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Development of Indicators of Sustainability for Effluent Reuse in the Intensive Livestock Industries: Piggeries and Cattle Feedlots

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FEEDLOTS

DEVELOPMENT OF INDICATORS OF SUSTAINABILITY FOR EFFLUENT REUSE IN THE INTENSIVE LIVESTOCK INDUSTRIES:

PIGGERIES AND CATTLE FEEDLOTS

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Issue 1 – Draft (dated 22 October 2002) circulated to the steering committee for comment.

Issue 2 - Draft (dated 20 December 2002) circulated to the steering committee for comment. This document was also circulated to other industry parties (industry) by steering committee members.

Issue 3 - Draft (dated 31 March 2003) included updates from the consultation process and was circulated to the steering committee members for comment.

Issue 4 - This Summary Document and accompanying Resource Manual have been compiled to meet the requirements of Australian Pork Limited Consultancy Agreement: 1816 (dated 19 March 2002).

This document provides summary information to address the aims and objectives of the Consultancy Agreement as set out by Australian Pork Limited. More detailed information is contained in the accompanying Resource Manual.

This Summary Document supersedes all previous versions of the document that were distributed for comment.

Disclaimer:

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1. INTRODUCTION

Australian Pork Limited (APL), Meat & Livestock Australia (MLA) and NSW Environment Protection Authority (EPA) wish to develop indicators of environmental sustainability for the reuse of effluent and solid by-products of the intensive livestock industries: piggeries and cattle feedlots. These sustainability indicators could be applied to the EPA-administered load based licensing (LBL) scheme in New South Wales.

The principal aims of this project are to produce a Resource Manual containing appropriate sustainability indicators for the reuse of effluent and solid by-products for piggeries and cattle feedlots, and to provide tools for producers to use to determine and demonstrate sustainability. This document is a summary of the main practical points from the Resource Manual.

The LBL scheme is New South Wales' polluter pays licensing scheme. The scheme links licence fees to potential environmental impact and provides an economic incentive to reduce pollution. Under the scheme, licensees may receive up to a 100% rebate of load fees for sustainable effluent reuse. The LBL scheme includes piggeries and cattle feedlots under the Intensive Livestock Production activity category. Stage 1 of the LBL scheme has been implemented. This involved a subset of activities that were currently licensed by EPA. The following criteria were considered when defining the initial scope of the scheme:

- The potential for environmental harm.
- The ready availability of load estimation techniques.
- The state of development of the licensing framework for the industry.
- The resources required in implementing the scheme.

The activities to be included in the first phase of the scheme were those with the significant potential for environmental harm, which had traditionally been covered by the licensing scheme. It was originally intended that most of the remaining, currently licensed activities would be progressively phased into the scheme at a later stage.

Load fees for piggeries and cattle feedlots were not included in stage 1 of the LBL scheme. This report provides extensive information on the application to land of piggery and cattle feedlot effluent and solid by-products. The sustainability indicators that are provided are designed to assist in the sustainable management of reuse systems for these industries and are not particularly suggested as limits to calculate and apply LBL fees.

The authors advise that it is important that the NSW EPA and operators of piggeries and cattle feedlots recognise that it is extremely difficult to develop tools for determining and demonstrating sustainability and indicators of sustainability that cover all situations. It is probable that the tools for determining sustainability will overstate the likely risk to the environment 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 investigations.

2. PROJECT OBJECTIVES

The Resource Manual intends to address the absence of readily available data and analysis techniques on the reuse of effluent and solid by-products for piggeries and cattle feedlots. It provides suggested sustainability indicators for these intensive livestock industries. Specifically, it:

- Examines the LBL scheme.
- Examines current guidelines and regulatory requirements for piggeries and cattle feedlots.
- Discusses effluent and manure production for piggeries and cattle feedlots.
- Investigates the effects that nutrients and salts can have on soil and water resources.
- Identifies appropriate indicators for sustainable effluent and solid by-products reuse that could be used by piggery and feedlot operators and regulatory agencies to measure environmental performance and improve sustainability via changes in management of the system (whether or not LBL applies).
- Summarises methods for protecting soil, surface and groundwater resources through good design and management.
- Outlines how mass balance principles can be used to decide appropriate nutrient and salt loading rates based on land use. This section includes suggested maximum nutrient application rates based on land use. It also suggests techniques for estimating the loads of key pollutants applied to land by intensive livestock industries licensed by the EPA, and methods for estimating nutrient removal by cropping.
- Defines a risk assessment procedure to be used for deciding the minimum (cost-effective) monitoring requirements that individual facilities could use to demonstrate sustainability. The type and level of monitoring for any facility would depend on the risk to surface water, groundwater and soil resources. This will include suggested monitoring parameters and monitoring frequency for each by-product for reuse (e.g. effluent or solids) and each reuse area at any given enterprise.
- Recommends practices to reduce the risk of adverse environmental impacts from effluent or solid by-products reuse.
- Identifies areas needing further research.

The accompanying Resource Manual draws on state, national and international research. Its development has also relied on extensive consultation with those undertaking applicable research. It provides the best currently available scientific basis to improve the quality of LBL monitoring requirements. It also provides a useful starting point for the consideration of sustainability indicators for other intensive livestock industries.

This Summary Document has been compiled from the Resource Manual and outlines the practical points from the main report, including indicators of sustainability, a risk assessment process and monitoring recommendations.

3. NSW LOAD BASED LICENSING SCHEME

3.1. Background

The Load-Based Licensing Scheme was introduced in July 1999 under the Protection of the Environment Operations (General) Regulation 1998. The LBL Scheme was a major overhaul of the NSW environment protection licensing system.

Previously, licensing fees were mainly based on the scale and type of a licensed activity, or the maximum allowable volume of wastewater permitted to be discharged. The LBL Scheme is based on two key principles:

- The primary measure and limit tool for licensed discharges is the annual pollutant load (or mass emitted) instead of the concentration of pollutants contained in the discharges. This new approach is designed to provide a stronger outcomes-based focus for the licensing system, and thus greater assurance of environment protection. It is also intended to provide greater flexibility for licensees to find cost-effective and innovative options for meeting environmental requirements.
- The pollution load licence fee is designed to provide ongoing incentives for pollutant load reductions. The fee is based on the quantity and type of pollutants discharged, with adjustments for the manner of discharge and the condition of the receiving environment.

