain or meteorological conditions, consider other accepted dispersion models **the relevant approved authority should be contacted before doing modelling to discuss the appropriate model to be used for each individual site.**

A4.2 Odour Intensity

Odour intensity is a useful dimension to quantify, because some odours are perceived as being stronger than others. In other words, all odours will be just detectable at a concentration of 1 odour unit (OU)/m^3. hHowever, at twice the concentration, or 2 OU/m^3, some odours may be perceived as very weak, while others may be perceived as distinct. At 10 times the concentration, or 10 OU/m^3, one odour may be perceived as distinct, while another odour may be perceived as very strong.

An odour intensity study uses dynamic olfactometry to determine odour concentration and then odour intensity. The data are used to establish an odour concentration / odour intensity relationship applicable to the odour sources site. This study would need to comply with the German standard guidelines (VDI 1992) for determining odour intensity. This type of study would only be applicable to Level 3 assessments.

A4.3 Percentile Occurrence

A wide range of percentile occurrences is available for use in odour impact criteria, with different percentiles generally suited to different purposes. Very high percentile occurrences such as 99.9% (i.e. odour from a piggery does not cause impact 99.9% of the time each year), allow very few instances where the criteria may be exceeded, and the modelling results are thus sensitive to outliers and errors in the meteorological data.

Conceptually, such stringent criteria are suited to acute impacts caused by highly concentrated odours. Piggery odours are complex mixtures of odorants released from area and volume sources. As a result, these odours are at relatively low concentrations, at distances away from the odour sources. Consequently, any off-site receptors are more likely to experience a chronic impact (caused by repeated exposure to relatively low concentrations) than an acute impact. Conceptually, Such impacts are more accurately represented by lower percentile occurrences.

These guidelines use a 98-percentile odour concentration occurrence to provide a better assessment of repeated low level odour exposure, and to reduce the impact on results of outliers in meteorological data files. More detailed discussion on this topic is presented in Pacific Air and Environment (2003c).

A4.4 Averaging Time

These guidelines use an averaging time consistent with the meteorological data file averaging, which is generally one hour. The use of meteorological data that represents an average condition over the period of 1 hour, means that the actual odour concentration during that hour will be varying above and below the predicted average concentration. As human perception of odour typically occurs over very short time periods, odour impacts that do occur, may take place at an odour concentration that is higher than the average concentration predicted.

Two main methods are available to account for short-term concentration variations – the use of a reduced averaging time (such as 3-minute averaging through the AUSPLUME dispersion model), or the use of a more stringent odour impact criteria. These guidelines incorporate the potential effects of plume concentration fluctuations into the odour impact criteria, rather than using a separate factor.

A4.5 Assessment Point for Criteria

The assessment point for odour impact criteria should be based on a risk assessment process tailored to the site. For extensive rural areas with low population density, the risk of odour plumes affecting people is low in outlying areas of a property, and highest at houses, yards and sheds. In more closely settled areas, it is likely that all areas of the property will be more frequently used, and this needs to be considered as part of a risk assessment, along with the times of day these areas would be used, the potential activities in those areas and the odour potential of those activities. As most piggeries are in rural use areas, odour impact criteria would usually be applied at receptors.

It is important to assess likely future receptor points as part of the risk assessment process. For facilities sited close to towns, the local council should be contacted for an indication of the land zonings in the area surrounding the piggery site. A community consultation process is particularly useful as part of the risk assessment process, as it can assist in identifying future or pending developments on surrounding land.

A4.6 Odour Impact Criteria

For these guidelines, the standard odour impact criteria are:

- 3 OU, 98%, 1 hour average for a rural dwelling
- 2 OU, 98%, 1 hour average for a rural residential receptor
- 1 OU, 98%, 1 hour average for a town receptor.

These criteria are different from those used in most states. Section A.2 provides references for state requirements for odour impact assessments. **These references should be consulted, or the approved authority contacted to determine the requirements that must be met.** These impact criteria relate to odour emissions measured to the Australian Standard 4323.3:2001 (Standards Australia/Standards New Zealand 2001).

For Level 1 and Level 1.5 assessments, the impact criteria are equivalent to 75% of the standard impact criteria. These criteria are applied to the Level 1 assessment to provide conservative results for the standard formula, thus compensating for situations that are not covered well by some of the generalisations made within the formula. For Level 2 and Level 3 assessment, the standard impact criteria are used. Table A.1 lists the odour impact criteria used in these guidelines.

TABLE A.1 Impact criteria applied in these guidelines

Impact criteria	Percentile occurrence	Odour Concentration in OU			Averaging time	Assessment point
		Rural	Residential	Town		
Level 1	98%	2.25	1.5	0.75	1 hour	Receptor
Level 1.5	98%	2.25	1.5	0.75	1 hour	
Level 2	98%	3	2	1	1 hour	
Level 3	98%	3	2	1	1 hour	

OU = odour unit

A4.7 Meteorological Data

High-quality Australian meteorological data are scarce outside the major population centres. As most piggery operations are in rural areas, it is often difficult to obtain suitable wind speed and wind direction data for dispersion modelling. CSIRO has developed 'The Air Pollution Model' (TAPM) which can generate meteorological data files for dispersion modelling applications (Harris 2002).

Meteorological data should only be generated by someone who understands the capabilities and limitations of the model used. Any data used in the Level 1.5 assessment and dispersion modelling must be assessed for errors, and to ensure they adequately represent meteorological conditions at the site.

Validated data collected using a meteorological recording station is the preferred source for modelling input data. However, each file should be examined to assess its suitability for a given site. Where no site-representative data are available from surface recording stations, two options are available:

- an on-site recording station may be set up to record one year's worth of on-site data
- a computer-generated data file may be used, although care needs to be taken in the selection of model settings to obtain representative data.

The data proposed for use in modelling should be discussed with the approved authority. The APL-commissioned report, Pacific Air and Environment (2003a), provides guidance on meteorological data for odour dispersion models.

A4.8 Surface Roughness

Surface roughness values are an important parameter in dispersion modelling. For Level 1 and Level 1.5 assessments, values are tabulated and clearly explained. For Level 2 and Level 3 assessments, the guidance provided by the model being used should be followed.

A4.9 Risk Assessment

During the initial stages of an odour impact assessment, it is important to establish the structure of the assessment and the procedures that will be used. A site risk assessment is useful to ensure that all relevant factors are considered during the assessment, including factors such as:

- location of receptors with respect to prevailing winds, particularly during high temperatures, when modelling mechanically ventilated sheds
- background odour levels from other intensive livestock or processing facilities in the area
- houses in air drainage lines downstream of piggery sites.

Most of these occurrences will be addressed in the environmental management plan for the site, and most can be prevented, or minimised, through appropriate site management.

A5 Level 1 and Level 1.5 Assessments

A5.1 Introduction

Odour has been identified as the principal community amenity concern in relation to piggery developments. Separation distance requirements are thus generally determined on the basis of limiting the potential of nuisance odours to an acceptable level. Separation distances can assist in managing some of the community impacts of conventional piggeries, and are used to ensure the long-term protection of the receptor and the piggery enterprise. Optimum separation distances between the piggery complex and receptors depend on a number of factors, including the size of the piggery, the topographical features, vegetation and surface roughness between the piggery and receptors, and the operating and management procedures at the piggery.

Separation distances specified in these guidelines are divided into site-specific and minimum distances. Site-specific separation distances from piggeries to receptors are based on the number of SPUs, receptor type, topography, vegetation (surface roughness), wind frequency and piggery design and operation. Minimum separation distances provide appropriate distances between the piggery complex and relevant features. Separation distances are measured from the edge of the piggery complex, not the centre.

The minimum fixed distances are included largely to account for inaccuracies with predicting odour impact at close distances. Both the site-specific and minimum separation distance to receptors (each relevant receptor class) must be calculated, and the greater distance of the two applied for each receptor.

The piggery complex is generally considered to be any land, building or other structure, or any part thereof, whether temporarily or permanently used for the purpose of keeping, feeding or watering of pigs. The term includes any ponds and manure storage areas used in conjunction with the keeping of pigs, any loading or unloading facilities and carcass management sites, but it does not include by-product reuse areas. Separation distances from by-product reuse areas and relevant receptors and features are included in these guidelines, depending on the type of reuse system employed. By-product reuse areas are not included as part of the piggery complex because of the often infrequent application of by-products and the diverse spread of reuse areas on a farm.

A detailed explanation on how the Level 1 assessment process was developed is presented in APL Project 1921 (Nicholas and McGahan, 2003).

A5.2 Calculation Method

The separation distance of the piggery complex from receptors depends on a number of factors, including:

- piggery size, defined as the number of SPUs in the complex
- piggery design, particularly the shed type and the effluent removal and treatment processes used at the piggery
- piggery siting:
  - receptor type (e.g. town, rural residence etc.)
  - topography features (hills etc.) between the piggery and the receptor
  - vegetation / surface roughness between the piggery complex and the receptor
  - wind frequency
- terrain effects around the site, particularly the effects of terrain features on meteorology of the area.

Site-specific separation distances are based on the dispersion of odours from their source.

Different air quality objectives were chosen for different receptor types, based on the assumption that there is more probability that people will be affected by odour in larger population centres, due to the higher population density in these areas.

Calculation of separation distances for each receptor type follows the form:

$$\textbf{separation distance (D)} = N^{0.55} \times S1 \times S2 \times S3$$

N = number of standard pig units (SPU)

$^{0.55}$ = piggery size exponent determined using the results of modelling

S1= piggery design factor for estimating the relative odour potential for the piggery design selected for a particular site *(S1 = effluent removal factor, $S1_R$ x effluent treatment factor, $S1_T$)*

S2 = piggery siting factor for estimating the relative odour dispersion potential for the selected piggery site *(S2 = receptor type factor, $S2_R$ x surface roughness factor, $S2_S$)*

S3 = terrain weighting factor for estimating the potential changes to odour dispersion, in situations where meteorological conditions may be influenced by local terrain influences

The same formula is used for the Level 1.5 assessment with an additional S4 factor. Refer to section A5.9.

The S1, S2 and S3 factors to be used with this formula are presented in Table A.2.

The separation distance is the distance from the closest point within the piggery complex to the receptor (e.g. town boundary, residence, school, church or hall). The available separation distances between the piggery complex and receptors are generally the key factors limiting the number of pigs that can be accommodated on a particular site. Separation distances to all relevant receptors must be assessed to ensure the potential for unacceptable odour nuisance is minimised. Where other significant odour sources are located in proximity to the proposed piggery, the cumulative odour impact from both sites may need to be considered.

TABLE A.2 **Summary of S factors for use with Level 1 calculations**

Factor Description		Value
S1 Factor = Effluent Removal System Factor, $S1_R$ * Effluent Treatment Factor, $S1_T$		
Effluent Removal System		
Conventional shed – static pit, pull plug or flushing system		1.00
Deep litter system, pigs on single batch of litter ≤ 7 weeks		0.63
Deep litter system, pigs on single batch of litter > 7 weeks		1.00
Effluent Treatment		
Pond with >40% separation of volatile solids before pond		0.80
Pond with 25 – 40% separation of volatile solids before pond		0.90
Pond with <25% separation of volatile solids before pond		1.00
Permeable pond cover **–** preliminary factor, subject to change		0.63
Impermeable pond cover		0.50
Deep litter system – spent bedding stockpiled / composted on-site		0.63
No manure treatment or storage on-site – effluent / litter removed from site		0.50
S2 Factor = Receptor Type Factor, S2R x Surface Roughness Features Factor, S2S		
Receptor Type		
Town		25
Rural Residential		15
Rural Dwelling		11.5
Surface Roughness Features		
Limited ground cover / short grass		1.00
Undulating hills		0.93
Level wooded country		0.85
Heavy timber		0.77
Significant hills and valleys		0.68
S3 Factor – Terrain Weighting Factor		
Terrain	**New Weighting Factor**	
	Downslope of site	**Upslope of site**
Narrow valley (1-2%)	1.2	0.5
Sloping terrain (1-2%)	1.5	1
Flat (<0.1% in all directions)	1	1
Broad valley/Drainage (0.1-1%)	1.6	1
Hilltop (>4%)	1.2	N/A

Notes: S1 factors for an outdoor piggery would need to be negotiated with the relevant approved authority.

A5 LEVEL 1 AND LEVEL 1.5 ASSESSMENTS

A5.3 Piggery Size

The equivalent number of SPUs is calculated using standard multipliers for each class of pig. A SPU is equal to an average size grower pig (40 kg). Multipliers are then applied to each class of pig based on their relative volatile solids production (in their manure and waste feed) as compared to an average size grower pig. The pig mass, age and standard multipliers for each class of pig are provided in Table A.3.

TABLE A.3 Standard SPU multipliers for different classes of pig

Pig class	Definition	SPU factor
Gilt	24-30 wks	1.8
Boar	100-300 kg	1.6
Gestating sow	160-230 kg	1.6
Lactating sow	160-230 kg	2.5
Sucker	0-4 wks	0.1
Weaner	4-10 wks	0.5
Grower	10-16 wks	1.0
Finisher	16-24 wks	1.6
Heavy finisher	Over 24 wks	1.8

A5.4 Piggery Design Factor, S1

A number of piggery design factors will influence the amount of odour emissions from a piggery. The factors having the most influence on the site emissions are discussed below. A composite 'design factor' for the site is obtained by multiplying the effluent treatment and removal factors together.

Odour emission rates from feedlot outdoor piggeries in Australia have not been reported, so it is not currently possible to develop S1 factors for feedlot outdoor piggeries. **Consequently, S1 factors for use in a Level 1 assessment for a feedlot outdoor piggery would need to be negotiated with the relevant approved authority.**

Effluent removal, $S1_R$

The effluent removal factor relates to the odour potential of piggeries based on the management of effluent in the piggery buildings. Good shed management practices, including maintaining clean conditions within the sheds, is known to reduce odour emissions. Table A.4 lists effluent removal factors based on the effluent removal system used.

TABLE A.4 **Values of effluent removal factor, SI_R**

Effluent Removal System	Factor
Conventional shed – static pit, pull plug or flushing system	1.00
Deep litter system, pigs on single batch of litter ≤ 7 weeks[a]	0.63
Deep litter system, pigs on single batch of litter > 7 weeks[a]	1.00

[a] The effluent removal factor is 0.63 for deep litter systems, stocked at recommended rates, with good management practices for up to 7 weeks on a single batch of litter. This assumes that sheds are maintained in a relatively clean condition (e.g. sufficient bedding equivalent to >0.6 kg of straw/pig/day), there is no liquid effluent treatment system and solid stockpiles are removed from sheds as soon as practical after the end of a batch. Where low bedding rates are supplied (<0.6 kg/pig/d). or pigs are housed >7 weeks between shed clean-outs, a factor of 1 should be used. Where pigs are held for >7 weeks, but higher bedding usage or partial clean-out of the shed is undertaken between shed clean-outs, a factor lower than 1 is justified.

This table refers to the shed odour emissions at a site. and represents the reduction in shed odour arising from the design and management of the sheds. The factor used is 1 minus 75% of the odour emissions reduction. For, example, reduction in shed odour emissions of 50% gives a factor of 1 – (75% of 50%) = 0.63. Where different building design or management practices exist within the piggery complex, the effluent removal factor should be weighted according to the number of SPUs included in each management system. The effluent removal factor could be adjusted if there is new odour-reducing technology employed that can be demonstrated and quantified.

Effluent treatment, SI_T

The effluent treatment factor relates to the odour potential of piggeries based on the design of the effluent treatment system – the anaerobic pond for conventional shed systems, spent deep litter management for deep litter systems. Table A.5 lists effluent treatment factors. For conventional piggery systems, these factors may change according to whether solids separation is used before the pond.

These guidelines assume a maximum anaerobic effluent treatment pond size equivalent to half the size calculated using the Rational Design Standard. Under these circumstances, pond treatment efficiency is not significantly affected, but regular desludging is required. Where pond design varies significantly from this design volatile solids loading rate, the effluent treatment factor may need to be altered accordingly. Nicholas *et al* (2003) provides information for estimating the effect of different pond designs.