The activities to be included in the first phase of the scheme were those with the significant potential for environmental harm, which had traditionally been covered by the licensing scheme. Load fees for piggeries and cattle feedlots were not included in Stage 1 of the LBL scheme. This report provides extensive information on sustainability indicators for piggery and cattle feedlot effluent and solid by-products application.

3.2. Load Calculation Protocol

The current version of the Load Calculation Protocol for use by holders of NSW Environment Protection Licences was gazetted on 10 May 2002.

The assessable load of a pollutant is the least of the actual, weighted or agreed load. The actual load of a pollutant is the mass (in kg) of the pollutant released to the environment. The weighted load of a pollutant is the actual load adjusted using specified load-weighting methods that recognise practices or circumstances that effectively reduce the environmental harm without reducing the actual load. The agreed load is a load that will be achieved through future improvements as part of a Load Reduction Agreement.

The methods suggested for calculating actual loads in the Load Calculation Protocol are:

- Source monitoring – this involves directly measuring volume and concentration data either continuously or periodically, for example from an irrigation outlet pipe.
- Emission factor – this uses either generic emission data derived from broad average emission data or site-specific emission factors.

- Mass balance calculations – These assume that the discharge to the environment is the difference between inputs and outputs. This method is only applicable when input and output streams can be accurately quantified. Where the declared error range of the mass balance exceeds 10%, the amount equal to the portion of the error range exceeding 10% must be added to the estimated load values. Mass balance principles can be applied to individual components of an activity or across an entire activity.

Fee reductions of up to 100% for sustainable effluent reuse can be applied. Reuse discount factors for each pollutant are the sum of a ‘pollutant management factor’ (0, 0.25 or 0.5, where 0 represents sustainable performance) and a ‘water management factor’ (0, 0.25, 0.5, where 0 represents sustainable performance). Better performance leads to a lower factor and thus greater discounting.

To gain a full discount (0) for nitrogen and phosphorus they must be applied so that they are effectively used for plant growth or sustainable assimilation by the soil system. If nitrogen and phosphorus levels below the plant root zone are rising, the average amount of effluent applied per unit area must be decreased. The sustainable rate of application of nutrients (such as nitrogen and phosphorus) can sometimes limit the quantity of effluent to be used for irrigation in a given area. To obtain the fee discount, licensees must:

- Have developed a 15-year forward management plan that shows how proposed annual nutrient application rates compare with the annual amounts to be taken up by the biological or physical processes of the crop–soil system. This should be done before the construction of the effluent reuse scheme. Nutrient application rates must be based on the sustainable assimilation of nutrients over a rolling 15-year period.
- Review the plan every 3 years to ensure that future planned application rates will continue to achieve sustainable assimilation over a rolling 15-year period.
- Prepare annual nutrient balances showing nutrient application rates and the results of soil monitoring completed in accordance with the management plan, and how these outcomes compare with those anticipated in the management plan. Documentation of plan and annual balances must be kept for at least 4 years.

To gain a partial discount (0.25) for nitrogen and phosphorus the same criteria apply, except the planning timeframe is only 5-15 years.

A full discount (0.0) for water management is gained if the application rate is controlled by irrigation scheduling or soil moisture monitoring to ensure that effluent or liquid waste does not percolate deeper than the root zone or intersect groundwaters, except during scheduled salt flushing as per management plan.

A partial discount (0.25) for water management is gained if application ceases during and after rainfall as necessary to prevent waterlogging or runoff.

Discount factors for salt management are calculated depending on the TDS concentration (mg/L), the SAR, the concentration of Na^+ and Cl^- (mg/L) and management practices employed. Effluent applied so that nutrient budget requirements are met. The amount of effluent applied is dependent on the value of the above parameters. See http://www.epa.nsw.gov.au/licensing/lblprotocol/index.htm for more information.

3.3. Advantages and Disadvantages of LBL for Piggeries and Cattle Feedlots

3.3.1. Advantages of LBL

It is preferable from an environmental sustainability viewpoint to license activities by mass of pollutants released rather than by effluent concentration. A concentration-based approach allows pollutants to be released in low concentrations, however, the cumulative effect of pollutant releases gives rise to environmental degradation. The concentration-based approach discourages the reuse of water and may encourage water wastage for dilution purposes. This is not as relevant to piggeries or feedlots since the concentration of nutrients and organic matter in the effluent they produce does not meet discharge standards, even after substantial treatment.

3.3.2. Disadvantages of LBL

A major difficulty in applying LBL to effluent and solid by-product reuse areas is determining appropriate indicators of sustainability. It is very difficult to adequately consider the wide variation in natural resources that may exist for an individual enterprise or indeed across the industries and the related utilisation of by-products. Also, piggeries and cattle feedlots primarily reuse their by-products (effluent and solids) in a cropping or pasture system. Cropping and pasture systems will always lose some nutrients to the environment via runoff, leaching or gaseous loss, whether they are fertilised with animal manure by-products, fertilised with inorganic fertilisers or even left in the virgin state (unfertilised). Identifying benchmarks or triggers for assessing the sustainability of a system is very complex due to the large variations in resources, climatic conditions and management practices between sites.

4. AUSTRALIAN ENVIRONMENTAL GUIDELINES & REGULATORY REQUIREMENTS

Each Australian state has a separate regulatory regime for licensing piggeries and cattle feedlots. This section of the document identifies the current regulatory requirements for effluent and solid by-product reuse in piggeries and feedlots throughout Australia, placing the LBL scheme in context. The relevant national and state guidelines for New South Wales' piggeries and cattle feedlots are listed in sections 4.1 and 4.2. Section 4.3 summarises generic guidelines. Further details are provided in the Resource Manual.

4.1. Guidelines and Regulatory Tools for NSW Piggeries

National guidelines and regulatory tools applying to piggeries include:

- Draft Effluent Management Guidelines for Intensive Piggeries.
- National Pollutant Inventory (NPI).

NSW EPA has model licence conditions for piggeries.