TABLE A.5 **Values of effluent treatment factor, $S1_T$**

Effluent Treatment	Factor
Pond with >40% separation of VS before pond[a]	0.80
Pond with 25 – 40% separation of VS before pond[a]	0.90
Pond with <25% separation of VS before pond[a]	1.00
Permeable pond cover[b] – preliminary factor, subject to change	0.63
Impermeable pond cover[c]	0.50
Deep litter system – spent bedding stockpiled / composted near sheds	0.63
No manure treatment / storage on-site – effluent / litter removed from site[d]	0.50

VS = volatile solids

[a] Solids separation efficiency should be based on results published in technical reports. Where VS removal is not reported, measures of total solids removal will generally provide a conservative estimate of VS removal efficiency. Summary information for a range of separators is available in Watts *et al* (2002). The reduction factors in this table assume that pond surface area is reduced as a result of the use of the separator. No reduction applies if the pond surface area remains unchanged.

[b] A permeable pond cover assumes a consistent odour reduction of at least 75%.

[c] An impermeable pond cover assumes a 100% pond odour reduction.

[d] No manure / effluent treatment on-site assumes that some temporary storage or mixing area exists near the sheds, but that design and management of the storage / mixing area minimises emissions from this source.

This table refers to the odour emissions from the effluent treatment system and represents the reduction arising from the design and management used. As shed odour emissions have already been considered, reductions in total site odour are presented in this table to ensure the formula calculations are sensible. For the purposes of these guidelines, a piggery is assumed to have two main odour sources – ponds are assumed to contribute 75% to total site odour and sheds 25%. The factor used is 1 – (75% of the odour emissions reduction). For example, a reduction in total pond odour emissions of 33% will reduce total site odour emissions by 25%, giving a factor of 1 - (75% of 25%) = 0.81. Where different building design or management practices exist within the piggery complex, the effluent treatment factor should be weighted according to the number of SPUs included in each management system.

Permeable covers are generally only installed over the anaerobic pond, which is assumed to contribute 90% of the total pond odour at a piggery (thus contributing 68% of total site odour). The factor used is 1 – (75% of the odour emissions reduction). For example a reduction in anaerobic pond odour of 75% will reduce total site odour by 75% of 90% of 75% = 50%, giving a factor of 1 – (75% of 50%) = 0.63.

Piggery design factor, S1 summary

The two factors listed above provide the basis for estimating the relative odour potential for the piggery design selected for a particular site. Multiplying these factors together gives a total piggery design factor *(ie piggery design factor, S1 = effluent removal factor, $S1_R$ x effluent treatment factor, $S1_T$)*.

Example Calculation:

Consider a proposed 1000-sow farrow-to-finish piggery growing pigs out to 24 weeks, breeder pigs housed in conventional sheds, all progeny in deep litter after three weeks of age, and using a run-down screen separator. Batches of weaned pigs are housed in weaner deep litter sheds from 3-10 weeks, and then moved into grower deep litter sheds from 10-24 weeks on one batch of litter. Bedding is added to the deep litter sheds at approximately 0.65 kg/pig/day, and spent litter is stockpiled on-site before spreading.

The piggery will have approximately 10,000 pigs and approximately 10,000 SPU.

The conventional sheds will house approximately 2000 SPU, the weaner deep litter sheds approximately 1000 SPU and the grower deep litter sheds approximately 7000 SPU.

The effluent removal factor for the site, $S1_R$ = (2000 SPU/10,000 SPU x 1) + (1000 SPU/10,000 SPU x 0.63) + (7000 SPU/10,000 SPU x 1) = 0.906

A properly designed and maintained run-down screen will separate 25% of the VS from the effluent before the pond.

The effluent treatment factor for the site, $S1_T$ = (2000 SPU/10 000 SPU x 0.9) + (8000 SPU/10,000 SPU x 0.63) = 0.684.

The piggery design factor for the site, S1 = 0.906 x 0.684 = 0.62.

The relatively low value of this design factor reflects the fact that the piggery is housing most of its pigs on deep litter. Consequently, the size of the anaerobic pond at the site is very much smaller than it would be for a conventional piggery, substantially reducing the potential odour emissions from the site. The run-down screen also reduces the required pond size.

A5.5 Piggery Siting Factor, S2

A number of piggery siting factors will influence the dispersion of odours emitted from a piggery. These factors differ from site to site, and have a substantial influence on the potential odour impact at receptors. The factors having the most influence on odour dispersion are discussed below. A composite 'siting factor' for the piggery is obtained by multiplying the factors together.

Receptor type factor, $S2_R$

The receptor factors presented in Table A.6 account for the variation in population density, odour sensitivity and risk of exposure for receptors located in the vicinity of a piggery. Different receptor factors have been adopted for the various receptor types.

TABLE A.6 Values of receptor type factor, $S2_R$

Receptor Type	Factor
Town	25
Rural Residential	15
Rural Dwelling	11.5

Notes: The receptor definitions should be based on local authority classification.

The separation distance is to be measured to the edge of the town, not the centre. When determining the location of the edge of the receptor, land zoning and pending development applications lodged, but not yet under construction, should be taken into account. Local councils can provide this information. Public areas, such as camping grounds or picnic areas, may need to be considered as part of the assessment. The frequency of use and the time of day the area is occupied, provide guidance to the level of protection required. For example, day-use only areas are a substantially lower risk for odour impact than areas frequently used at night.

Surface roughness factor, $S2_S$

The surface roughness factor varies according to the roughness of the earth's surface between the piggery and the receptor. The principle elements that determine surface roughness are vegetation density and surface topography. Recommended values of surface roughness are provided in Table A.7. The values presented in this table are not to be added; only the value for the single category that best represents the site conditions should be selected.

The roughness factors given in Table A.7 assume that the selected roughness is continuous between the piggery and the receptor. Where roughness is variable or non-continuous, judgement should be used in selecting an appropriate composite factor.

The values given in Table A.7 should be used with care and a number of qualifications apply to their use. For receptors located at larger separation distances, more than one surface roughness factor may apply over different sections of the separation. In this instance, the surface roughness factor applied should be selected after considering the relative weighting of the different factors. When selecting factors based on the presence of vegetation, some consideration should be given to the potential for the vegetation to be cleared during the life of the piggery. For example, off-site vegetation is beyond the control of the piggery, but may be regarded as permanent depending on the owner of the land (e.g. national park / state forest where no timber harvesting is undertaken).

APL commissioned a report providing guidance on meteorological data for odour dispersion models (Pacific Air and Environment, 2003a). This report also provides some guidance regarding surface roughness factors for use in dispersion modelling.

TABLE A.7 Values of surface roughness factor, $S2_S$

Surface Roughness Features	Description	Factor
Long grass, few trees	Open country with few or scattered trees. Topography would be predominantly flat to slightly undulating.	1.00
Undulating hills	Situations where topography consists of continuous rolling, generally low-level hills and valleys, but without sharply defined ranges, ridges or escarpments *(assumes minimal vegetation).*	0.93
Level wooded country	Open forest country, with tree density not sufficient to provide a continuous canopy, but sufficiently dense to influence air movement. There would be little or no lower storey vegetation. The density is such that the vegetation can be considered as a continuous belt.	0.85
Heavy timber	Generally tall forests with dense timber stands, providing a continuous canopy. There is limited understorey vegetation, mainly associated with regrowth.	0.77
Significant hills and valleys	Situations where one or more lines of hills, sufficiently large enough to influence air movement, exist between the receptor and the piggery	0.68

Piggery siting factor, S2 summary

The factors listed above provide the basis for estimating the relative odour dispersion potential for the selected piggery site. Multiplying these factors together gives a total piggery siting factor (i.e. *piggery siting factor, S2 = receptor type factor, $S2_R$ x surface roughness factor, $S2_S$*). For sites with more than one receptor type located nearby, a piggery siting factor will be calculated for each receptor type.

Example Calculation:

Consider the proposed 1000-sow farrow-to-finish piggery described earlier. The site is located 8 km west of the nearest town, but is 2.5 km west of a rural residential subdivision. A number of farm houses are sited on properties adjoining the proposed piggery site – the nearest is located 1150 m to the north, another is 1300 m to the north-east, another 1700 m to the west and another 1950 m to the south. The local council has been consulted regarding the boundary of residential zonings for the town and rural residential developments. The piggery site, town boundary and the boundary of the rural residential site have been located using a global positions system (GPS) with +/- 5 m accuracy. The separation to the farmhouses has been estimated from maps.

The property is located in an area of flat to undulating topography, with mixed farming and forestry the dominant land-uses. The forestry land has not been logged for many years, with logging or clearing unlikely to occur in the near future. The land between the proposed piggery site and the farmhouses to the north and north-east is undulating, with an established 500 m thick continuous timber-belt along the northern and eastern boundary of the piggery property, located within the property. Forestry land extends from the eastern boundary of the property to the boundary of the rural residential development. The land between the proposed piggery site and the farmhouses to the south and west is flat to undulating, with scattered clumps of trees and a few trees along fences.

Separation distances will need to be calculated for three receptor classes, town ($S2_R$ = 25), rural residential ($S2_R$ = 15) and rural dwelling ($S2_R$ = 11.5). Where different surface roughness categories exist for a particular receptor class, separation distances need to be calculated for each combination of receptor class / surface roughness category.

The surface roughness used for the town and the residential area would be heavy timber ($S2_S$ = 0.77) due to the well-established continuous stand of forest and the fact that it is unlikely to be cleared.

The surface roughness used for the farmhouses to the north and north-east would be level wooded country ($S2_S$ = 0.85) due to the undulating nature of the terrain, plus the continuous belt of established timber within the property in those directions.

The surface roughness used for the farmhouses to the south and the west of the residential area would be limited ground cover / short grass ($S2_S$ = 1.0) due to the flat to undulating nature of the terrain and the lack of a continuous, thick tree cover.

The piggery siting factor (town) for the site:	S2 = 25 x 0.77 = 19.25
The piggery siting factor (residential) for the site:	S2 = 15 x 0.77 = 11.55
The piggery siting factor (rural – N / NE) for the site:	S2 = 11.5 x 0.85 = 9.8
The piggery siting factor (rural – S / W) for the site:	S2 = 11.5 x 1 = 11.5

A5.6 Terrain Weighting Factor, S3

The terrain weighting factor (S3) relates to the potential for a piggery odour plume to be exaggerated in particular directions, and relatively small in others. Recently completed work funded by APL (APL Project 1921, Milestone Report 2, Nicholas and McGahan 2003) provides a methodology for incorporating important wind features, based on the topography of a specific site. This method provides an estimation of the potential changes to odour dispersion in situations where meteorological conditions may be influenced by local terrain.

The recommended factors are shown in Table A.8, along with the direction in which each factor should be applied. The slope referred to is determined by the topographical features of each site. The use of these terrain weighting factors does not affect the application of surface roughness factors discussed in Section A5.2.

TABLE A.8 Values of terrain weighting factor, S3

Terrain	New Weighting Factor	
	Downslope	Upslope
Broad valley/Drainage (0.1-1%)	1.6	1
Sloping terrain (1-2%)	1.5	1
Flat (<0.1% in all directions)	1	1
Hilltop (>4%)	1.2	-
Narrow valley (1-2%)	1.2	0.5

Notes:

1. These factors may not apply where sea breezes have a significant influence on weather patterns (i.e. in coastal regions) or where odour is emitted from elevated vent sources.
2. Downslope factors should be applied across an angle of 90° centred on the terrain feature. Upslope factors should be applied across an angle of 60° centred on the terrain feature.

The location of the piggery should be checked in relation to the topography. For example:

- If the piggery is situated on a slight slope (<1%) within a broad valley, a terrain weighting factor of 1 should be used upslope and 1.6 downslope of the facility
- If the piggery is situated on a moderate slope (1-2%), a terrain weighting factor of 1 should be used upslope and 1.5 downslope of the facility.

Weighting factors should be applied for the range of distances applicable to piggery impacts. However, the application of these weighting factors is dependent on the homogeneity of terrain between source and receptor. For example, if the terrain remains similar between the piggery and receptor, the weighting factor can be applied for an indefinite distance. The weighting factor is, however, less reliable if significant terrain changes occur between source and receptor.

The terrain weighting factors apply to most locations. If, however, the site is not described by these factors, the terrain weighting factor of 1.0 should be used.

Example Calculation:

Consider the proposed farrow-to-finish piggery site described in the previous example.

The terrain of the area is flat to undulating, thus the terrain weighting factor, S3 = 1.

The required separation distance (town) for the site:
$D = (10{,}000)^{0.55} \times 0.62 \times 19.25 = 1892$ m

The required separation distance (residential) for the site:
$D = (10{,}000)^{0.55} \times 0.62 \times 11.55 = 1135$ m

The required separation distance (rural – N / NE) for the site:
$D = (10{,}000)^{0.55} \times 0.62 \times 9.8 = 963$ m

The required separation distance (rural – S / W) for the site:
$D = (10{,}000)^{0.55} \times 0.62 \times 11.5 = 1130$ m

A5.7 Maximum Pig Numbers

The maximum number of pigs allowed on the site can also be calculated, by rearranging the formula, as shown in the example below.

Example Calculation:

Consider the proposed farrow-to-finish piggery site described in the previous example. The factor values are calculated in the same manner as presented in the previous examples.

Maximum pig numbers will need to be calculated for the distance available for each combination of receptor class / surface roughness category. For each combination of receptor class / surface roughness category, choose the closest receptor to use in calculations. The maximum number of pigs allowed for the site is equivalent to the smallest value from the calculations.

Maximum pig numbers (N) = $(D / (S1 \times S2 \times S3))^{1/0.55} = (D / (S1 \times S2 \times S3))^{1.82}$

The maximum pig numbers (town) for the site:
$N = (8000 / (0.62 \times 19.25 \times 1))^{1.82} = 139{,}250$ SPU

The maximum pig numbers (residential) for the site:
$N = (2500 / (0.62 \times 11.55 \times 1))^{1.82} = 42{,}480$ SPU

The maximum pig numbers (rural – N / NE) for the site:
$N = (1150 / (0.62 \times 9.8 \times 1))^{1.82} = 13{,}940$ SPU

The maximum pig numbers (rural – S / W) for the site:
$N = (1700 / (0.62 \times 11.5 \times 1))^{1.82} = 21{,}220$ SPU

The maximum number of pigs allowed on the proposed site, using the proposed design and management options, is the smallest number above - 13,940 SPU.

A5.8 Minimum Separation Distances

Minimum separation distances are included largely to account for inaccuracies with predicting odour impact at close distances. Both the site-specific and minimum separation distance to receptors (town, rural residential and rural dwelling) must be calculated, and the greater distance of the two applied. **The relevant approved authority should be contacted to determine the minimum separation distances applicable, or methods for calculating them.**

A5.8.1 Piggery complex separation

Minimum separation distances required for a piggery complex are shown in Table A.9. Sites that have separate piggery units on the one property should apply the separation formula to the combined units, and for each receptor apply the separation distances from the nearest part of the closest piggery complex. Guidance should be obtained from the relevant approved authority to apply the separation formula individually to separate units on the same property.

TABLE A.9 Separation distances from piggery sites to other relevant features

Feature	Distance (m)
Public road – carrying > 50 vehicles per day	200
Public road – carrying < 50 vehicles per day	100
Town	750
Rural residential area	500
Rural dwelling	250
Property boundary	20

Notes:

1. The measuring point for a public road shall be the surveyed boundaries of the road, on the same side of the road as the piggery operation.
2. Traffic volume excludes vehicles associated with the piggery operation.
3. These are minimum fixed separation distance to towns, rural residential areas and rural dwellings. The variable separation distance must also be calculated, and the greater distance of the two applied.

A5.8.2 Separation from by-product reuse areas

Separation distances from reuse areas to relevant receptors and features are shown in Table A.10, depending on the type of reuse system employed. Reuse areas are not included as part of the piggery complex, because by-product application occurs infrequently and because there may be multiple reuse areas on a farm that are not all used at the same time. These distances are in addition to separation zones for the piggery complex and are determined separately. Whenever by-products (liquids, solids or slurry) are transported or conveyed across a property boundary or along public roads, they shall be contained in a closed vessel or pipe. **It will also be necessary to gain permission from the land owner or approved authority (e.g. local government agency and / or road authority).** The following categories describe the reuse method employed, with the specified distances for each category listed in Table A.10.

Category 1

- Effluent is discharged or projected to a height in excess of 2 metres above ground level.
- Separated solids or sludge that remain on the soil surface for more than 24 hours (i.e. are not immediately ploughed in).
- Spent bedding that is spread immediately (i.e. is not stockpiled / composted) and remains on the soil surface for more than 24 hours (i.e. is not immediately ploughed in).

Category 2

- Mechanical spreaders and downward discharge nozzles. The discharged material shall not be projected to a height in excess of 2 metres above ground level.
- Spent bedding that has been stockpiled before spreading.

Category 3

- Discharge by injection directly into the soil (to a depth of not greater than 0.4 metres) and at a rate not exceeding either the hydraulic or nitrogen, phosphorus and potassium limits determined for the local soil type(s).
- Spent bedding / solids that have been composted.
- Application of effluent / spent bedding / solids in combination with immediate incorporation of material into the soil.

Where more than one category is used, the more (or most) stringent category controls will apply.

TABLE A.10 Separation distances surrounding by-product reuse areas

Feature	Category no.		
	1	2	3
Town	1000	750	300
Rural residential area	600	400	150
Rural dwelling	300	200	100
Public road – carrying > 50 vehicles per day	50	25	0
Public road – carrying < 50 vehicles per day	25	15	0
Property boundary	25	20	0

Notes:

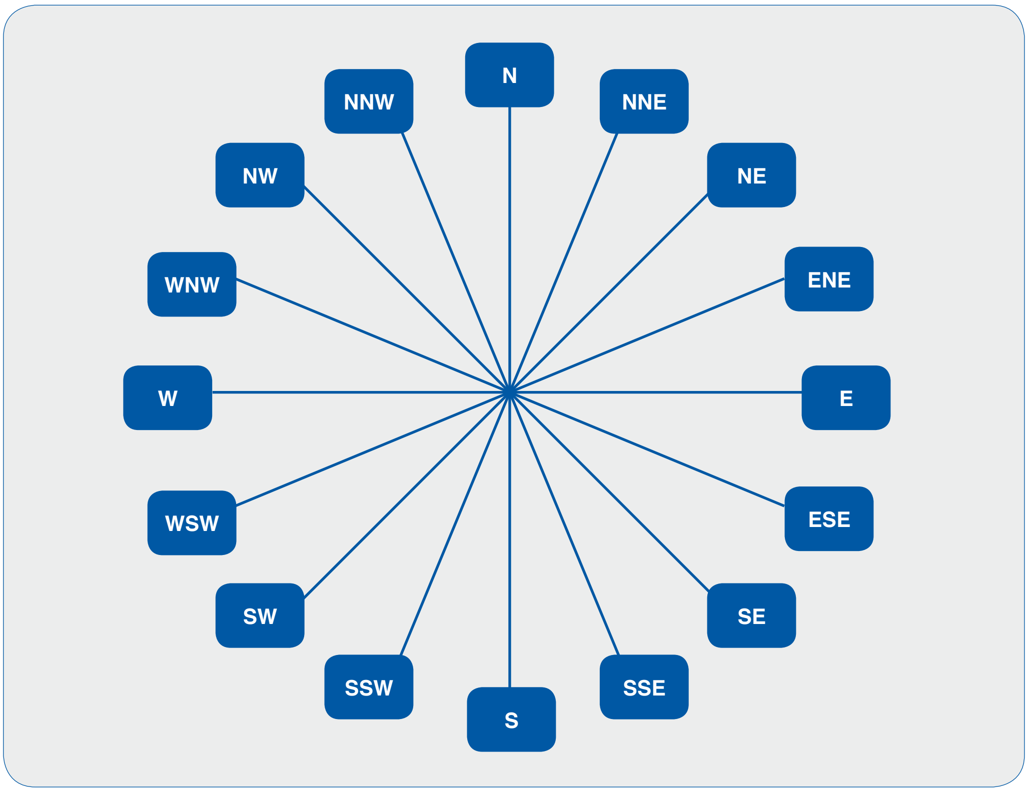
1. Distances shall be measured from the perimeter of the area used for handling or reuse of effluent.
2. The fixed separation distances surrounding by-product reuse areas should be used as a guide. Dispensation may be obtained for these distances following site-specific assessment from the relevant approved authority.
3. Traffic volume excludes vehicles associated with the piggery operation.

A5.9 Level 1.5 Assessments – Wind Frequency Factor, S4

Tonkin Consulting (2008) developed a method for adjustment of the Level 1 separation distances determined by S factors to prevailing wind directions and wind direction frequencies. The method developed analyses wind frequencies for low wind speeds below a certain threshold, and not for all winds or prevailing wind directions.

The method (Level 1.5 Assessment) applies wind direction frequencies to the Level 1 separation distances that are already calculated (as described in sections A5.1 to A5.6). This is done by calculation of the percentage of the wind direction frequencies for the sixteen compass points illustrated in Figure A5.7.1 below, for wind speeds below a certain threshold. Wind speeds above a certain threshold are excluded, as the dispersion conditions predicting the greatest odour impact occur in low wind speed conditions.

FIGURE A5.7.1 Compass points used for adjustment of Level 1 separation distances



Tonkin Consulting (2008) investigated the optimum wind speed cut off threshold, by comparing the contour for the calculated wind direction frequency adjusted separation distances to the contours for dispersion modelling (using AUSPLUME) results for the 98th percentile and 1 hour averages. It was found that a cut off threshold of 3 m/s presented the best match overall, between the dispersion modelling (using AUSPLUME) predicted odour contours for 1 odour unit (OU), 2 OU and 3 OU and the wind direction frequency adjusted Level 1 separation distances for the three receptor types described in Section A5.5.

For added conservatism, a safety factor of 20% was added to the calculated reduced separation distances, to cover sites with lower average wind speed. **The appropriate safety factor to use may vary, and this should be discussed with the approved authority before calculating separation distances using this method.** Furthermore, only meteorological data sets approved by the approved authority should be used. The Level 1.5 method used to calculate wind frequency factors (S4 factors) for a given site, does not allow the calculated adjusted separation distances to be greater than the calculated separation distances using the Level 1 assessment.

The steps used to calculate the 16 wind frequency factors (S4 factors) for a given site (Level 1.5 assessment method) are:

1. Obtain a meteorological file representative of the site that has been approved by the approved authority (see Section A6.3)
2. Calculation of wind direction frequencies for the 16 compass points (see Figure A 5.7.1) for wind speeds ≤ 3m/s. Thus, all wind speeds > 3 m/s need to be deleted before the analysis is conducted
3. Division of wind direction frequencies for each of the sixteen compass points with the direction with the highest frequency. This will achieve a reduction of the Level 1 separation distance from the highest frequency set to 1.0
4. Assigning of wind direction frequencies S to N, NNE to SSW etc., to account for wind blowing from odour source (piggery) to impact area (downwind). This means that wind direction frequencies need to be switched 180^0 to account for winds blowing from source to receptor
5. Presentation of wind direction frequencies result percentages in table (see column 2 of example below – Table A.11)
6. Addition of safety factor (agreed to by the applicable regulatory authority) to the wind direction frequencies (see column 3 of example below – Table A.11)
7. Division of adjusted wind speed frequency by 100 to determine the 16 wind speed frequency factors (S4 factors) for the site. See column 4 of Table A.11 below that shows the 16 wind frequency factors calculated for Roseworthy with a safety factor of 20%.

TABLE A.11 **Calculation of wind frequency factors for roseworthy**

Compass point direction	S factor wind direction frequency	S factor wind direction frequency including 20% safety factor	Wind frequency factors (S4) for Roseworthy
North	71%	91%	0.91
North North-east	71%	91%	0.91
North-east	67%	87%	0.87
East North-east	55%	75%	0.75
East	42%	62%	0.62
East South-east	41%	61%	0.61
South-east	54%	74%	0.74
South South-east	47%	67%	0.67
South	65%	85%	0.85
South South-west	66%	86%	0.86
South-west	100%	100%	1.00
West South-west	96%	100%	1.00
West	99%	100%	1.00
West North-west	79%	99%	0.99
North-west	50%	70%	0.70
North North-west	67%	87%	0.87

Calculation of separation distances for each receptor type follows the form:

separation distance (D) = $N^{0.55}$ x S1 x S2 x S3 x S4

Definitions for N, S1, S2 and S3 are provided in section A5.2. S4 is the wind frequency factor for estimating the relative odour impact due to the frequency of wind direction for wind speeds less than 3 m/s for a site.

A5 LEVEL 1 AND LEVEL 1.5 ASSESSMENTS

Example Calculation:

Consider a 4000 SPU deep litter piggery located near Roseworthy. Bedding is added to the deep litter sheds at approximately 0.65 kg/pig/day and spent litter is stockpiled on-site before spreading. The piggery is surrounded by limited ground cover / short grass. We wish to calculate the minimum distance to a rural dwelling in the 16 compass points surrounding the piggery. The piggery is surrounded by flat open terrain in all directions.

The piggery will have approximately 10,000 pigs and approximately 10,000 SPU.

The effluent removal factor for the site, $S1_R$ = 1.0.

The effluent treatment factor for the site, $S1_T$ = 0.63.

The piggery design factor for the site, S1 = 1.0 x 0.63 = 0.63.

The receptor type factor to be calculated (rural dwelling), $S2_R$ = 11.5.

The surface roughness factor for the site S2s = 1.0

The terrain weighting factor for the site, S3 = 1.0

The required separation distance in all directions to a rural dwelling using the Level 1 assessment is:

$$\mathbf{D = (4000)^{0.55} \times 0.63 \times 11.5 \times 1.0 = 694\ m}$$

Now, applying the wind frequency factors (S4 factors) for the site (Roseworthy), gives the following 16 separation distances to a rural dwelling:

The wind frequency factor to the north, $S4_N$ = 0.91, thus D_N = 629 m

The wind frequency factor to the north, $S4_{NNE}$ = 0.91, thus D_{NNE} = 629 m

The wind frequency factor to the north, $S4_{NE}$ = 0.87, thus D_{NE} = 600 m

The wind frequency factor to the north, $S4_{ENE}$ = 0.75, thus D_{ENE} = 520 m

The wind frequency factor to the north, $S4_E$ = 0.62, thus D_E = 426 m

The wind frequency factor to the north, $S4_{ESE}$ = 0.61, thus D_{ESE} = 421 m

The wind frequency factor to the north, $S4_{SE}$ = 0.74, thus D_{SE} = 510 m

The wind frequency factor to the north, $S4_{SSE}$ = 0.67, thus D_{SSE} = 461 m

The wind frequency factor to the north, $S4_{NE}$ = 0.85, thus D_{NE} = 590 m

The wind frequency factor to the north, $S4_{SSW}$ = 0.86, thus D_{SSW} = 595 m

The wind frequency factor to the north, $S4_{SW}$ = 1.00, thus D_{SW} = 694 m

The wind frequency factor to the north, $S4_{WSW}$ = 1.00, thus D_{WSW} = 694 m

The wind frequency factor to the north, $S4_W$ = 1.00, thus D_W = 694 m

The wind frequency factor to the north, $S4_{WNW}$ = 0.99, thus D_{WNW} = 689 m

The wind frequency factor to the north, $S4_{NW}$ = 0.70, thus D_{NW} = 486 m

The wind frequency factor to the north, $S4_{NNW}$ = 0.87, thus D_{NNW} = 605 m

Figure A5.7.2 shows the application of the wind speed frequency factor for the example 4000 SPU deep litter piggery located at Roseworthy, with the separation distance calculated using the Level 1 method, and the adjusted separation distance with the inclusion of the wind frequency factors (S4 factors) of the Level 1.5 method.

FIGURE A5.7.2 **Application of wind speed frequency factor on a 4000 SPU deep litter piggery located at Roseworthy for a rural dwelling**

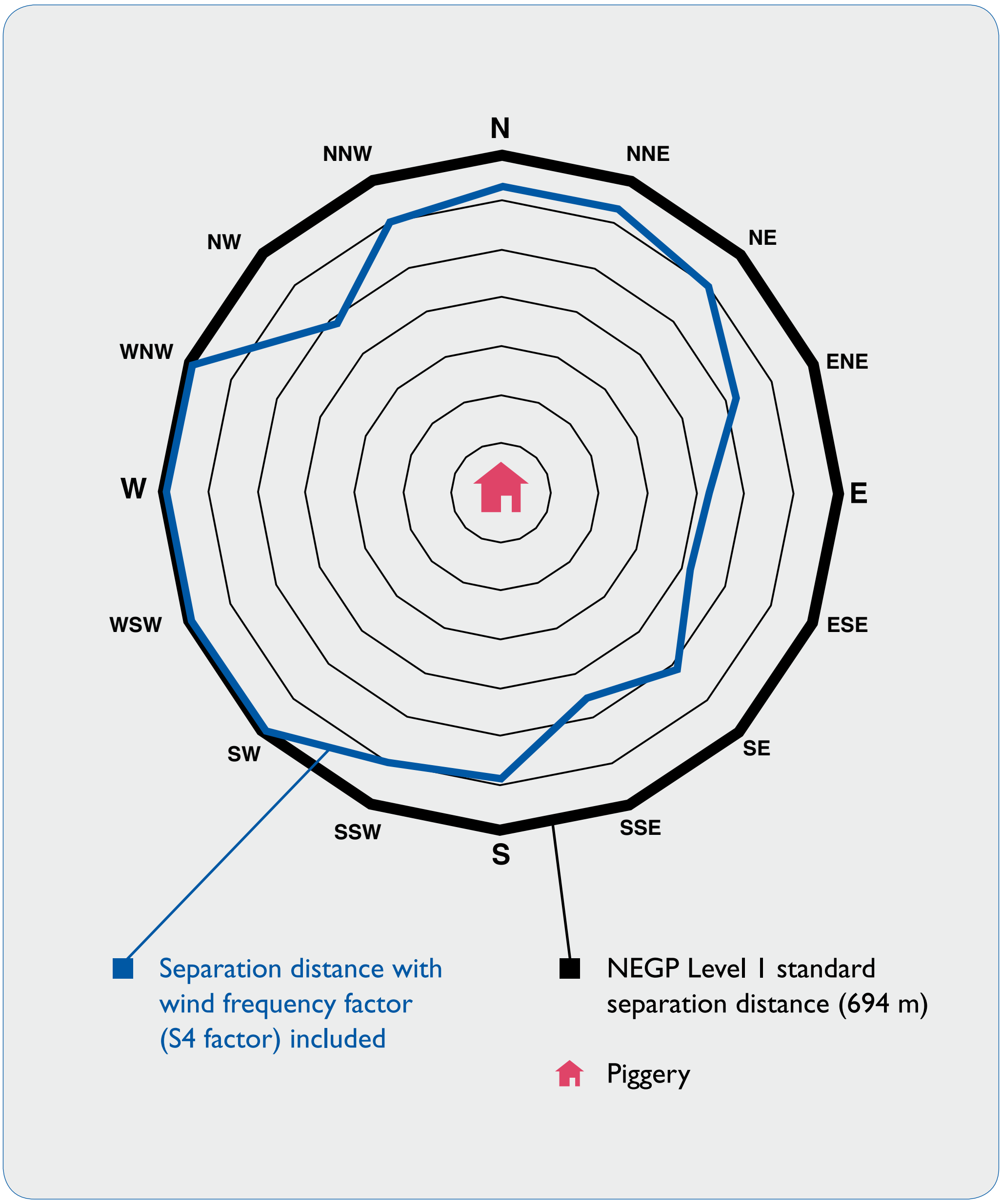


Table A.12 shows the calculated wind frequency factors for six different sites with agreed meteorological files and safety factors by the relevant regulatory authority. For calculation of wind frequency factors for additional sites, the above methodology needs to be employed.