4.2. Feedlots

National guidelines and regulatory tools applying to cattle feedlots include:

- National Feedlot Accreditation Scheme (NFAS).
- National Feedlot Guidelines.
- National Beef Cattle Feedlot Environmental Code of Practice.
- National Pollutant Inventory (NPI).

NSW Agriculture also developed “The Feedlot Manual”.
NSW EPA has model licence conditions for cattle feedlots.

4.3. Generic Guidelines

The NSW Draft Effluent Irrigation Guidelines cover best practices and procedures for establishing an effluent irrigation system.

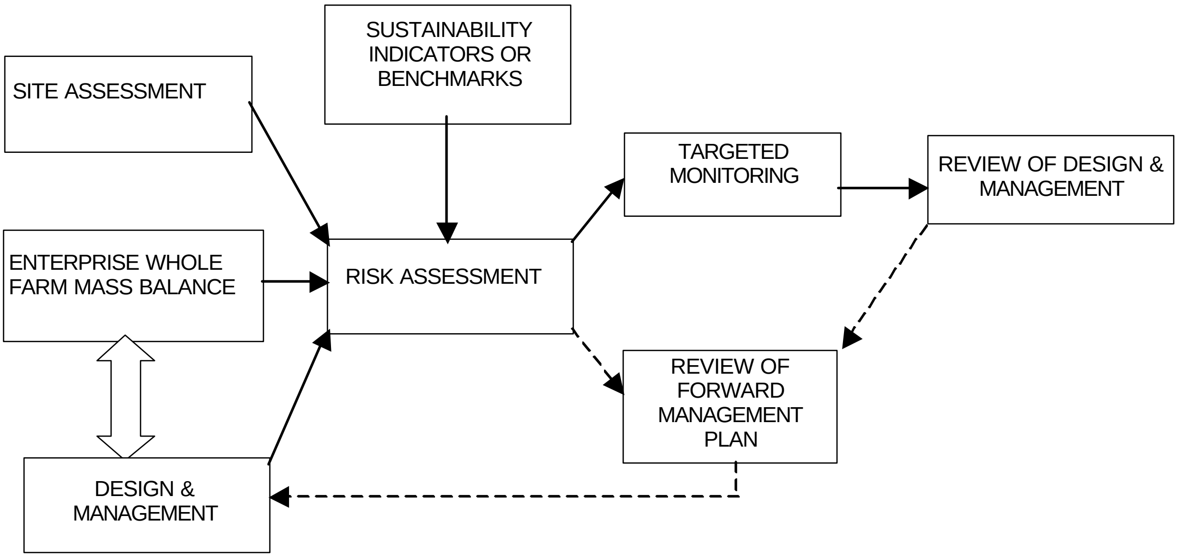
There are also three Australian Standards relating to products containing composts:

- AS4454 – Compost, Soil Conditioners and Mulches.
- AS3743 – Potting Mixes.
- AS 4419 – Soils for Landscaping and Garden Use.

5. SUSTAINABLE EFFLUENT AND MANURE REUSE

Figure 1 provides a framework to achieve sustainable effluent and by-product reuse for piggeries and cattle feedlots. It assumes that environmental monitoring requirements for piggery or feedlot reuse areas match the potential risk to the environment. Consequently, the framework provided uses a **risk assessment process** to decide monitoring requirements. The level of risk depends on the environmental vulnerability of the site, the quantity of water, nutrients and salt for reuse and the design and management of the reuse areas.

FIGURE 1. MANAGING SUSTAINABLE REUSE SYSTEMS: PIGGERIES AND CATTLE FEEDLOTS



The first stage in an environmental risk assessment is a site assessment. This identifies the resources that could be vulnerable to any adverse environmental impacts associated with reuse and the site factors that could influence reuse. The site assessment includes an evaluation of the site’s soils, the nearby surface water resources, groundwater depth and quality, the climate of the area (rainfall, evaporation etc), the land area available for reuse, and the type and yield of the crops or pastures grown. Different sections of one reuse area can have different vulnerabilities depending on the natural resources of these areas. Also, different reuse areas on a property may have different vulnerabilities. Thus, the process identified in Figure 1 should be applied separately to each individual reuse area.

Next, the quantity of nutrients and salts for reuse, and the design and management of reuse areas must be examined. **An enterprise whole farm mass balance can be used to estimate the mass of nutrients for reuse and the mass of nutrients removed from reuse areas, stored in the soil or lost to the environment**. The nutrients and salts production of an enterprise can be taken from standard ‘text book’ values, estimated using mass balance principles or calculated from the measured salt and nutrient concentrations in the by-products and the quantity of effluent or solids applied (for operating enterprises). Nutrient and salt removal can be estimated from ‘text book’ or analysed nutrient composition data multiplied by measured or estimated plant yields.

The standard of design and management of the reuse areas influences the risk of environmental harm. It is most important where environmentally vulnerable resources are identified or where water, nutrient or salt loading rates are high. However, poor design or management can cause environmental harm even when resources are not particularly vulnerable.

The actual risk assessment considers the combined effect of the environmental vulnerabilities of the site, the quantity of water, nutrients and salt for reuse and the design and management of the reuse areas to decide whether adverse environmental impacts are likely.

Theoretically, the simplest measure of sustainability is a match between nutrient application rate to a land area and the nutrient removal by plant harvest from that area. This will never occur in reality due to a number of other factors, including:

- The soil/by-product dynamics after application.
- Nutrient availability of by-products.
- Losses such as nitrogen volatilisation.
- Storage of nutrients such as phosphorus in the soil.
- Leaching of salts through the soil profile.
- Exports of some elements in surface water runoff.
- The need to address pre-existing soil nutrient deficiencies (to bring these up to normal agronomic levels).

Thus, application rates need to be closely matched to estimated uptake rates, plus *acceptable* storage and losses of nutrients for a system to be sustainable.

Sustainability indicators measure the effects on the environment of nutrients lost from reuse areas. These indicators are not absolute measures, so a process is needed to assess what the indicators tell about the site. **A risk assessment has been selected as the most appropriate process to interpret sustainability indicators**. This provides flexibility to evaluate a broad range of sites without needing to compromise the assessment's accuracy.

To determine the environmental risk and consequently the scope of environmental monitoring required, a matrix process is suggested. This leads naturally into suggested monitoring parameters and frequencies. The following sections of the document provide guidance for a piggery or cattle feedlot operator to complete a matrix and determine their level of environmental risk.

In Section 6 and 7 the risks associated with the design and management of the reuse area are determined. These include a knowledge of the nutrients in effluent and manure available for reuse (Section 6), knowledge of the size of land area available and application rate of nutrients (Section 7) and the risk associated with the application method of effluent and solids (Section 7).

In Section 10 a site vulnerability assessment needs to be conducted. This is assessment of the reuse against the soils of the site (texture, depth, slope, soil dispersion, nitrogen levels and phosphorus levels), surface water (water quality and flood potential) and groundwater (depth to groundwater and soil type).

A matrix is developed by multiplying the risks associated with the design and management of the reuse area, against the site vulnerability assessment (soils, surface water and groundwater).

Where significant environmental risk exists, a piggery or feedlot operator could improve the design or management of the reuse practices or the reuse area to reduce the likelihood of adverse impacts through a Review of the Forward Management Plan. This would necessitate a reassessment of risk and monitoring requirements.

The outcomes of the targeted monitoring step require review and interpretation. Depending on the findings, a feedlot or piggery operator may decide at this stage to change their operation’s design or management to improve environmental performance

6. EFFLUENT AND MANURE PRODUCTION (MASS BALANCE)

Nutrients and salt management for effluent and manure reuse areas requires quantification of these constituents. Under the LBL protocol, the mass of nutrients and salts for reuse can be determined in a number of ways, including measuring the volume and concentration of nutrients in effluent, using emission data or using mass balance calculations. This section provides some general guidance on the amount of nutrients produced by piggeries and cattle feedlots, it does not attempt to distinguish between the amount partitioned to the effluent and solids components.

6.1. Estimating Nutrients and Salts in Effluent & Solids – Concentration and Quantity Method

If a piggery or cattle feedlot is operating, the concentration of elements in the effluent or solid by-products and the total quantity of effluent or solid by-products for reuse provides a measure of the mass of any element available for reuse. This is usually the best method to determine application rates, providing representative samples of effluent or solid by-products are collected and the mass or volume applied is accurately known.

6.2. Estimating Nutrients and Salts in Effluent & Solids – Emissions Data

Another method for estimating nutrients and salts in effluent and solids is through the use of emission factors. An emission factor is an estimated pollutant emission rate relative to the level of readily measurable activity. Such factors can be used under the LBL Load Calculation Protocol and the National Pollution Inventory.

For intensive piggeries, the Standard Pig Unit (SPU) concept is a surrogate generic emission factor. The Environmental Code of Practice for Queensland Piggeries (Streeten and McGahan, 2000) defines an SPU as: *The unit of measurement for determining the size of a pig production unit in terms of its waste output. One SPU produces an amount of volatile solids equivalent to that produced by an average size grower pig (approximately 40 kg*). Although the SPU multiplier for each class of pig is based on volatile solids production, it provides similar multipliers between pig classes for other elements (total solids, nitrogen, phosphorus and potassium). Thus, with typical pig diets used in Australia, one SPU excretes about 108 kg of total solids, 90 kg of volatile solids, 18 kg of ash, 9.2 kg of nitrogen, 3.0 kg of phosphorus and 2.4 kg of potassium annually.

Providing a generic emission factor for feedlot cattle is difficult because reported values for feedlot cattle excretion vary widely for total solids, volatile solids, nitrogen and phosphorus. Partly, this is because the literature is generally based on manure production estimated from animal mass and does not consider likely manure production based on feed intake. The accompanying Resource Manual contains modified Standard Cattle Unit (SCU) multipliers for each feedlot animal class based on the estimated volatile solids production. These multipliers assume that one SCU is equivalent to a Korean steer (150 days on feed, liveweight in of 380 kg, and liveweight out of 600 kg). Using mass balance, “conservative” estimates suggest that some 15 kg/SCU/yr of nitrogen and 11.3 kg/SCU/yr phosphorus would be available for plant uptake.

6.3. Estimating Nutrients and Salts in Effluent & Solids – Mass Balance

A mass balance estimates the quantity of nutrients and salts in by-products through the difference between inputs (generally stock in, feed and water) and outputs excluding effluent and solid by-products (stock out, nitrogen volatilisation). It also provides details of nitrogen losses via ammonia volatilisation and nutrient partitioning in effluent treatment ponds between supernatant and sludge. Each of these elements is important in accurately estimating the quantity of nutrients in the effluent for reuse. Nutrients and salts excreted by pigs can be estimated using predictive models, such as PigBal, BeefBal and MEDLI (piggeries and cattle feedlots).

6.4. Risk Assessment: Nutrients in Manure and Effluent

To be able to manage a reuse area in an environmentally sustainable manner it is important to know the amount of nutrients applied. Better quantification of the nutrients for reuse enables better management. This section provides a process for assessing the risk an enterprise poses to the environment based on the level of precision of nutrient quantification. It is important to note that knowledge of the nutrients for reuse is only a small part of their sustainable reuse. The vulnerability of natural resource (surface water, groundwater and soil) and the overall standard of design and management are also important. These are considered further in Section 11.2.

Low Risk	The quantity of effluent and solids reused is measured and the quality of effluent and solids reused is regularly measured (at least annually, more frequently if required to ensure sound management of nutrients). OR You have developed a mass balance of nutrient production from your piggery or cattle feedlot using accepted design tools, such as PigBal, BeefBal or MEDLI using conservative figures. (There can be a great variation in nutrient predictions from mass balance models).
High Risk	You have never measured, but only estimated the mass of nutrients applied using “text-book” values, such as those provided in Section 6.2.

A risk weighting of 1 or 3 applies to the Nutrients and Manure criterion. A low risk attracts a risk weighting of “1” and high risk attracts a risk weighting of “3”.

Transfer these values to the Risk Assessment Matrices for soils, surface water and groundwater (Table 10, Table 11 and Table 12).