TABLE A.12 Wind frequency (S4) factors

Compass point direction	S4 factors for Mt Gambier	S4 factors for Murray Bridge	S4 factors for Padthaway	S4 factors for Renmark	S4 factors for Roseworthy	S4 factors for Strathalbyn
North	1.00	1.00	0.84	0.87	0.91	0.82
North north-east	0.75	0.98	0.75	0.87	0.91	0.79
North-east	1.00	0.83	0.65	0.92	0.87	1.00
East north-east	0.95	0.65	0.74	1.00	0.75	0.90
East	0.98	0.57	0.77	1.00	0.62	0.86
East south-east	0.83	0.50	0.81	0.73	0.61	0.96
South-east	0.94	0.50	0.82	0.52	0.74	1.00
South south-east	1.00	0.69	0.83	0.38	0.67	1.00
South	1.00	1.00	1.00	0.52	0.85	1.00
South south-west	0.99	0.97	0.66	0.60	0.86	0.80
South-west	1.00	0.44	0.57	0.84	1.00	0.72
West south-west	0.72	0.32	0.55	0.85	1.00	0.59
West	0.73	0.34	0.48	0.84	1.00	0.64
West north-west	0.73	0.41	0.61	0.75	0.99	0.47
North-west	0.95	0.50	1.00	0.74	0.70	0.60
North north-west	0.77	0.76	1.00	0.74	0.87	0.63

A6 Odour Modelling

A6.1 Introduction

Dispersion models can provide concentration estimates over an almost unlimited grid of user-specified locations, and can be used to evaluate emissions from proposed expansions or new developments. The results of the dispersion modelling analysis can be used to develop control strategies that should ensure compliance with the odour performance criteria. Dispersion models can also be used to estimate the cumulative impacts of various facilities that are located sufficiently close to one another.

Meteorological conditions govern the transport and dispersion of odours. It is therefore important, when modelling emission sources, to use meteorological data that are specifically representative of the site and the surrounding region in general. Sufficient meteorological data should be available to ensure that 'worst case' conditions are adequately represented in the model predictions. This requirement is especially important given that the odour performance criteria need to be determined and reported on a statistical basis. Meteorological data requirements are discussed further in Section A2.3.

The AUSPLUME dispersion model is widely accepted by Australian regulatory authorities as the default model to use for odour impact assessments on new and expanding premises. **Where complex terrain exists, other accepted models may be used, but these should be checked with the appropriate approved authority before conducting an assessment.** More detailed discussion on the selection and use of odour dispersion models is provided in Pacific Air and Environment (2003b).

A6.2 Method

The general process for odour modelling is:

1. List all potential odour sources. Include all sources within the site boundary, and any nearby sources beyond the boundary, if they could contribute to cumulative odour impacts.
2. Gather data for each release point. For each release point:
   - select area or volume source options within the chosen dispersion model
   - determine source location coordinates in metres relative to a fixed origin.
3. Determine appropriate impact criteria. Where a range of receptor types is present around a piggery, select the appropriate odour impact criteria for each receptor.
4. For all sites:

   Estimate emission quantities. The APL Variable Emission File (VEF) Maker Software provides recommended emission rates for most piggery odour sources. Site-specific data should be used where available.

A6 ODOUR MODELLING

- Odour emissions should be presented as mass emission rates in OU / second.
- Where applicable, include periodic variations in emission rates.

Estimate source release parameters. The APL VEF Maker provides methods for incorporating emission release characteristics into odour modelling.

- For diffuse area sources determine surface area, side length and release height.
- For diffuse volume sources determine side length and release height.

5. Incorporate other dispersion modelling parameters:
   - appropriate averaging time (i.e. 1 hour).
   - location of receptors (and likely future receptors) such as rural dwellings, rural residential areas, schools and towns.
   - a meteorological data file for the site.
6. For all sites, consider what scenarios to include in analysis. Alternative scenarios may be investigated to assess:
   - the odour reduction potential of different design and management processes source release parameters.
   - the sensitivity of model results to changes in key model parameters (e.g. different land use factors).
7. Prepare dispersion model input files and run computer-based model.
8. Process dispersion model output files.
9. Analyse dispersion model results. For Level 2 and Level 3 odour impact assessments, determine the impacts equivalent to the standard odour impact criteria (i.e. 3 OU, 98%, one hour average). Graphical and tabulated results should be compared to the impact criteria.
10. Prepare odour impact assessment report. An odour impact assessment report should address each of the following areas in detail:
    - site plan
    - description of the activities carried out on the site
    - description of meteorological data
    - emission inventory
    - dispersion modelling.

These guidelines assume all piggery odour sources are accurately represented as either area or volume sources. As a result, different modelling protocols may be required at some piggery sites particularly those that include:

- point or line sources
- receptors in the near-field (typically 10 x the largest source dimension)
- complex terrain or meteorological conditions.

In these cases, advice regarding appropriate modelling protocols should be obtained from the relevant approved authority.

A6.3 Site Sources and Emission Rates

A6.3.1 Piggery odour emissions

From an odour production perspective, the basic piggery designs used in Australia are generally referred to as conventional systems or deep litter (bedded) systems. Any given piggery site may include both conventional and deep litter systems.

The primary odour sources in a conventional piggery system are:

- effluent treatment ponds
- pig accommodation sheds.

The secondary odour sources in a conventional piggery system are:

- effluent reuse areas
- solid by-products reuse areas
- areas for storing or composting carcasses / separated solids / sludge (some sites)
- effluent settling basins (some sites).

The primary odour sources in a deep litter piggery system are:

- pig accommodation sheds.

The secondary odour sources in a deep litter piggery system are:

- spent bedding storage / composting areas
- carcass composting areas (some sites)
- solid by-products reuse areas.

Piggery layouts vary substantially between sites. In some cases, the sheds, effluent treatment and by-products storage or composting areas are all located in close proximity. At other sites, effluent treatment and by-products storage or composting may be separated from the sheds. Sometimes groups of sheds may be sited separately, with their effluent storage and by-product storage or composting areas.

When using site-specific or site-representative data, key points for consideration include:

- data quality
- seasonal or other temporal factors that impact on odour emissions
- similarity of climatic conditions
- similarity of design and management practices
- possible effects of terrain features on the collection of the initial data
- odour measurement methodology and the general level of agreement on any adjustment factors.

Odour concentration measurements should be undertaken using dynamic olfactometry to the Australian Standard – *Air quality – Determination of odour concentration by dynamic olfactometry*, AS /NZS 4323.3:2001 (Standards Australia / Standards New Zealand 2001).

A6 ODOUR MODELLING

The recommended odour emission rates from the APL Variable Emission File (VEF) Maker Software (Pacific Air and Environment 2004) should be used unless site-specific or site representative data are available. VEF Maker was developed by Australian Pork Limited (APL) for distribution to research and consulting groups. The software is designed to produce hourly varying emission files representing odour from pig sheds and effluent ponds, that can be used with dispersion models. This software includes the latest emissions data for the piggery industry in Australia for both buildings and treatment systems. VEF Maker calculates odour emission rates based on equations presented in Nicholas *et al* (2003).

Piggery odour sources are generally consistent, but intermittent high emissions may occur as a result of management (e.g. pond desludging) or other events. As these emissions rarely occur, it is more effective to assess these situations using a site risk assessment, and manage the potential impact through a site management plan.

For site-specific sampling of odours, procedures should be discussed with the appropriate approved authority.

An Australian Standard for sampling odours from area sources has been developed: Stationary Source Emissions – Method 4: Area Source Sampling – Flux Chamber Technique (ASNZS4323.4:2009).

Publications arising from APL project 1628 (e.g. Galvin *et al* 2002) have discussed the significant variability in odour concentration found from different sampling points on an anaerobic pond surface. For effluent treatment ponds, it is recommended that odour samples be collected from a minimum of six different points set out in a grid across the surface (excluding the surface above the side batters).

Smith *et al* (1999) discuss the variation in odour concentration within pig sheds. Substantial variation was found depending on ventilation design and wind direction. Therefore, sampling requirements will depend largely on the shed ventilation design.

Programs for collecting odour samples from piggery sources will need to factor background odours into their design. For downwind samples, this can be achieved by collecting samples of background air for analysis by olfactometry, or, for wind tunnels / flux hoods, by charcoal filtering of the air forced through the sampling equipment.

A6.3.2 Odour intensity measurements

Using dynamic olfactometry to determine odour concentration to the Australian Standard 4323.3:2001 (Standards Australia/Standards New Zealand 2001), and then odour intensity to the German Standard (VDI 1992), a suitable relationship between concentration and intensity can be determined, allowing different odour types to be compared. Stevens Law and the Weber-Fechner Law are examples of formulae that have widespread acceptance for defining the relationship between odour intensity and concentration for a particular odorant (including complex mixtures).

Once the odour intensity/concentration data are available, the Weber-Fechner law (shown below) should be used to develop the mathematical relationship between intensity and concentration. This relationship may then be solved for the odorant concentration that corresponds to an appropriate criterion. Generally, an intensity of three ('distinct') is used, but this value may vary depending on the averaging time percentile used in the odour impact criteria.

$$I = k_w \log(C/C_o) + const$$

where:

- I intensity (perceived strength), dimensionless;
- kw Weber-Fechner constant;
- C concentration of odorant;
- C_o concentration of odorant at the detection threshold (by definition equals one when using odour units);
- const a constant which relates to the use of mean intensity levels. This constant is calculated from the line of best fit for each odorant.

The Weber-Fechner law has been chosen over Stevens Law because it is simpler to derive from experimental data. It is also described in the German Standard (VDI 1992) with a worked example.

Facilities that have multiple odour sources should determine the odour intensity concentration relationship for each source and, as a minimum, use the concentration that relates to the strongest odour (highest intensity) for modelling.

Odour intensity results are input into a dispersion model using a measurement of odour emission rate (OU/s) and the results compared to odour concentration at the receptor equivalent to an intensity level of 'weak', for the same averaging period and the same percentile as is used in the odour impact criteria. For sources that are intermittent, and emit odour for only a fraction of the hours of the year, the variation in these emissions should be used to develop a criterion that is applicable for that source. By way of indication, the criterion would be likely to retain an intensity of 'weak' over the same averaging period, but with a higher percentile to reflect the degree of intermittency. Such an approach would give a level of protection against the highest events in the year, from intermittent sources similar to that given by the above criterion for continuous emissions.

An odour intensity assessment may be used as part of a Level 3 Assessment.

A6.4 Meteorological Data

APL has commissioned a report providing guidance on meteorological data for odour dispersion models (Pacific Air and Environment, 2003a), which provides more detailed discussion on this topic.

For the AUSPLUME dispersion model, the meteorological parameters required are:

- wind speed (m/s)
- wind direction (°)

- ambient temperature (°C)
- atmospheric stability class
- mixed layer height (m).

Wind speed, wind direction and ambient temperature can be directly measured, but atmospheric stability class and mixed layer height need to be indirectly determined by using other meteorological parameters with empirical formulae.

A meteorological station needs to measure and electronically log wind speed, wind direction and ambient temperature. In addition, for determining atmospheric stability class, either sigma theta (the standard deviation of the horizontal wind direction fluctuation) or total solar radiation, in conjunction with temperature measurements at two levels, must be measured and electronically logged. All parameters must be logged as one-hour average values, as a minimum requirement. An averaging time of no more than 5 minutes is necessary to determine the influence of mesoscale eddies on stable flows. With modern data logging facilities, many 'turbulence' characteristics can be computed continuously. If surface sources are likely to dominate the odour impact, serious consideration should be given to using a two-level (e.g. 10 m and 1 m) tower in order to estimate boundary layer characteristics and near-surface wind speeds, as these can affect dispersion and emission rates. All meteorological stations used to collect data for dispersion modelling purposes must use an anemometer that has a stall speed of 0.5 m/s or less.

Methods described in USEPA (2000) to calculate these factors are generally accepted by Australian regulatory authorities. The report should include a description of the meteorological data used, or alternatively, a reference to a publicly available report that contains this information. The description is to include details on the methodology used to derive stability classes and mixing heights, and is to present (as a minimum) the annual wind rose and annual stability frequency distribution. The description should also include details on the quality of the anemometer used and its starting threshold.

It is generally accepted that a minimum of five years of site-specific meteorological data are required in order to obtain confident model predictions. As the data set is reduced, uncertainties and under-predictions increase in model estimates.

A Level 2 or Level 3 odour impact assessment requires at least one year of site-specific meteorological data, for impact assessments based on dispersion modelling. Where possible, a one-year, site-specific data set should be correlated against a site-representative meteorological database of at least five years (preferably five consecutive years). If site-specific meteorological data is not available, it is required that at least one year of site-representative meteorological data be used for conducting impact assessments based on dispersion modelling.

To determine whether particular meteorological data is in fact site-representative, it must be clearly established that the data adequately describes the expected meteorological patterns at the site under investigation (e.g. wind speeds, wind direction, ambient temperature, atmospheric stability class, inversion conditions and katabatic drift).

For complex terrain, consideration should be given to determining streamline deflection and complex drainage flows by the short-term use of a network of 3 - 4 single-level anemometer stations. It is likely that flow characteristics can be established from 2 - 3 months of monitoring in both winter and summer.

A6.5 Model Selection

APL commissioned a report providing guidance in the selection and use of odour dispersion models - APL Project 1980, Task 2 (Pacific Air and Environment 2003b) - which provides more detailed discussion on this topic.

The models, procedures and data used in the assessment must be demonstrably capable of simulating, or accounting for, all of the features that are important in determining the air quality impact of the project. The proponent is responsible for identifying and properly accommodating these. The following list includes some examples of complex situations that may require the application of alternative processes to those included in these guidelines:

- vertical plume dispersion in convective conditions
- sea breeze trapping, recirculation of odour
- near-surface dispersion under very stable calm conditions (a feature of Western Australian winter meteorology)
- topographic influences - impact of plumes on elevated terrain, effect on spatially varying wind fields, valley winds (anabatic and katabatic winds), ponding of air in stable conditions
- surface roughness
- effects of positive or negative buoyancy.

The AUSPLUME model is frequently used in an acceptable manner for modelling odour emissions, but it has limitations that model users should understand.

A6.6 Multiple Odour Sources and Cumulative Impacts

Odours from intensive livestock facilities are typically complex mixtures of many odorants. The cumulative and interactive effects of individual odorants are not well understood, but it is generally assumed that where more than one source of a complex mixture of odorants are located in proximity, the potential odour impact on receptors is the sum of the potential individual impact of all odour sources. This approach is likely to provide a conservative assessment of the potential cumulative odour impacts.

APL commissioned a report providing guidance in the selection and use of odour dispersion models - APL Project 1980, Task 2 (Pacific Air and Environment 2003b). This report suggests that AUSPLUME should not be used for modelling multiple sites.

The necessity of including other odour sources in odour modelling will need to be judged according to individual site assessments. The major factors influencing the potential interaction of odour plumes will be:

- the size of each facility
- the prevailing meteorological conditions and topography of the area
- the design and management of each facility.

A simple method for assessing the need to include other facilities in modelling is to use a separation formula method (where available) to calculate separation distances for each facility. The calculated separation distance essentially approximates the odour plume. Where the odour plume from any neighbouring facility overlaps the odour plume from the facility being modelled, cumulative odour impact is possible, and that neighbouring facility should be included in modelling.

A6.7 Reporting Requirements

A6.7.1 Odour Sampling

Reports presenting results of odour sampling should include factors listed below.

A6.7.2 Objective

Before undertaking an odour measurement program, it is important to identify the objective of the program so that an appropriate program structure can be developed. The objective should be stated, and referred to, when justifying the sampling method and modelling undertaken.

A6.7.3 Sampling Program

Justification of sampling method in relation to the measurement objective should be included in the report. The sources sampled, and the timing of the samples taken, will depend on the objectives of the measurement program. Source conditions at the time of sampling should be appropriate for the purposes of modelling. For example, for most sources it will be necessary to sample during 'worst case normal' operating conditions.

A6.7.4 Contour Plots

The report should include plots of odour contours at appropriate intervals and values, to indicate the predicted impact of the piggery on the surrounding area. Contours should be overlaid on a map of the area, if possible, or should at least provide a clear indication of major features, such as the source, nearest receptors and major roads.