7. DESIGN AND MANAGEMENT OF REUSE AREAS

The design and management of reuse areas are important in deciding the risk of environmental impacts, particularly where vulnerable resources are concerned. This section of the Resource Manual provides background information on design and management options. The design and management practices partly determine the environmental risk of a reuse activity. They feed into the risk assessment process, along with the predictions of nutrients produced (mass balance), the assessment of the natural resources and the sustainability indicators.

The end of this section includes a process for evaluating the environmental risk associated with the design and management of the reuse areas.

7.1. Type of Crop/Pasture Grown and Yield

The type of crop grown on the reuse area determines the nutrient uptake through its dry matter yield and nutrient content. Table 1 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. Further information for other crops can be found in various references, such as the *Draft Guidelines for Industry – The Utilisation of Treated Effluent for Irrigation*.

Grazed pasture is an ineffective method of utilising nutrients from reuse areas. Most of the nutrients are simply recycled through the grazing animal and returned to the reuse area. Grazing systems typically require at least ten times more area than a system using a removal process (e.g. cut and cart).

7.2. 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, phosphorus storage, nitrogen volatilisation and other acceptable losses. This information needs to be known in order to manage a reuse area in an environmentally sustainable manner.

The first step in the risk assessment process is nutrient quantification for the reuse area. The recommended method for estimating nutrients and salts from piggeries and feedlots is mass balance considering inputs and outputs. This estimates the net mass of nitrogen, phosphorus and salt added to reuse areas as the difference between additions via effluent, solid by-product and/or inorganic fertiliser applications and removal via crop harvest and acceptable losses (nitrogen volatilisation and salt leaching).

The mass balance could be a desktop study (e.g. PigBal, BeefBal, MEDLI) or could use physical measurements coupled with a desk top study (e.g. the quantity of nutrients applied could be determined by effluent or solids analysis and measurement of application rates.

This would then be compared with the expected nutrient removal rate by cropping). In the absence of site-specific mass balance modelling, figures given in Sections 6.2 can be used.

TABLE 1 – NUTRIENT CONTENT AND ANTICIPATED DRY MATTER YIELD OF VARIOUS CROPS

Crop	DM Nutrient Content (%)			Normal Yield Range (DM t/ha)	Normal Nutrient Removal Range (kg/ha)		
	N	P	K		N	P	K
Dry Land Pasture (cut)	2.0	0.3	1.5	1 - 4	20 - 80	3 - 12	15 - 60
Irrigated Pasture (cut)	2.0	0.3	1.5	8 - 20	160 - 400	24 - 60	120 - 300
Lucerne Hay (cut)	3.1	0.3	2.5	5 - 15	155 - 465	15 - 45	125 - 375
Maize Silage	2.2	0.5	2.0	10 - 25	220 - 550	50 - 125	200 - 500
Forage Sorghum	2.2	0.3	2.4	10 - 20	220 - 440	30 - 60	240 - 480
Winter Cereal Hay	2.0	0.3	1.6	10 - 20	200 - 400	30 - 60	160 - 320
Seed Barley	1.9	0.3	0.4	2 – 5	38 – 95	6 – 15	8 – 20
Seed Wheat	1.9	0.4	0.5	2 – 5	38 - 95	8 - 20	10 – 25
Triticale	1.9	0.4	0.6	1.5 - 3	29 - 57	6 - 12	9 – 18
Rice	1.4	0.3	0.4	4 - 8	56 - 112	12 - 24	16 - 32
Seed Oats	1.5	0.3	0.4	1 - 5	15 - 75	3 - 15	4 – 20
Grain Sorghum	2.0	0.3	0.3	2 - 8	40 - 160	6 - 24	6 – 24
Grain Maize	2.0	0.3	0.4	2 - 8	40 - 160	6 - 24	8 – 32
Chickpea	4.0	0.4	0.4	0.5 - 2	20 - 80	2 - 8	2 – 8
Cowpea	3.0	0.4	2.0	0.5 - 2	15 - 60	2 - 8	10 – 40
Faba Bean	4.0	0.4	1.2	1 - 3	40 - 120	4 - 12	12 – 36
Lupins	4.5	0.3	0.8	0.5 - 2	22.5 - 90	1.5 - 6	4 – 16
Navy Bean	4.0	0.6	1.2	0.5 - 2	20 - 80	3 - 12	6 – 24
Pigeon Peas	2.6	0.3	0.9	0.5 - 2	13 - 52	1.5 - 6	4.5 – 18
Cotton	2.0	0.4	0.8	2 - 5	40 - 100	8 - 20	16 – 40
Asparagus	0.4	0.4	2.5	0.5 - 2	2 - 8	2 - 8	12.5 - 50
Beans	3.1	0.3	2.6	4 - 8	124 - 248	12 - 24	104 - 208
Beetroot	4.2	0.3	4.0	5 - 15	210 - 630	15 - 45	200 - 600
Broccoli	3.9	0.5	3.0	5 - 15	195 - 585	25 - 75	150 - 450
Cabbage	3.5	0.4	4.0	5 - 15	175 - 525	20 - 60	200 - 600
Carrot	0.9	0.4	1.7	5 - 15	45 - 135	20 - 60	85 - 255
Cauliflower	3.6	0.5	4.3	5 - 15	180 - 540	25 - 75	215 - 645
Celery	2.1	0.3	4.0	5 - 15	105 - 315	15 - 45	200 - 600
Lettuce	4.0	0.5	6.0	5 - 15	200 - 600	25 - 75	300 - 900
Onion	1.3	0.4	2.2	5 - 15	65 - 195	20 - 60	110 - 330
Peas	2.0	0.2	1.2	4 - 8	80 - 160	8 - 16	48 - 96
Potato	2.5	0.2	2.2	5 - 15	125 - 375	10 - 30	110 - 330
Tomato	3.6	0.7	4.7	5 - 15	180 - 540	35 - 105	235 - 705

Sources: Reuter, D.J., Robinson, J.B. (eds) (1997) and National Research Council (1984).

In the simplest form, a system is sustainable if nutrient removal by crop harvest matches nutrient applications, the soil resource is maintained or improved, and the environment and public health is protected. However, there are good arguments for modifying this definition for the reuse of effluent or solid by-products from piggeries and cattle feedlots. For example, most soil types have a significant capacity to store phosphorus. Since many Australian soils are also inherently deficient in phosphorus, it makes good agronomic sense to apply phosphorus to the soil at rates exceeding the nutrient uptake by cropping. Also, most Australian soils used for crop production have a good capacity to retain phosphorus. Salt tends to be more complex since growing plants remove relatively small amounts of salts.

The Mass Balance Equation for reuse areas is:

Crop Uptake + Allowable Losses + Safe Soil Storage = Amount Applied

To solve this equation, it is necessary to quantify the following parameters, considering the management practices employed and the natural resources of the site:

- Allowable losses
- Safe phosphorus storage capacity

Allowable losses may include:

- N volatilisation during and after application
- Leaching – provided it does not exceed an acceptable level OR degrade the groundwater source.

7.3. Control Measures and Practices to Minimise Export of Nutrients

Measures typically used to minimise nutrient export from reuse areas include:

- Vegetative filter strips located downslope of the reuse area.
- Terminal ponds located downslope of the reuse areas.
- Contour banks installed on sloping land and runoff diversion banks/ditches upslope of reuse area.
- Maintaining continuous ground cover.
- Direct injection of slurry and incorporation of solids as soon as possible after application.
- Use of phosphorus sorbing treatments (e.g. red mud, ferric chloride).
- Using sound reuse practices (including irrigation scheduling and the use of soil moisture sensors).

These measures are effective at both reducing soil erosion and filtering nutrients from runoff water. However control measures, such as vegetative filter strips and terminal ponds should not be used as a 'quick-fix' for poor reuse practices. They provide secondary environmental protection after sustainable reuse based on mass balance principles and/or monitoring. Employing these control measures at intensive animal operations with sustainable application rates, is likely to achieve lower nutrient losses than those expected from 'conventional' cropping practices using inorganic fertilisers.

7.4. Risk Assessment: Design and Management of Reuse Areas

This section provides information to decide the risk class of various reuse design and management options. These design and management options include:

- Sizing reuse areas for sustainable reuse.
- Application methods for effluent and solid by-products.

- Providing safeguards for minimising nutrient exports via processes such as erosion and leaching.

Sizing reuse areas and using appropriate application methods for applying effluent and solid by-products are primary methods for minimising the environmental risks associated with reuse. These design and management options, as well as the risk associated with the nutrients in effluent and solids (Section 6.4) are evaluated against the natural resources (surface water, groundwater and soil) vulnerability assessment criteria for the site in Section 11.2.

Providing design or management based safeguards for minimising nutrient exports is a secondary method for reducing nutrient exports by reducing resource vulnerability.

7.4.1. Size of Land Area and Application Rate

Select the appropriate risk category for each sub-heading below. The **highest** risk weighting for section 7.4.1 is then transferred into the "Size of Land Area" row of Table 2.

Knowledge of Size of Land Area

Low Risk	From farm or paddock maps, you accurately know the area (ha) of each effluent or manure reuse paddock under each management regime (e.g. soil properties, land use).
Medium Risk	You know the approximate area (ha) of each effluent or manure reuse paddock under each management regime.
High Risk	You do not know the area of the effluent or manure reuse paddocks.

Knowledge of Yields of Crops or Pastures Grown on Reuse Areas

Low Risk	For your property and soil type, you know typical yields for the pastures or crops grown on reuse areas.
Medium Risk	You know typical district yields for the pastures or crops grown on reuse areas.
High Risk	You do not know typical yields for the pastures or crops grown on reuse areas.

Knowledge of Nutrients Applied to Reuse Areas

Low Risk	You have calculated the nitrogen (kg/ha/yr) and phosphorus (kg/ha/yr) loading rates to reuse areas from estimated nutrient production.
High Risk	You have not calculated the nitrogen (kg/ha/yr) and phosphorus (kg/ha/yr) loading rates to reuse areas.

Nitrogen Mass Balance for Reuse Areas

Low Risk	You have calculated that the net mass of nitrogen applied (kg/ha/yr) as effluent or solid by-products is equal to the mass of nitrogen (kg/ha/yr) that plant harvest should remove.
High Risk	The net mass of nitrogen applied to reuse areas (kg/ha/yr) exceeds the mass removed or you do not know the net mass of nitrogen applied to the reuse area.

Phosphorus Mass Balance for Reuse Areas

Low Risk	You have calculated that the net mass of phosphorus applied (kg/ha/yr) as effluent or solid by-products is equal to the mass of phosphorus (kg/ha/yr) that plant harvest should remove plus phosphorus storage calculated from a site-specific phosphorus sorption test or from generic phosphorus sorption data for similar soil types.
High Risk	The net mass of phosphorus applied to reuse areas (kg/ha/yr) exceeds the mass removed plus storage calculated from a site-specific phosphorus sorption test or from generic phosphorus sorption data for similar soil types or you do not know the mass of phosphorus applied to the reuse area.

Select the highest risk weighting from the above categories to transfer to the “Size of land area and Application rate” row of Table 2.

7.4.2. Effluent & Solid By-Product Application Methods

If you reuse effluent on-site, select the appropriate risk category for “Effluent Irrigation” based on the information presented below. If you reuse solid by-products on-site, select the appropriate risk category for “Solids Spreading” from the information presented below. If you reuse effluent and solids on the same area, select the risk weighting that is **highest** from either the “Effluent Irrigation” or “Solids Spreading” sections below (e.g. if you have a rating of *low* for effluent irrigation and a rating of *medium* for solids spreading, the overall risk weighting you choose for the area is *medium*).

The results then need to be transferred into the “Application Methods” row of Table 2 and converted into a risk weighting. A separate copy of Table 2 needs to be developed for separate reuse areas (e.g. effluent areas V solid areas) or reuse areas posing different risks (e.g. one effluent reuse area might be low risk, another high risk).

Effluent Irrigation

Low Risk	You use a low-pressure, travelling spray or drip irrigation system or a low-pressure solid set spray or drip irrigation system or a well designed and maintained flood irrigation system that is not on sandy to sandy loam soil. The system also applies effluent evenly and at target rates.
High Risk	You use a hand-shift sprinkler or hose or a poorly designed or managed flood irrigation system (e.g. land has not been levelled or effluent is unshandied or surface soil is sandy to sandy loam).