A6.7.5 Complaint Verification/Ground Truthing

Where complaints mapping has been used, a map showing locations from which complaints were received should also be included in the report and compared with modelled results. Maps and tables indicating results of any ground truthing (including comparison with modelled results) should be included in the report.

For environmental odours, ambient odour concentrations will generally be too low for determination using olfactometry, so ground truthing would typically involve qualitative assessment of ambient odour. Ormerod (2002) suggested that field observations can provide estimates of odour concentrations that appear to be similar in reliability to model predictions. It was noted that this work was based on the odour emissions from a stack source, where the odour plume exhibited substantial variation in concentration. Piggery odour plumes typically have lower concentration variation within the plume, and more gradual changes in concentration. As a result, it would be difficult to detect concentration variation using field observation, and there would be a higher potential for odour habituation to reduce observation accuracy.

A6.7.6 Olfactometry Testing

All results of olfactometry analysis should include the following information:

- how 'worst case' normal operating conditions were captured by sampling
- confirmation of sampling methodology and protocols (what standards were used)
- confirmation of what, if any, sample dilution was used during sample collection
- laboratory where olfactometry undertaken
- confirmation of method used (Australian Standard 4323.3:2001 Stationary source emissions - Determination of odour concentration by dynamic olfactometry is the preferred method); to ensure rigorous quality assurance and quality control procedures are adhered to when using these methods, consultants should generally be accredited by the National Association of Testing Authorities (NATA)
- time between sample collection and olfactometry analysis
- number of panellists and identification code of each
- certified reference material used, and its concentration
- result matrices for odour intensity analyses (see Figure 1 of the German Standard (VDI 1992)
- plot of the odour intensity-concentration relationship(s).

A6.7.7 Odour Modelling

The dispersion modelling and impact assessment report should address the information requirements specified below:

Site Plan

- layout of the site clearly showing all unit operations
- all emissions sources clearly identified
- plant boundary
- receptors (e.g. nearest residences)
- topography and large water sources in the area.

Description of the Activities Carried Out on the Site

- plans clearly showing all operations carried out on the premises
- detailed discussion of all operations carried out at the site, including possible operational variability
- detailed list of all process inputs and outputs
- plans and descriptions that clearly identify and explain all odour control equipment, and odour control or management techniques used
- operational parameters of all potential emission sources, including all operational variability, such as location, release type (e.g. stack, volume or area) and release parameters (e.g. stack height, stack diameter, exhaust velocity, temperature, emission rate) and process type (e.g. batch or continuous).

A6 ODOUR MODELLING

Description of Meteorological Data

- detailed discussion of the prevailing dispersion meteorology at the proposed site, typically including wind rose diagrams and an analysis of wind speed, wind direction, stability class, ambient temperature and joint frequency distributions of the various meteorological parameters
- description of the techniques used to prepare the meteorological data into a format for use in the dispersion modelling
- quality assurance / quality control analysis of the meteorological data used in the dispersion modelling. Any relevant results of this analysis should be provided and discussed
- meteorological data used in the dispersion modelling supplied in a suitable electronic format.

Emission Inventory

- detailed discussion of the methodology used to calculate the expected odour emission rates for each source
- where site-specific data is available, all supporting source emission test reports etc, methodologies used for the sampling and analysis for odour emissions
- where appropriate, a table showing all stack and fugitive source release parameters (e.g. temperature, exit velocity, stack dimensions and emission rates).

Dispersion Modelling

- detailed discussion and justification of all parameters used in the modelling, and the manner in which topography, and other site-specific peculiarities that may affect plume dispersion, have been treated
- the value(s) of the roughness length and details on how this was determined
- detailed discussion of predicted odour impacts, based upon predicted concentrations at all receptors
- odour isopleths (contours) and tables summarising the predicted odour concentrations at receptors
- all input, output and meteorological files used in the dispersion modelling supplied in suitable electronic format.

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Appendix B.

Environmental Risk Assessment

B1 Introduction

The purpose of an environmental risk assessment is to identify any actual or likely impacts that a piggery, or proposed piggery developing, may pose to the environment. This provides the basis for reducing impacts (or risks of impacts) through improved design, improved management or monitoring. There are three steps in this process:

- rate the vulnerability of the major natural resources
- rate the risk of each of the major design and operation features of the piggery
- evaluate the likelihood of an environmental impact.

Note that the information in Appendix B is designed to provide a guide to the risk of an environmental impact only. It is not designed to provide a guide to risk in other areas (e.g. workplace health and safety.

For an electronic version of this Environmental Risk Assessment please go to www.australianpork.com.au

B2 Natural Resources and Amenity (Vulnerability Ratings)

The first step in an environmental risk assessment is to rate the vulnerability of each of the major natural resources or amenities associated with the piggery, including:

- soils of reuse areas (if utilising by-products on-farm)
- groundwater quality and availability
- surface water quality and availability
- community amenity.

Information to assist in deciding resource and amenity vulnerability 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 the site vulnerability using these tables. To use the risk assessment:

1. Read the statements in the individual rating criteria.
2. Select the most appropriate rating for your farm. To do this, go through the options and tick the one of most relevance to your farm. The highest rating option ticked is your overall rating. For example, if you have ticked comments in the rating 1, 2 and 3 options, but not in the rating 4 option, your piggery is rating 3 for that vulnerability area.
3. Record the appropriate rating at the bottom of the page along with any comments that assisted in selecting the specific rating. This will allow for more ready identification of monitoring requirements later in the risk assessment process.

B2.1 Vulnerability Rating – Soils in Reuse Areas

Rating Criteria	Rating
Reuse areas, including outdoor rotational piggeries, are:	
• suited to growing a broad range of broadacre crops and pastures	1 ☐
• suited to growing crops or pastures that can be cut and carted	3 ☐
• unsuited to growing or harvesting crops or pastures that can be cut and carted	4 ☐
Reuse areas, including outdoor rotational piggeries, have a soil depth of :	
• at least 1 m	1 ☐
• at least 0.75 m	2 ☐
• at least 0.5 m	3 ☐
• less than 0.5 m	4 ☐
Reuse areas, including outdoor rotational piggeries, have soils that are:	
• well structured, non-rocky, non-saline and non-sodic	1 ☐
• non-rocky, non-saline and non-sodic	3 ☐
• soils are rocky or saline or sodic	4 ☐
Reuse areas, including outdoor rotational piggeries, have soils that are:	
• loam (25-30% clay) to medium clay (45-55% clay) in texture	1 ☐
• sandy loam (10-25% clay) to heavy clay (>50% clay) in texture	2 ☐
• sandy in texture	4 ☐
Reuse areas, including outdoor rotational piggeries, are:	
• not prone to waterlogging	1 ☐
• prone to waterlogging	4 ☐
Reuse areas, including outdoor rotational piggeries:	
• flood at a frequency of less than once every ten years	1 ☐
• flood at a frequency of less than once every five years	2 ☐
• flood more than once every five years on average	4 ☐
Reuse areas, including outdoor rotational piggeries, have slopes that promote:	
• infiltration, rather than runoff or erosion	1 ☐
• runoff or erosion	4 ☐
OVERALL RATING	☐

B2.2 Vulnerability Rating – Groundwater Quality and Availability

Rating Criteria	Rating
The 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	1 ☐
• always at least 10 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, and protected by a significant rock or clay band	2 ☐
• always at least 2 m below the ground surface or the base of any piggery infrastructure	3 ☐
• sometimes present at a depth of less than 2 m below the ground surface or the base of any piggery infrastructure	4 ☐
Water for potable use is:	
• not sourced from bores located within 1 km of the piggery	1 ☐
• sourced from bores located within 1 km of the piggery	4 ☐
If groundwater is used in the piggery, there is:	
• ample allocation and supply that is of a suitable quality to meet requirements	1 ☐
• sufficient allocation and supply that is of a suitable quality to meet requirements	3 ☐
• marginal or insufficient allocation or supply (and no other water source), or the water is of a marginal quality to meet requirements	4 ☐
OVERALL RATING	

B2.3 Vulnerability Rating - Surface Water Quality and Availability

Rating Criteria	Rating
The piggery is located:	
• at least 200 m from the closest watercourse	1 ☐
• at least 100 m from the closest watercourse	2 ☐
• within 100 m from the closest watercourse	4 ☐
The piggery is located:	
• at least 800 m from the closest major water supply	1 ☐
• within 800 m from the closest major water supply	4 ☐
Reuse areas, including outdoor rotational piggeries:	
• comply with the buffer distances in Table 6.1 of the National Guidelines, and there are also vegetative filter strips, or terminal ponds, between these areas and all watercourses	1 ☐
• comply with the buffer distances in Table 6.1 of the National Guidelines	2 ☐
• don't comply with the buffer distances in Table 6.1 of the National Guidelines, but there are effective VFSs (designed as per section 6.1 of the National Guidelines), or terminal ponds, between these areas and all watercourses	3 ☐
• don't comply with the buffer distances in Table 6.1 of the National Guidelines, and there are not effective VFSs (designed as per section 6.1 of the National Guidelines), or terminal ponds, between these areas and all watercourses	4 ☐
The piggery is located:	
• above the 1-in-100 year flood line	1 ☐
• above the 1-in-50 year flood line	3 ☐
• within the 1-in-50 year flood line	4 ☐
Reuse areas are located:	
• above the 1-in-10 year flood line	1 ☐
• above the 1-in-5 year flood line	2 ☐
• within the 1-in-5 year flood line	4 ☐
If surface water is used in the piggery, there is:	
• ample allocation and supply that is a suitable quality to meet requirements	1 ☐
• marginal or insufficient allocation or supply (and no other water source) or the water is of a marginal quality to meet requirements	4 ☐
OVERALL RATING	☐

B2.4 Vulnerability Rating - Community Amenity

Rating Criteria	Rating
The piggery has received:	
• no complaints from the public or regulators for at least five years	1 ☐
• less than two complaints per year (on average) over the past five years	2 ☐
• less than four complaints per year (on average) over the past five years	3 ☐
• four or more complaints per year (on average) over the past five years	4 ☐
Levels of odour, dust and noise around the property boundary are:	
• checked at least weekly	1 ☐
• checked at least monthly	2 ☐
• checked occasionally	3 ☐
• not routinely monitored	4 ☐
The piggery provides:	
• separation distances meeting the Level 1 criteria specified in Appendix A of the National Guidelines	1 ☐
• a separation distance of 80-99.9% of the Level 1 separation distance criteria, specified in Appendix A of the National Guidelines	3 ☐
• a separation distance of <80% of the Level 1 separation distance criteria, specified in Appendix A of the National Guidelines	4 ☐
Surrounding land is:	
• all designated rural, and is not designated for future development or rezoning	1 ☐
• all designated rural, but some is designated for either future development or rezoning	3 ☐
• not all designated rural	4 ☐
The piggery is:	
• well concealed from roads and neighbours	1 ☐
• fairly well concealed from roads and neighbours	2 ☐
• partly concealed from roads and neighbours	3 ☐
• clearly visible from roads and / or neighbours	4 ☐
The entrance point to farm provides:	
• at least 300 m good visibility in both directions	1 ☐
• at least 200 m good visibility in both directions	2 ☐
• at least 150 m good visibility in both directions	3 ☐
• less than 150 m good visibility in at least one direction	4 ☐

B2.4 (Continued)

Rating Criteria	Rating
Vehicle movements and other noisy activities:	
• occur only during the day, except under exceptional circumstances	1 ☐
• are generally scheduled to occur only during the day	3 ☐
• occur at any time of the day or night	4 ☐
Mechanical equipment used on-farm is:	
• all fitted with manufacturer-specified exhaust devices	1 ☐
• generally fitted with manufacturer-specified exhaust devices	2 ☐
• not fitted with manufacturer-specified exhaust devices	4 ☐
Dust from traffic movements, solid by-products handling and reuse and feed milling is:	
• controlled as needed	1 ☐
• not specifically controlled and dust is an issue at times.	3 ☐
There is:	
• a complaints management procedure in place that includes complaints recording, investigation and corrective action, along with appropriate consultation	1 ☐
• a complaints management procedure in place that includes complaints recording, investigation and corrective action	2 ☐
• no complaints management procedure in place, or the procedure that is in place does not include complaints recording, investigation and corrective action	4 ☐
Mediation is:	
• used to try to settle disputes with neighbours	1 ☐
• generally used to try to settle disputes with neighbours	2 ☐
• not generally used to try to settle disputes with neighbours	4 ☐
OVERALL RATING	☐

B3 Design and Operation (Risk Assessment)

The second step of the environmental risk assessment is to rate the risk of each of the major design and operation features of the piggery, including:

- pig housing
- the nutrient content of manure
- the effluent collection system
- the solids collection system
- the effluent treatment system
- solid by-products storage/treatment
- 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. Where factors are irrelevant for a given situation, they do not require evaluation.

To use the risk assessment:

1. Read the statements in the individual rating criteria.
2. Select the most appropriate rating for your farm. To do this, go through the data options and tick the comments of most relevance to your farm. The highest rating option ticked is your rating. For example, if you have ticked options with the ratings 1, 2 and 3, but not option 4, your piggery is rating 3 for that design and management item.
3. Record the appropriate rating at the bottom of the page along with any comments that assisted in selecting the specific rating. This will allow for more ready identification of monitoring requirements later in the risk assessment process.

B3.1 Risk Assessment - Pig Housing

Rating Criteria	Rating
Sheds:	
• are oriented east-west and are constructed from materials that maintain temperatures at the required range with minimal mechanical heating or cooling	1 ▢
• require significant mechanical heating or cooling to maintain temperatures at the required range	3 ▢
• have a strong reliance on mechanical heating or cooling to maintain temperatures at the required range	4 ▢
Sheds bases are:	
• concreted for conventional sheds and either concreted or compacted for a permeability of 1 X 10-9 m/s for a depth of at least 300 mm for deep litter sheds and feedlot pens	1 ▢
• formed from well-compacted clay or other low permeability material for deep litter sheds and feedlot pens	3 ▢
• not concreted for conventional sheds and not formed from concrete, well-compacted clay or other low permeability material for deep litter sheds and feedlot pens	4 ▢
Feeding systems:	
• minimise feed wastage	1 ▢
• rarely allow feed to be visually detectable on the floor or in the bedding near the feeders	2 ▢
• often allow significant quantities of waste feed to be visible on the floor or in the bedding near the feeders	3 ▢
Naturally ventilated sheds are:	
• well ventilated, as the sheds are separated by a distance of at least five times their height	1 ▢
• quite well ventilated, as the sheds are separated by a distance of at least four times their height	2 ▢
• reasonably well ventilated, as the sheds separated by a distance of at least three times their height	3 ▢
• not well ventilated	4 ▢
Stocking densities:	
• meet the requirements of the Model Code of Practice for the Welfare of Animals Pigs	1 ▢
• do not meet the requirements of the Model Code of Practice for the Welfare of Animals Pigs	4 ▢

B3.1 (Continued)

Rating Criteria	Rating
Conventional sheds are:	
• frequently cleaned to maintain very clean lanes, pens and handling areas. Pigs are clean	1 ☐
• regularly cleaned to maintain very clean lanes, pens and handling areas. Pigs are generally clean	2 ☐
• regularly cleaned but the lanes, pens and handling areas are often visibly dirty and generally some pigs are dirty	3 ☐
• not regularly cleaned. Pigs are generally dirty	4 ☐
The bedding in deep litter sheds (except for dunging areas):	
• is always kept dry and friable. Pigs are clean	1 ☐
• is mostly kept dry and friable. Pigs are generally clean	2 ☐
• causes most pigs to be dirty towards shed clean out, because of its moisture content	3 ☐
• is frequently damp or wet and pigs are dirty	4 ☐
The inflow or outflow of water from sheds and feedlot pens is:	
• prevented by controls	1 ☐
• mostly prevented by controls	3 ☐
• not well controlled	4 ☐
Wash-down water is:	
• always contained	1 ☐
• mostly well contained	3 ☐
• not well contained	4 ☐
OVERALL RATING	

B3.2 Risk Assessment – Nutrient Content of Manure

Rating Criteria	Rating
The quantities of:	
• effluent and solid by-products used on-farm is measured and recorded each time reuse occurs, and each type of by-product used is tested at least annually	1 ☐
• nutrients in the piggery by-products have been estimated using conservative figures in accepted industry nutrient mass balance models or publication	2 ☐
• nutrients in by-products that will be applied to land, including by outdoor rotational piggeries, is estimated	3 ☐
• nutrients to be applied, including by outdoor rotational piggeries, is not generally measured or estimated	4 ☐
OVERALL RATING	

B3 DESIGN AND OPERATION (RISK ASSESSMENT)

B3.3 Risk Assessment – Effluent Collection System

The effluent collection system can include effluent pits or channels, drains or pipes and/ or sumps.

Rating Criteria	Rating
Stormwater runoff, including roof runoff:	
• is excluded from entering the effluent collection system (or the system is designed to handle the runoff)	1 ☐
• is mostly excluded from entering the effluent collection system, and the system does not generally overflow as a result	2 ☐
• enters the effluent collection system, and the system sometimes overflows as a result	3 ☐
• enters the effluent collection system, and the system often overflows as a result	4 ☐
Effluent collection systems for conventional sheds are:	
• concreted and impervious (no significant cracks)	1 ☐
• concreted and have good integrity (minimal cracking)	3 ☐
• are pervious because they are not made from concrete (or similar), or because of deterioration of the material they are constructed from	4 ☐
Feedlot Outdoor piggery drains:	
• have a design permeability of 1 X 10-9 m/s for 300 mm depth	1 ☐
• well compacted, but the design permeability is unknown	3 ☐
• are not well compacted	4 ☐
Effluent pits, sumps and drains are:	
• sized and managed so that they do not spill	1 ☐
• sized and managed so that they only spill infrequently	3 ☐
• inadequately sized or managed and spill at least once a year	4 ☐
Effluent pits and drains:	
• are self-cleaning and manure solids are not present in these after flushing or draining	1 ☐
• are not self-cleaning, but are cleaned at least weekly to remove manure solids	2 ☐
• have manure solids present in them after flushing or draining that are removed at least monthly	3 ☐
• have manure solids present in them after flushing or draining and these are removed less than once a month	4 ☐

B3.3 (Continued)

Rating Criteria	Rating
There are:	
• appropriate contingency measures to prevent spills from the system	1 ▢
• contingency measures to prevent spills from the system, but these need improvement to reduce the spill frequency	3 ▢
• no specific contingency measures to prevent spills from the system	4 ▢
Flushing channels are flushed:	
• at least daily and static pits and pull plugs are emptied at least weekly, with pits emptied in rotation, to promote uniform loading of the effluent treatment system	1 ▢
• at least every second day, and static pits and pull plugs are emptied at least fortnightly	2 ▢
• at least twice a week, and static pits and pull plugs are emptied at least once every three weeks	3 ▢
• less than twice a week, and static pits and pull plugs are emptied less than once every three weeks	4 ▢
Drains, pits and sumps are:	
• inspected after each flush or draining for solids accumulation, leakage and deterioration	1 ▢
• inspected after every second flush or draining for solids accumulation, leakage and deterioration	2 ▢
• inspected at least monthly for solids accumulation, leakage and deterioration	3 ▢
• not regularly inspected for solids accumulation, leakage and deterioration	4 ▢
OVERALL RATING	

B3.4 Risk Assessment – Solids Separation System

Rating Criteria	Rating
The solids separation system (including any associated storage areas) has:	
• a base 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)	1 ☐
• a well compacted base	3 ☐
• an uncompacted base	4 ☐
The solids separation system (including any associated storage areas):	
• sits within a controlled drainage area, and there is no uncontrolled outflow of effluent	1 ☐
• does not sit within a controlled drainage area, OR there is uncontrolled outflow of effluent	4 ☐
Effluent from the solids separation system and associated storage areas is:	
• directed to a storage designed to cater for this inflow	1 ☐
• not directed to a storage designed to cater for this inflow	4 ☐
The out-loading bay, where present:	
• is kept clean of excess solids. There is no significant spillage from transport vehicles	1 ☐
• is generally kept clean of accumulated solids. Significant spillage from transport vehicles happens less than once a year on average	2 ☐
• frequently contains accumulated solids, OR there is significant spillage from transport vehicles twice a year on average	3 ☐
• generally contain accumulated solids, OR there is significant spillage from transport vehicles more than once every six months, on average	4 ☐
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	1 ☐
• checked at least weekly and cleaned or maintained after this check, as needed, to ensure it is performing to the design specification	2 ☐
• checked at least fortnightly and cleaned or maintained after this check, as needed, to ensure it is performing to the design specification	3 ☐
• not checked and cleaned or maintained at least fortnight	4 ☐
OVERALL RATING	☐

B3.5 Risk Assessment – Effluent Treatment System

Rating Criteria	Rating
The effluent treatment 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	1 ☐
• is designed to capture, treat, store and reuse all effluent. It has no significant isolated sections. Inlets and outlets are positioned to minimise short-circuiting	2 ☐
• is designed to capture and store all effluent. However, treatment capacity is compromised because the inlets and outlets are close together, OR because significant isolated sections don't provide active treatment capacity	3 ☐
• does not capture, effectively treat or store all effluent produced by the piggery	4 ☐
The effluent treatment system:	
• is designed and managed such that odour emissions are acceptably low	1 ☐
• is designed and managed such that odour emissions are generally acceptably low	2 ☐
• sometimes produces strong odours, but these don't generally impact beyond the property boundary	3 ☐
• produces strong odours that can be detected beyond the property boundary	4 ☐
The effluent treatment system is:	
• designed to allow for ease of desludging, OR to store at least ten years sludge	1 ☐
• difficult to desludge and this needs to occur every five to ten years	2 ☐
• difficult to desludge and this needs to occur every two to five years	3 ☐
• difficult to desludge and this needs to occur more than once every two years	4 ☐
The effluent treatment 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	1 ☐
• has a design permeability of 1 X 10-9 m/s for a depth of at least 300 mm of compacted clay	2 ☐
• is lined with well compacted clay	3 ☐
• is not lined with well compacted clay or a well-maintained impervious synthetic liner	4 ☐

B3.5 (Continued)

Rating Criteria	Rating
The depth to the water table from the base of the effluent treatment system is always:	
• at least 2 m	1 ▢
• sometimes less than 2 m	4 ▢
Freeboard of :	
• at least 500 mm is provided on any effluent treatment system ponds	1 ▢
• less than 500 mm is provided on one or more effluent treatment system ponds	4 ▢
The effluent treatment system has a design overtopping frequency:	
• of once every 10 years (or less often)	1 ▢
• exceeding once every 10 years	4 ▢
OVERALL RATING	▢

B3.6 Risk Assessment – Solid By-products Storage/Treatment

Rating Criteria	Rating
Solid by-product storage areas:	
• sit within a controlled drainage area, and all leachate or effluent is directed to effluent ponds, or storages designed to receive this inflow	1 ▢
• sit within a controlled drainage area, and most leachate or effluent is directed to effluent ponds, or storages designed to receive this inflow	3 ▢
• are not within a controlled drainage area, OR leachate or effluent is not directed to effluent ponds, or storages designed to receive this inflow	4 ▢
The bases of solid by-product storage areas are:	
• sealed for a design permeability of 1 X 10-9 m/s for a depth of 300 mm	1 ▢
• well compacted clay or other low permeability material	3 ▢
• not built from well compacted clay or other low permeability material	4 ▢
The depth to water tables beneath the base of solids storage areas:	
• exceeds 2 m at all times	1 ▢
• may be less than 2 m at times	3 ▢
Solid stockpiles/windrows are:	
• always managed to maintain low odour emissions	1 ▢
• generally managed to maintain low odour emissions, but significant odour releases occur about once a year on average	2 ▢
• generally managed to maintain low odour emissions, but significant odour releases occur about four times a year on average	3 ▢
• not managed to maintain low odour emissions, and significant odour releases occur more than four times a year on average	4 ▢
Spilt or spoilt feed or leachate from wet feedstuffs is:	
• promptly cleaned up	1 ▢
• cleaned up within 4 days	2 ▢
• cleaned up within 7 days	3 ▢
• frequently present in the mill area	4 ▢
OVERALL RATING	▢

B3 DESIGN AND OPERATION (RISK ASSESSMENT)

B3.7 Risk Assessment – Carcass Management

Rating Criteria	Rating
Dead pigs are:	
• always removed from the sheds or pens daily	1 ▢
• almost always removed from the sheds or pens daily	2 ▢
• usually removed from the sheds or pens daily	3 ▢
• frequently left in the sheds or pens for more than 24 hours	4 ▢
Carcass management (e.g. placement in a composting pile, burial etc,):	
• always occurs within 24 hours of death	1 ▢
• always occurs within 36 hours of death	2 ▢
• always occurs within 48 hours of death	3 ▢
• does not always occur within 48 hours of death	4 ▢
Carcass management is by:	
• rendering or composting	1 ▢
• burial or proper incineration	3 ▢
• burning or dumping	4 ▢
Carcass management areas:	
• always provide at least 2 m depth between base level and groundwater; and are concreted or sealed to a design permeability of 1X10-9 for a depth of 300 mm	1 ▢
• always provide at least 2 m depth between base level and groundwater; and are lined or built from compacted clay or gravel	3 ▢
• sometimes provide less than 2 m depth between base level and groundwater; OR are not on a well sealed site	4 ▢
Where carcass 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	1 ▢
• generally promptly covered with at least 300 mm of sawdust or alternative carbon source (if composting) or soil (if burying) and continuously kept covered	2 ▢
• 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	4 ▢
Where carcass management is by composting, burial or burning this:	
• occurs within a controlled drainage area with stormwater diverted away from the area	1 ▢
	▢

B3.7 (Continued)

Rating Criteria	Rating
• does not occur within a controlled drainage area	4
In the event of mass mortalities, there is:	
• a suitable site selected and a detailed plan for managing mass mortalities	1
• a suitable site selected and a plan for managing mass mortalities	2
• a suitable site selected but no real plan for managing mass mortalities	3
• no site selected or plan for managing mass mortalities	
OVERALL RATING	

B3 DESIGN AND OPERATION (RISK ASSESSMENT)

B3.8 Risk Assessment – Design and Management of Reuse Areas

Rating Criteria	Rating
The nutrients in by-products are:	
• budgeted to ensure they are applied at rates determined from mass balance principles, based on past property crop / pasture yields OR from soil test results	1 ▢
• budgeted to ensure they are applied at rates determined from mass balance principles based on typical district harvested yields for the crops / pastures grown	2 ▢
• are not budgeted using mass balance principles, or the recommendations from soil test results	4 ▢
Nutrient export from reuse areas is:	
• minimised through good management and physical barriers (e.g. appropriately designed VFS; terminal ponds to catch the first 12 mm of runoff; contour banks; or maintaining average groundcover over whole area of at least 70%) and good farming practices (e.g. conservation tillage)	1 ▢
• minimised through good management and physical barriers (VFS; contour banks; or maintaining average ground cover over whole area of at least 70%) and good farming practices (e.g. conservation tillage)	2 ▢
• not specifically prevented	4 ▢
Effluent irrigations occur:	
• only when the soil is dry enough to absorb the water and when rain is not expected	1 ▢
• only when the soil is dry enough to absorb the water	3 ▢
• irrespective of soil moisture conditions or expected weather conditions	4 ▢
By-products are spread:	
• evenly and at times when active plant growth is expected	1 ▢
• somewhat unevenly, but generally only spread when active plant growth is expected	3 ▢
• very unevenly or at times when active plant growth is not likely	4 ▢
High-pressure spray guns are:	
• not used	1 ▢
• used	4 ▢

B3.8 (Continued)

Rating Criteria	Rating
Flood irrigation is used:	
• only on sites with an even grade and loam or heavier soils, and with good flow control	1 ☐
• on sites with uneven grades and sand-sandy loam soils, and/or inadequate flow control	4 ☐
By-products are:	
• only irrigated / spread when weather conditions are conducive to odour dispersion, and not on weekends or public holidays	1 ☐
• generally only irrigated / spread when weather conditions are conducive to odour dispersion, and not normally on weekends or public holidays	2 ☐
• irrigated / spread at any time of the day, but not normally on weekends or public holidays	3 ☐
• irrigated / spread at any time of the day, or commonly on weekends or public holidays	4 ☐
Soils of reuse areas are:	
• tested at least annually, and the results considered when determining future reuse rates	1 ☐
• tested at least annually	2 ☐
• regularly tested	3 ☐
• not regularly tested	4 ☐
OVERALL RATING	☐

B3.9 Risk Assessment - Chemical Use and Storage

Rating Criteria	Rating
MSDS, emergency response plans for spills and spill kits or suitable clean up equipment are:	
• provided for all chemicals used	1 ▢
• provided for most chemicals used	3 ▢
• not generally provided	4 ▢
Quantities of chemicals stored on-farm are:	
• minimised	1 ▢
• not minimised	3 ▢
Chemicals with a low toxicity and low water contamination potential are:	
• preferentially selected	1 ▢
• not preferentially selected	3 ▢
Chemicals and fuel are:	
• always stored and used in accordance with manufacturer's instructions, or advice from the state agricultural department, WPH&S codes of practice, and only in accordance with the registered use. Records of use are maintained	1 ▢
• always stored and used in accordance with manufacturer's instructions, or advice from the state agricultural department, WPH&S codes of practice, and only in accordance with the registered use	3 ▢
• not always stored and used in accordance with manufacturer's instructions, or advice from the state agricultural department, WPH&S codes of practice, and only in accordance with the registered use	4 ▢
Staff members are:	
• trained in the correct handling and use of all chemicals of relevance to their position	1 ▢
• not trained in the correct handling and use of all chemicals of relevance to their position	4 ▢
Empty container and sharps disposal is:	
• always in accordance with manufacturer's instructions	1 ▢
• generally in accordance with the manufacturer's instructions	3 ▢
• not generally in accordance with the manufacturer's instructions	4 ▢

B3.9 (Continued)

Rating Criteria	Rating
Where there are underground petroleum storage systems (UPSS) on-site:	
• applicable regulatory requirements for monitoring are always followed	1 ▢
• applicable regulatory requirements for monitoring are not followed	4 ▢
Where chemical contractors are used:	
• only accredited contractors are engaged	1 ▢
• accredited contractors are generally engaged	2 ▢
• non-accredited contractors are commonly engaged	4 ▢
OVERALL RATING	

B4 Overall Risk Assessment

The third step in evaluating the likelihood of an environmental impact, is assessment of the combined effect of resource vulnerability and the design and operation risk. The two-dimensional matrix below is used for this step.

The overall risk can be used to help decide the action to be taken. A low overall rating would not trigger any action. A medium overall rating may trigger some action. A high overall rating would trigger some action. The design and/or operation of the piggery should be examined to decide the most appropriate action, which may take the form of environmental improvements or monitoring. Examining the reasons for vulnerability and risk ratings listed in the applicable tables can assist in deciding the action to be taken.

B4.1 Environmental Risk Assessment Matrix

The environmental risk assessment matrix should be completed by multiplying the vulnerability rating designated for each natural resource and amenity category rating, by the risk rating designated for each design and operation factor. The shaded cells in the table should not be filled in.

Natural resource vulnerability ratings (1-4)	Design and operation risk ratings (1-4) (based on site assessment)			
	Soils of reuse areas	Ground-water quality and availability	Surface quality & availability	Community amenity
Pig housing				
Nutrient content of manure				
Effluent collection system				
Solids separation system				
Effluent treatment system				
Solid by-product storage / treatment				
Carcass management				
By-product Reuse – design and management				
Chemical storage				

A combined rating of 1–4 means a low risk and would not trigger any action.
A combined rating of 5–11 means a medium risk and may trigger explanation or action.
A combined rating of 12–16 means a high risk and would trigger explanation or action.

For proposed piggeries, actions might involve choosing a better site for piggery facilities, or raising the standard of design. For existing piggeries, actions would be to improve the environmental performance through better design, management or monitoring. Refer to the example that follows.

B5 Example Risk Assessment

The example below assesses the potential impact of carcass management practices on groundwater.

B5.1 Groundwater Vulnerability

Groundwater is always at least 8 m beneath the soil surface (rating 3).