Solids Spreading

Low Risk	The spreading method used disperses solids evenly and at target rates.
Medium Risk	The spreading method used disperses solids fairly evenly and within 20% of target rates.
High Risk	The spreading method used disperses solids unevenly or at uncontrolled rates (not within 20% of target rates).

Select the highest risk weighting from the above categories to transfer to the “Application methods” row of Table 2.

Table 2 is a template for summarising the design and management risk weightings for each design and management criterion. To complete the table, insert a risk weighting of 1, 2 or 3 against each criterion. A low risk attracts a risk weighting of “1”, medium risk attracts a risk weighting of “2” and high risk attracts a risk weighting of “3”. These numbers are transferred to Table 10, Table 11 and Table 12.

TABLE 2 – DESIGN AND MANAGEMENT REUSE AREA RISK ASSESSMENT SUMMARY

Design and Management Criteria	Design & Management Risk Weighting (Low = 1, medium = 2, high = 3)
Size of land area and Application rate	e.g. 3
Application methods	

Transfer these values to the Risk Assessment Matrices for soils, surface water and groundwater (Table 10, Table 11 and Table 12).

8. SUSTAINABILITY INDICATORS

This section of the Resource Manual provides the technical background needed to identify appropriate indicators of environmental sustainability for effluent and solid by-product reuse. These indicators represent best current knowledge and available information. For some indicators, the knowledge of processes involving the indicator is limited, or available data regarding the relationship between the indicator and particular environmental effects is poorly defined or limited to particular geographical locations. In instances where knowledge or data is limited, regulatory authorities often apply the precautionary principle to establish a conservative guideline.

The following sustainability indicators have been judged to provide the best practical and objective measures of sustainability. It is expected that in most cases they will provide a good tool for the assessment of sustainability. However, it is important to recognise that non-compliance with the triggers associated with the indicators does not necessarily suggest that a system is unsustainable. In these instances, operators of piggeries and cattle feedlots may use other indicators to demonstrate sustainability.

8.1. Nitrogen

Nitrogen in the nitrate form is extremely mobile and readily leached. Consequently, high nitrate-nitrogen levels in the subsoil pose a risk to groundwater. Once the nitrogen moves below the plant root zone, it is no longer available for plant uptake and can leach to groundwater. An obvious sustainability indicator of nitrogen in reuse areas is the nitrate-nitrogen concentration below the plant active root zone.

Subsoil nitrate-nitrogen concentrations exceeding a soil solution concentration of 10 mg nitrate-N/L may produce some nitrogen leaching losses. The 10 mg/L nitrate-N is based on the *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC, 1992) which state that nitrate-nitrogen concentrations should not exceed the 10 mg/L level in groundwater used for human consumption.

Applying a drinking water quality standard is likely to be overly stringent in many cases since the groundwater under reuse sites is unlikely to be used for human drinking water and it assumes there is no further losses or dilution before it reaches the groundwater. This limit is commonly exceeded in normal agricultural soils. Vertosols, for example, can have relatively high nitrate-nitrogen levels in their natural state. When assessing the sustainability of a reuse practice in terms of nitrogen levels, a number of factors need consideration, including the value or use of surrounding groundwater resources (human consumption, animal consumption, irrigation etc), the depth to groundwater, soil type overlaying the groundwater (e.g. clay) and baseline levels of nitrate-nitrogen in soil below the active root zone.

Monitoring nitrate-nitrogen levels throughout the soil profile provides an excellent indication of nitrogen availability for crop growth and sustainability. Once nitrate-nitrogen has moved below the plant root zone, it is no longer available for plant uptake, but can leach to groundwaters. A nitrate-nitrogen limit of 10 mg/L below the active root zone is suggested only as a trigger for further investigation. This further investigation would involve the comparison of monitoring results from the reuse area with those of the same soil that has not had effluent or manure applied (e.g. under a fenceline). If the level of nitrate below the active root zone show signs of build-up over-time (nitrate bulges), the reuse practices employed will need review in line with the forward management plan of the operation. Thus, comparing nitrate-nitrogen monitoring results against baseline data provides a measure of the nitrogen sustainability of a reuse area.

Other matters to consider when determining the sustainability of the reuse practice in terms of nitrogen include the risk of nitrate moving off-site in surface water and groundwater, the quality (value) of the groundwater and the amount of deep drainage of the soil of the reuse area. These need to be evaluated as part of the risk assessment of the reuse area.

The amount of deep drainage will vary with soil type, rainfall, the amount of effluent or fresh water irrigated and the type of crop production. For example, deep drainage may range from 10mm/yr to 150 mm/yr for a black vertosol and a loamy-sand respectively, when a crop of improved pasture is grown and a total of 750 mm of rainfall and effluent irrigation is applied. With 10 mg/L of nitrate-N in the deep drainage, this represents a loss of 1 kg of N/ha/yr for the black vertosol and 15 kg of N/ha/yr for the loamy sand.

The depth of the root zone depends on the crop type, soil depth, climatic condition 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). Thus, sampling below the root zone may not always be practically and economically feasible. Sampling to a depth of at least 60 cm 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 (Table 3). It should be noted that soil nitrate-nitrogen concentration levels from effluent and manure reuse areas and indeed from conventional cropping systems using inorganic fertiliser, will often exceed those shown in Table 3.

Soil nitrate-N (mg/kg) = Soil gravimetric moisture conc. at field cap. (g water/g soil) x Soil sol. nitrate-N (mg/L)

TABLE 3 – 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_3-N / 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

8.2. Phosphorus

Skerman (2000) states that significant leaching of phosphorus generally occurs only when the soil is heavily overloaded with phosphorus. Table 4 gives surface soil available phosphorus concentrations that will meet plant requirements and should not result in significant losses to surface water, provided runoff is controlled via good design and management. Since these limits are commonly exceeded in normal agricultural soils, they are triggers for further investigation via comparison against results from ‘virgin’ soils receiving no effluent or manure or if there are doubts about the sustainability of the reuse practice. The limits used in Table 4 do not apply to vertosols, as they may have high levels of available phosphorus in their ‘virgin’ state. Site-specific, background available phosphorus levels are likely to be required for these soil types.