Nearby groundwater sources are only used for irrigation (rating 1).

Groundwater is not used in the piggery (not applicable).

Highest rating is 3, so rating 3 applies.

B5.2 Carcass Management

Dead pigs will always be removed from shed daily (rating 1).

There will always be same-day management of carcasses (rating 1).

It is proposed to bury carcasses in pits, which will be lined with compacted clay (rating 3).

There is a contingency plan in place as part of the Environmental Management Plan for mass mortalities (rating 1).

Highest rating is 3, so rating 3 applies.

B5.3 Overall Risk Rating

Groundwater vulnerability rating is 3 and carcass management rating is 3.
Hence: overall risk rating is: 3 x 3 = 9

A combined rating of 1-4 = low risk, no action.
A combined rating of 5-11 = medium risk, may trigger explanation or action.
A combined rating of 12-16 = high risk, would trigger explanation or action.

Hence, the proposed mortality management practices pose a medium risk at this site, which might trigger the need for changes to the management of mortalities. In this case, switching to well-managed composting on an impervious, bunded pad would reduce the carcass management rating to 1 and the overall rating to 3 (low risk).

Appendix C.

Complaints Register

C1 Complaints Register

The rate of complaints received cannot be used as a sustainability indicator, as it is an imprecise measure of community amenity impact. However, 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.

Complaint 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 ☐ fax ☐ 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 (or reuse area) 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 D.

Sample Collection and Analysis

D1 Introduction

This appendix details methods for collecting, storing, handling and treating samples of water, effluent, solid by-product, plants and soil, in order to monitor quality and quantity.

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
- couriers that can transport the samples to the laboratory (if needed)
- sampling equipment
- sampling procedures
- monitoring parameters.

Many approved authorities have their own monitoring guidelines and requirements. **Advice should be sought from the approved authority when planning sampling and monitoring, particularly where requirements are specified a licence**. In the absence of specific advice from the approved authority, the following guidelines may be used.

D2 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, it is generally worth using the same laboratory each year. Some regulators may also have specific laboratory testing method requirements, so it is important to check your requirements thoroughly. It is worth contacting the laboratory about your analysis requirements, as they will often:

- provide suitable clean sample containers and preservatives (if required)
- analysis request forms
- advise which days are best for receipt of samples
- confirm requirements for storage (e.g. ice) and transit times.

D3 Surface Water Sampling

D3.1 Sampling Location

Suitable sites that can be located and accessed for monitoring must be identified. Discuss selected sampling locations with the relevant approved authority before sampling, to ensure the results will be acceptable.

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.

D3.2 Monitoring Interval

Surface water quality monitoring may be done at a set interval (e.g. quarterly, biannually or annually) or may be triggered by specific events (e.g. an overtopping effluent pond). Water quality varies with time of day, flow rate and recent weather conditions, so these factors should be noted at the time of sampling.

If a pond spill to a watercourse is the trigger for sampling, samples of effluent should be taken during the spill, as well as being from upstream and downstream from where the effluent enters the watercourse.

D3.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- appropriate sample containers and preservatives. 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
- a sampling rod. A rod with a large clamp for holding the sampling container allows greater reach when sampling liquids. The sample should be taken from upstream of your feet, to ensure that disturbed sediment is not collected
- a bucket that has been washed several times with clean water and then rinsed several times with the water to be sampled
- 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
- personal protective clothing
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D3.4 Sampling Procedure

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, your 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 (matching those recorded on the sample bottles), sampling location, sampling date and analysis parameters.
3. Organise bottles and rods for sample collection. Grab samples should be collected directly into sample containers. A grab sample is a single sample collected at a particular time and place, that represents the composition of the material being sampled. Composite samples should be collected using a similar bottle and mixed in a clean plastic bucket. A composite sample comprises several grab samples collected over several minutes. Composite samples of five grab samples should be collected if there is little movement in the watercourse or for a dam. 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 you are taking a composite sample, thoroughly mix the grab samples in a clean plastic bucket before pouring into a sample bottle. Add any required preservative and replace the lid.
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. Do not completely fill the sample bottle if you intend to freeze the sample. Do not freeze 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.*

8. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky.
9. Deliver the samples or arrange for courier delivery.
10. Contact the laboratory to confirm the samples have been received.

D3.5 Recording

At each sampling, record:

- the location and name of sampling site (clearly identified location allows return to the same site for future sampling)
- the date and time of day of sampling occurs (water quality varies over time)
- a general description of the flow rate (in watercourses) or approximate depth of water in dams or storages
- weather conditions at the time of sampling, as these may influence water quality
- the method of sampling (grab sample or composite sample)
- the name of the sampler
- the date and time that samples were dispatched to laboratory
- the method of preserving samples (e.g. sample immediately put on ice in esky)
- analysis parameters requested (preferably keep a copy of the original analysis request forms).

D4 Groundwater Sampling

D4.1 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 hydro-geologist, or specialist consultant, for advice on the location, installation and sampling of bores.

D4.2 Monitoring Interval

Groundwater quality monitoring is also usually done at a set interval (e.g. quarterly, biannually or annually).

D4.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- appropriate sample containers and preservatives. Most laboratories will supply or advise on suitable sample containers, as well as any necessary preservatives. Obtaining sample containers or advice from the laboratory, reduces the chance of sample contamination and ensures that the sample size is adequate
- a sampling bailer, or pump, to draw water from the monitoring bores. 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 and allows for samples to be quickly collected
- a tape measure and plopper, or fox whistle, to determine depth to groundwater
- a bucket that has been washed several times with clean water and then rinsed several times with the water to be sampled
- 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
- personal protective clothing
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D4.4 Sampling Procedure

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, your 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 (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, it is recommended that you pump several bore volumes from the casing to ensure that you are not sampling stagnant water.

   Bore volume (L) = ((3.14/1000) 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 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. Add any required preservative and replace the lid.

7. Immediately place the sample in an esky, pack crushed ice completely around it and replace the esky lid.

8. 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 you intend to freeze the sample. Do not freeze samples in a freezer used for food storage.

9. 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.*

10. Complete the analysis request forms and photocopy for your own records (if you have access to a photocopier or fax machine). Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky. Store the esky in the shade.

11. Deliver the samples or arrange for courier delivery.

12. Contact the laboratory to confirm the samples were received.

D4.5 Recording

At each sampling, record:

- the name and location of bore or piezometer
- the depth to groundwater
- the date and time of day that sampling occurs
- the name of the sampler
- the date and time of sample dispatch to laboratory
- the method of preserving samples (e.g. sample immediately put on ice in esky)
- analysis parameters requested (preferably keep a copy of the original analysis request forms).

D5 Effluent

D5.1 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.

D5.2 Monitoring Interval

The monitoring interval for effluent depends on soil test results for the reuse area to ensure sustainable nutrient levels. If soil test results are acceptable, and monitoring results for the quality of the effluent over several years indicates similar results, it may be possible to reduce the monitoring frequency.

D5.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- appropriate sample containers and preservatives. 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 that the sample size is adequate
- a sampling rod. A rod with a large clamp for holding the sampling container allows greater reach when sampling. The sample should be taken from upstream of your feet, to ensure that disturbed sediment is not collected
- a bucket that has been washed several times with clean water and then rinsed several times with the water to be sampled
- 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
- personal protective clothing (disposable gloves)
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D5.4 Sampling Procedure

1. Assemble the sample containers and the sample preservatives. With a waterproof pen, label the sample containers with the enterprise name, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. effluent reuse area 1) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.

D5 EFFLUENT

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. 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. While you are waiting, rinse the bucket several times with the effluent from the pump. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Collect ten grab samples of effluent, and make up a composite by adding all of these to a bucket and thoroughly mixing by swirling the bucket. Fill the sample bottle from the composite sample. Add any required preservative and replace the lid.

5. If sampling from the pond: rinse the bucket several times with pond effluent. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Collect grab samples of effluent from 0.2 m below the water surface using the sampling bottle (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 you have collected five samples, 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 you intend to freeze the sample. 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.*

9. Thoroughly wash your hands.

10. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky. Store the esky in the shade.

11. Deliver the samples or arrange for courier delivery.

12. Contact the laboratory to confirm the samples were received.

D5.5 Recording

Each time effluent is sampled for analysis, record:

- the location and name of sampling site (e.g. anaerobic pond pump to irrigation area)
- the date and time of day that sampling occurs
- weather conditions at the time of sampling
- the name of the sampler
- the date and time of sample dispatch to laboratory
- the method of preserving samples (e.g. sample immediately put on ice in esky)
- analysis parameters requested (preferably keep a copy of the original analysis request forms).

Conventional piggery and effluent pond

D6 Solid By-products

D6.1 Sampling Location

Separate samples are needed for each type of solid by-product for reuse. This could include screenings, sediment, sludge, spent bedding and compost. If solids are stored or composted before reuse, then only the stored or composted product would generally need to be analysed.

D6.2 Monitoring Interval

The monitoring interval for solid by-products depends on soil test results for the reuse area, to ensure sustainable nutrient levels. If soil test results are acceptable, and monitoring results for the quality of the by-products over several years indicates similar results, it may be possible to reduce the monitoring frequency.

D6.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- appropriate sample containers and preservatives. For samples with a fairly low moisture content, ziplock plastic bags may be suitable. Wet samples are best stored in wide mouthed bottles that a laboratory can supply. Consulting the laboratory is recommended, as this should ensure the containers are suitable and the sample size adequate
- a sampling rod may be useful if sampling wet products (e.g. sludge)
- a shovel and trowel if sampling more solid materials
- a clean bucket
- cheap, Styrofoam eskies
- plenty of crushed ice to pack around the samples in the eskies
- a waterproof pen to mark sample bottles or bags
- waterproof tape to seal eskies
- personal protective clothing (disposable gloves)
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D6.4 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, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. compost area 1) and the date of sampling.

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. 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. Remove the sample bottle lid, taking care not to touch the inside of the lid or bottle. Sample the sludge by collecting at least 10 one-cup samples, adding each of these to the bucket. Thoroughly mix by swirling the bucket. Fill the sample bottle from 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 to collect at least 10 one-cup grab samples. Put each sample in the bucket and thoroughly mix with the garden trowel. Place about four cups 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 you intend to freeze the sample. 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.*
8. Thoroughly wash your hands.
9. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky. Store the esky in the shade.
10. Deliver the samples or arrange for courier delivery.
11. Contact the laboratory to confirm the samples were received.

D6.5 Recording

At each sampling, record:

- the location and name of sampling site (e.g. compost area)
- the date and time of day that sampling occurs
- weather conditions at the time of sampling
- the name of the sampler
- the date and time of sample dispatch to laboratory
- the method of preserving samples (e.g. sample immediately put on ice in esky)
- analysis parameters requested (preferably keep a copy of the original analysis request forms).

D7 Soils

D7.1 Sampling Location

Sampling locations should be chosen to represent the major soil types and land management practices (including land use and by-products spreading 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 and different soils vary in their capacity to retain nutrients, and in their productivity. Dig some holes and compare the soils of each hole. (Recording information as you go is important!).

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 by-products type (e.g. effluent, screenings, sludge, spent litter or compost) and application rate.

   As an example, if there is one (1) soil type across the reuse areas of the farm, two (2) land uses on these areas and only one (1) by-product (effluent) is used on farm, the number of soil sampling sites would be 1 X 2 X 1 = 2.

D7.2 Monitoring Interval

The monitoring interval for sampling soils should be based on the level of environmental risk based on soil test results. Sampling should occur at the end of a cropping cycle, or at a time when nutrients are most vulnerable to leaching (before the onset of the wet season).

D7.3 Sampling Equipment

The sampling equipment that may be required is listed below:

- a soil auger, shovel, post hole digger or hydraulic soil sampling rig (these can be hired)
- plastic sample bags. Most laboratories will supply suitable sample bags
- a ruler or tape measure
- a hand trowel
- a plastic sheet
- two clean plastic buckets

- cheap Styrofoam eskies
- a waterproof pen to mark sample bags
- waterproof tape to seal eskies
- personal protective clothing
- analysis request forms
- a pen to complete analysis request forms
- an envelope that analysis request forms will fit in.

D7.4 Sampling Procedure

1. Assemble the sample containers and the sample preservatives.

2. With a waterproof pen, label the sample containers with the enterprise name, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. Paddock 5) and the date of sampling. Label the container instead of the lid, as lids can get mixed up in the laboratory.

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 bags), sampling location, sampling date and analysis parameters.

4. When labelling the sample bags, remember to include the sampling depth (e.g. 0-10 cm, 30-60 cm).

5. Collect samples. There is a range of acceptable soil sampling methods. These include variations on:

    a. 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 by-product 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 GPS, so the same sites can be used in subsequent years. Collection of 25 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 monitoring plot, is recommended.

    b. 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. Collection of at least 5-10 topsoil and subsoil grab samples is suggested. These are combined to produce topsoil and subsoil composite samples for each area.

    c. 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. Collection of at least 5-10 topsoil and subsoil grab samples is suggested. These are combined to produce topsoil and subsoil composite samples for each area.

d. Random: samples are collected from random locations across the entire paddock. The number of samples required depends on the area of the paddock. Collection of at least 5-10 topsoil and subsoil grab samples is suggested. These are combined to produce topsoil and subsoil composite samples for each area.

6. 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, solid by-product 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 the each background plot should be recorded on a property map, or GPS, so the same sites can be used in subsequent years.

7. As you collect the samples, 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).

8. 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 or 2 lb). 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.

9. When all of the samples have been added to the esky, seal it with the waterproof tape.

10. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky.

11. Deliver the samples or arrange for courier delivery.

12. Contact the laboratory to confirm the samples were received.

13. While you are in the paddock, 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 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.

D7.5 Recording

Original copies of soil analyses should be kept indefinitely, along with records of sampling locations and land use. This assists with long-term farm management.

D8 Plant Tissue Samples

Each time crops are harvested from effluent irrigation or solid by-products spreading areas, the yield harvested should be recorded, and the dry matter yield and the approximate nitrogen and phosphorus removal rates should be 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 plants harvested by weighing or by estimating 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.

As an example, if 4 t/ha of barley is harvested, the dry matter yield is about 3.5 t/ha (4 t/ha X 88/100). A 4 t/ha winter cereal crop removes about 80 kg N/ha and 12 kg P/ha. Hence, the 3.5 t/ha crop will remove about 70 kg N/ha and 10.5 kg P/ha (i.e. 80 kg N/ha X (3.5t/4t); 12 kg P/ha X (3.5 t/4t)).

D8.1 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 samples of freshly cut material from several bales or bins.

D8.2 Monitoring Interval

For most enterprises, analysis of plant composition should not be required. This is only suggested for precision systems.

D8.3 Sampling Equipment

The sampling equipment for plants may include:

- large paper sample bags. Most laboratories will supply suitable sample bags. Brown paper bags will also be sufficient
- disposable gloves
- a clean sampling cup
- a clean bucket
- analysis request forms
- an envelope that analysis request forms will fit in
- a pen to mark sample bags and complete analysis request forms
- cheap Styrofoam eskies.

D8.4 Sampling Procedure

1. Assemble the sample containers and the sample preservatives.
2. With a waterproof pen, label the sample bags with the enterprise name, your telephone number, a unique sample number (new numbers should be used at each sampling), the sampling location (e.g. 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.

   For grain, it is suggested that at least five samples be collected from the field bin (or similar). These should be placed in the bucket and thoroughly mixed with gloved hands. A sub-sample should then be used to fill the sample bag.

   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.
5. Leave the tops of the paper bags open to allow excess moisture to escape.
6. 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.
7. 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.
8. Complete the analysis request forms and photocopy for your own records. Place the original forms in an envelope. Clearly address the envelope to the laboratory and add their phone number. In smaller writing, put the sender's address and phone number on the envelope. Firmly tape the envelope to the top of the esky. Store the esky in the shade.
9. Deliver the samples or arrange for courier delivery.
10. Contact the laboratory to confirm the samples were received.

D8.5 Recording

Original copies of plant tissue analyses should be kept indefinitely, along with records of sampling locations and land use. This assists with long-term farm management.

D9 Measuring Effluent Reuse Rate

It is necessary to measure the quantity of effluent irrigated to each paddock. A flow meter can accurately measure the effluent flow rate. In-line flow meters should be a non-corrosive type. 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 should be measured.

For a single hand-shift type sprinkler, 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. It can be very difficult to measure effluent volumes this way. 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 give 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 bulk tankers are used to spread effluent, tanker volume and emptying frequency provide a good estimate of the irrigation rate.

Each time effluent is irrigated, record:

- the date of irrigation
- the paddock irrigated
- the irrigation rate (mm or KL/ha).

The annual reuse rate (ML/ha) needs to be multiplied by the nutrient content (mg/L) for each nutrient of interest, to calculate the nutrient addition rate (kg/ha) to each reuse area.

D10 Measuring Solid By-Product Reuse Rate

If a tanker of a known volume (L or m^3) is used to spread wet solids (e.g. sludge), then the number of loads per hectare multiplied by the volume, gives the as-spread application rate. This needs to be converted to a dry matter spreading rate, since this is how nutrient analysis results are generally expressed. If the dry matter content of the solids is determined, this is calculated by multiplying the spreading rate (L/ha) by the dry matter content (% OR g/kg/1000).

For example, for solids with a dry matter content of 10% spread at a rate of 20,000 L/ ha, this would be calculated as: 20,000 L/ha X 10/100 = 2000 kg/ha.

If the dry matter data was expressed as 100 g/kg (10%) the calculation would be: 20,000 L/ha X 100/1000 = 2000 kg/ha.

If a manure of 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. Again, the spreading rate should be converted to a dry matter rate. Multiply the as-spread application rate (t/ha) by the dry matter content (%) or g/kg to convert to spreading rate (kg/t).

Each time solid by-products are spread on-farm, record:

- the date of spreading
- the paddock being spread
- the spreading rate (t/ha or m^3/ha).

The annual reuse rate (t/ha) needs to be multiplied by the nutrient content (g/kg) for each nutrient of interest, to calculate the nutrient addition rate (kg/ha) to each reuse area.

D11 Reusers

If by-products are provided to off-site users, record:

- date the material left the site
- quantity of material involved
- type of by-product
- 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 by-product recipients with analysis results for the material they are receiving, so that they can calculate appropriate irrigation or spreading rates.

Appendix E.

Useful Conversions

E1 Metric Conversions

Length

1 inch (in)	25.4 millimetres (mm)	1 mm = 0.04 in
1 foot (ft)	0.3 metres (m)	1 m = 3.3 ft
1 yard (yd)	0.9 m	1 m = 1.1 yd
1 mile (mi)	1.6 kilometres (km)	1 km = 0.6 mi

Weight

1 ounce (oz)	28.35 grams (g)	1 g = 0.035 oz
1 pound (lb)	0.45 kilograms (kg)	1 kg = 2.2 lb
1 t	1000 kg	

Area

1 square inch (in^2)	0.00065 square metres (m^2)	1 m^2 = 1,550 in^2
1 square foot (ft^2)	0.09 square metres (m^2)	1 m^2 = 10.8 ft^2
1 square yard (yd^2)	0.84 m^2	1 m^2 = 1.2 yd^2
1 acre (ac)	0.405 hectares (ha)	1 ha = 2.5 ac
1 hectare (ha)	10 000 square metres (m^2)	1 m^2 = 0.0001 ha

Volume

1 cubic inch (in^3)	16.4 cubic cm (cc, cm^3)	1 cc = 0.06 in^3
1 cubic foot (ft^3)	28.3 litres (L)	1 L = 0.035 ft^3
1 ft^3 = 6.2 gallon (gal) 1 gal = 0.16 ft^3		
1 cubic yard (yd^3)	0.8 cubic metres (m^3)	1 m^3 = 1.3 yd^3
1 acre foot (ac-ft)	1.23 ML	1 ML = 0.8 ac-ft
1 gallon (gal)	4.5 L	1 L = 0.22 gal

Pressure

1 gallon/hour (gph)	0.00125 litres per second (L/s)	1 L/s = 800 gph
1 pound/inch^2 (psi)	6.9 kilopascals (kPa)	1 kPa = 0.145 psi
1 pound/foot^2	47.9 pascals (Pa)(lb/ft^2)	1 Pa = 0.02 lb/ft^2
1 pascal (Pa)	1 newton/m^2 (N/m^2) (pressure units)	

Energy

1 ft-lb/spc	1.36 watts (W)	1 W = 0.74 ft lb/s
1 watt (W)	1 newton-metre/second (N-m/s)	
1 horsepower (hp)	0.75 kilowatts (kW)	1 kW = 1.34 hp
	550 ft-lb/sec	
	1 ft-lb/sec = 0.0018 hp	

Density

1 lb/ft^3	16 kg/m^3	1 kg/m^3 = 0.06 lb/ft^3
		1 kg/m^3 = 0.000036 lb/in^3

Force

1 pound force (lb)	4.45 newtons (N)	1 N = 0.22 lb

E2 Other Conversions

1 ML	1 000 000 L = 1000 m^3
1 m^3	1000 L = 0.001 ML
1 ML/ha	100 mm depth over 1 ha
ppm	mg/kg, mg/L
1 mg/kg	1 kg/t
1 mg/L	1 kg/ML

E3 SI Units

SI Units

Quantity	SI Unit	Other units
Length	metre (*m*)	inch (*in*), foot (*ft*), yard (*yd*)
Mass	kilogram (*kg*)	ounce (*oz*), pound mass (*lbm*)
Volume	metre^3 (m^3)	inch^3 (in^3), foot^3 (ft^3)
Time	second (*s*)	
Velocity	metre/second (*m/s*)	foot/second (*ft/s*), miles/hour (*mph*)
Acceleration	metre/second^2 (m/s^2)	inch/second^2 (in/s^2), foot/second^2 (ft/s^2)
Area	metre^2 (m^2)	inch^2 (in^2), foot^2 (ft^2)
Density	kilogram/metre^3 (kg/m^3)	pound mass/in^3 (lbm/in^3), pound mass/ft^3 (lbm/ft^3)
Force	newton (*N* [= kg-m/s^2])	pound force (*lb*)
Pressure	pascal (*Pa* [= N/m^2])	pound force/inch^2 (*psi*), pound force/foot^2 (lb/ft^2)
Power	watt (*W* [= *J/s* = *N-m/s*])	foot-pound/minute (*ft-lb/min*), horsepower (*hp*)

SI Unit Prefixes

Multiplication Factor		Prefix	Symbol
1,000,000	= 10^6	mega	M
1,000	= 10^3	kilo	k
100	= 10^2	hecto	h
10	= 10^1	deka	da
0.1	= 10^{-1}	deci	d
0.01	= 10^{-2}	centi	c
0.001	= 10^{-3}	milli	m
0.000,001	= 10^{-6}	micro	m

E4 Water Quality Conversions

TDS to EC	multiply TDS in mg/L by 640 to convert EC to dS/m
Nitrate-nitrogen	multiply nitrate-N (mg/L) by 4.427 to convert to nitrate
Nitrite-nitrogen	multiply nitrite-N (mg/L) by 3.284 to convert to nitrite
Phosphate-phosphorus	multiply phosphate-P (mg/L) by 3.066 to convert to phosphate
Sulphate-sulphur	multiply sulphate-S (mg/L) by 2.996 to convert to sulphate
Calcium	divide mg/L by 20.08 to convert to meq/L
Magnesium	divide mg/L by 12.15 to convert to meq/L
Sodium	divide mg/L by 22.99 to convert to meq/L
Potassium	divide mg/L by 39.1 to convert to meq/L

E5 Salinity Conversions

From ↓	To →	S/m	dS/m	mS/m	uS/m	mS/cm	uS/cm	TDS (mg/L)	meq/L
S/m		× 1	× 10	$\times 10^{3}$	$\times 10^{6}$	× 10	$\times 10^{4}$		× 100
dS/m		× 0.1	× 1	× 100	$\times 10^{5}$	× 1			× 10
mS/m		$\times 10^{-3}$	× 0.01	× 1	$\times 10^{3}$	× 0.01			× 0.1
uS/m		$\times 10^{-6}$	$\times 10^{-5}$	$\times 10^{-3}$	× 1	$\times 10^{-5}$			$\times 10^{-4}$
mS/cm		$\times 10^{-3}$	× 1	× 100	$\times 10^{5}$	× 1			× 10
uS/cm		$\times 10^{-4}$	$\times 10^{-3}$	× 0.1	× 100	$\times 10^{-3}$			× 0.01
TDS (mg/L)		$\times 1.56 \times 10^{-4}$	$\times 1.56 \times 10^{-3}$	× 0.156	$\times 1.56 \times 10^{-2}$	$\times 1.56 \times 10^{-3}$	× 1.56	× 1	$\times 1.56 \times 10^{-2}$
meq/L		× 0.01	× 0.1	× 10	$\times 10^{4}$	× 0.1			× 1

Glossary

Glossary

Ad libitum allowing pigs to eat an unrestricted amount of feed.

Adult any pig over the age of nine months.

Aerobic pond or lagoon a dam that uses aerobic micro-organisms to treat the effluent. These are micro-organisms that require free oxygen from the air to function. Consequently, aerobic ponds/lagoons have a large surface area to volume ratio. They are usually less than 1.5 m deep.

Anaerobic pond or lagoon a dam that uses anaerobic micro-organisms to treat the effluent. These are micro-organisms that do not need free oxygen from the air to function. These lagoons/ponds are usually quite deep (typically 4 m or deeper).

Approved authority local or state government entity with relevant statutory authority.

Ark a weatherproof moveable structure designed for housing sows and / or piglets in outdoor production systems.

AUSPLUME Environment Protection Authority - Victorian regulatory Gaussian dispersion model.

Available nutrient that portion of any element in the soil that can be readily absorbed and assimilated by growing plants.

Background site the 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 solid by-products.

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.

By-product manure, waste feed, spent bedding and carcasses.

Cation exchange capacity (CEC) the total of exchangeable cations that a soil can adsorb.

Community amenity the comfortable enjoyment of life and property, particularly in terms of air quality (i.e. odour and dust), noise, lighting and visual appearance.

Composite sample sample comprising several grab samples collected over minutes, hours or days according to a sampling program.

Compost is the product of the partial decomposition of organic matter by microorganisms.

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 or hosing.

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.

Dispersion modelling computer-based software modelling used to mathematically simulate plume dispersion of air emissions under varying atmospheric conditions; used to calculate spatial and temporal fields of concentrations and particle deposition due to emissions from various source types.

GLOSSARY

Dry scraping systems blades on cables that drag manure and wastewater from effluent channels under conventional sheds.

Dry sow a female pig that has been mated and has not yet farrowed.

Dry sow (or gestation) stall see 'Stall'.

Effluent liquid by-product stream

Effluent sumps pits that store effluent before pre-treatment, or before is directed to ponds or irrigation.

Electrical conductivity see 'Salinity'.

Environmental management plan (EMP) An EMP focuses 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 impacts are minimised; and processes for continual review and improvement.

Environmental management system (EMS) An EMS is a continual cycle of planning, implementing, reviewing and improving the processes and actions that an organisation undertakes to meet its business and environmental goals.

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.

Extensive pig farming a system in which the animals rely *primarily* on foraging and grazing rather than on supplementary feed to meet most (greater than 50%) of their nutritional requirements. This type of system is not covered by these guidelines.

Facultative pond a pond or lagoon that uses facultative micro organisms to treat the effluent stream. These are micro organisms 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 treated 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.

Gestation the period when a sow is pregnant.

Gestation stall see 'stall'.

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.

Grower pigs generally with liveweights of 20-60 kg.

Growing pigs weaners, growers and finishers.

Grower / grow-out unit a production system where pigs are grown from weaner, or grower weight, through to pork or bacon weight.

Hut see 'Ark'.

Hydraulic load the input of water via precipitation and irrigation applications into a pond or onto land.

Indoor piggery piggery system in which the pigs are accommodated indoors in either conventional or deep litter sheds.

Katabatic drift drainage of air in the absence of wind, whereby odour may drift with minimal dilution to lower areas, following the topography in the same way as watercourses.

Katabatic winds winds that occur mainly on cloudless nights when the land surface loses heat by radiation. Air that is cooled by contact with the cold land becomes denser than the surrounding air. The force of gravity on it is relatively greater and the air begins to flow down the slopes of mountains and hills. This downward flow becomes particularly evident as the air moves down the bottom of river valleys that lead to lower levels. Generally, these are rather light winds.

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.

Manure faeces plus urine.

MEDLI® a Windows-based computer model for designing and analysing effluent treatment systems and utilisation by land irrigation. It was developed jointly by the CRC for Waste Management and Pollution Control, the Department of Primary Industries and Fisheries - Queensland, and the Department of Natural Resources, Mines and Energy - Queensland.

Multi-site production a production system where there is physical separation of the breeder, weaner and grower pigs. Typically piglets are weaned at 2-4 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.

Odour units units for measuring the concentration of odorous mixtures. The number of odour units is the concentration of a sample divided by the odour threshold or the number of dilutions required for the sample to reach the threshold. This threshold (1OU) is the numerical value at which 50% of a testing panel (see 'Olfactometry') correctly detect an odour.

Offensive odour an odour that by reason of its nature, components, quality or strength, or at the time at which it is made, is likely to be offensive to, and/or to interfere unreasonably with the comfort or rest of people at, or beyond, the boundaries of the premises from which the odour originates.

Olfactometry a procedure in which a selected and controlled panel of up to eight respondents is exposed to precise variations in odour concentrations in a controlled sequence. The results are analysed using standard methods to determine the point at which half the panel can detect the odour (1OU).

Open flush gutters open gutters, or vee drains, running along solid flooring within or beside the pens that collect effluent from conventional sheds.

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.

Persistent bullying enduring aggression of a pig by one or more other pigs, leading the stockperson to consider that the welfare of a pig is being compromised.

pH a measure of the acidity or alkalinity of a product. The pH scale ranges from 1 to 14. A pH of 7 is neutral, a pH below 7 is acidic and a pH above 7 is alkaline.

Phase feeding the use of multiple diets that match the pig's requirements for optimal growth.

PigBal the nutrient mass balance model for piggeries developed by the Department of Primary Industries and Fisheries – Queensland (Casey *et al* 2000). It is a Microsoft Excel®-based spreadsheet model that was developed to estimate the waste production of piggeries, and to assist in the design of effluent treatment facilities, and in assessing the environmental sustainability of associated land reuse practices. At the time of publishing, the model had not been developed to a fully commercial standard. Copies are available from the department upon request, on the understanding that the model has not yet been finalised because not all the outputs have been thoroughly validated against measured data from operational piggeries. APL has commissioned a project to address this.

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 based 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 by-products on land for the purpose of utilising the nutrients and water they contain for crop or pasture growth.

Reuse area an area where by-products are spread for the purpose of utilising the nutrients and water they contain for crop or pasture growth.

Riparian vegetation Vegetation 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 pasture or cropping 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 watertable 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. Separation distances are measured as the shortest distance measured from the piggery complex to the nearest part of a building associated with the sensitive land use.

SEPS Sedimentation and Evaporation Pond Systems. This is an effluent treatment system consisting of two or three 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 twelve 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 cleaner water.

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 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.

Stall an enclosure, closely related to the pig's body size, in which gilts, sows and boars are kept individually. Stalls are normally joined together in rows and may be used for total confinement, or allow the pig free choice of access.

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.

Surface waters dams, impoundments, rivers, creeks and all waterways.

Sucker or suckling piglet a piglet between birth and weaning (i.e. an unweaned pig).

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 / 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^{0}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.

Wallow a depression in the ground where pigs raised in rotational outdoor piggeries can roll.

Wastload developed in South Australia, Wastload is a Microsoft Excel-based model designed to calculate sustainable by-products spreading rates. Inputs include soil properties, effluent and shandying water composition, land use and harvested yields. Outputs include potential loading rates for nitrogen, phosphorus and potassium, the sustainable effluent and/or solids application and salt dynamics (Clarke 2003).

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 up until approximately 30 kg in live-weight.

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).

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