TABLE 4 – SUGGESTED UPPER LIMITS FOR AVAILABLE PHOSPHORUS IN TOPSOIL (SKERMAN, 2000).

Clay Content	pH	Colwell phosphorus (mg/kg)
less than 30%	less than 7	31
less than 30%	greater than 7	59
greater than 30%	less than 7	75
greater than 30%	greater than 7	85

Note: These levels do not apply to some soils, e.g. black vertosols.

The Department of Land and Water Conservation (NSW), Soil And Land Information System (SALIS) database ranks various chemical test results for NSW soil tests, including Bray P. These rankings are shown in Table 5. The high ranking of 20-25 mg/kg Bray P in the surface soil could be used as a guideline measure of a trigger for further investigation. This further investigation could include comparison against background data.

TABLE 5 - CHEMICAL TEST RESULT RANKINGS FOR BRAY PHOSPHORUS (mg/kg)

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

Redding pers. comms. (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 6. It should be noted that these numbers are derived from a relatively small data-set and may need refining when more data is available.

TABLE 6 - BSES PHOSPHORUS (mg/kg) GUIDELINE LEVELS

Clay Content	Average	Standard Deviation	Guideline
less than 30%	17	14	31
greater than 30%	59	72	131

Both the Bray and BSES may be more appropriate measures of available P in certain soils (e.g. acid).

To investigate any possibility of P leaching, particularly with sandy soils, measurement of available P levels at 50 – 60 cm (or the base of the root zone) is also suggested.

The soil profile to the base of the crop root zone should be considered the safe storage interval for applied phosphorus. To prevent excessive leaching of phosphorus below the root zone, it is recommended that the equilibrium solution concentration of phosphorus of 0.5 mg P/L be used to estimate the safe phosphorus storage capacity. Thus, phosphorus applications exceeding removal by the plant material should not go beyond the phosphorus sorption capacity of the soil at an equilibrium solution concentration of phosphorus of 0.5 mg P/L. However, this soil solution concentration level needs review pending the findings of the recent Redding work. It would be possible to generate appropriate soil solution concentration levels for different soil types and regions from currently available data.

A reuse area should be used to store phosphorus only if it is good cropping land and providing a plan is in place to continually crop the area after effluent or solids reuse has ceased to remove the stored phosphorus as it is released. The phosphorus storage capacity of the reuse area should also be determined by measuring a P sorption isotherm every five years.

The P sorption capacity of the soil will generally change down the soil profile due to decreasing levels of available P and changes in soil texture. Phosphorus sorption capacity can be determined by a single average test of the soil profile to the base of the root zone to reduce significant analysis costs. However, it may be beneficial for producers to test the P sorption capacity of different soil layers in some instances.

8.3. Salt

A long-term objective for any reuse area should be to ensure that there are no consistent increases in soil salinity. Clearly there may be pronounced increases in soil salinity through the addition 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 be lower and it will take longer for salt removal to occur. Soils with an EC_{se} of up to 1.9 dS/m fall into the very low to low salinity rating. Thereafter, any increase in EC_{se} of 2.5 dS/m would shift the soil salinity rating by less than one salinity class. Consequently, it is considered that a trigger for further investigation should be any EC_{se} increase of 2.5 dS/m compared with similar soil sampled from 'virgin' sites and any result that places the salinity rating at “medium” or higher. Soil EC_{se} should be determined at a depth of 50-60 cm (or base of root zone).

It is suggested that soil sampling should occur at the end of the main growing season when the plants grown on the area have had time to assimilate nutrients and salts have had time to leach through the soil profiles. It is suggested that 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 investigations are warranted, the soil $Na^+ + Cl^-$ concentration throughout the profile should be determined for the reuse and background sites since sodium chloride is the main salt of interest from a soil degradation perspective. The soil $Na^+ + Cl^-$ concentration of the soil should be less than 150% of background levels.

8.4. Sodicity

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

The primary sustainability indicator for sodicity is ESP measured at depths of 0-10 cm and 50-60 cm (or base of root zone). A trigger for further investigation is a soil ESP exceeding 6%. If the ESP exceeds 6%, comparison with the soils of a background plot is necessary. 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 have potential to become dispersive if the soil salinity declines in the future. For example, in high rainfall years, 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 cessation of effluent reuse. Both these scenarios can give rise 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 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 application to amend the sodium imbalance while 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 gypsum. Gypsum 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).

8.5. Soil pH

Soil pH is important since it influences the availability of some nutrients. The pH throughout the profile should be within the range of 5-8. Soil pH has implications for nutrient uptake by plant growth since it may inhibit the availability of desirable nutrients or increase the availability of toxic elements.

9. PRACTICALITIES AND REALITIES OF EFFLUENT AND SOLID BY-PRODUCT REUSE

This section of the Resource Manual uses both case studies and research work to link theoretical calculations with reality. It includes examples of adverse environmental impacts from inappropriate reuse of intensive livestock effluent and solid by-products. These include problems such as soil acidification, soil structural problems (sodicity), groundwater contamination and surface water eutrophication. Also included are examples of long-term sustained effluent applications that have not caused adverse environmental impacts. This section also examines some theoretical research work showing the contribution of nutrient export from different land use practices, including piggeries and feedlots. This summary document does not contain any of this detailed information and for further details refer to the accompanying Resource manual.

10. SITE VULNERABILITY ASSESSMENT

This section contains details for assessing the state of the farm and its ability to handle effluent and manure reuse. It feeds into the risk assessment process (Section 11) used to evaluate the risk of adverse environmental impacts from reuse. The aim is to provide information to decide vulnerability classes (high, medium or low) for natural resources.

Good design and management practices can sometimes be used to reduce the vulnerability of natural resources. These include:

- Locating vegetative filter strips downslope of the reuse area to reduce the vulnerability of nearby surface waters
- Locating terminal ponds downslope of reuse areas to reduce the vulnerability of nearby surface waters
- Installing contour banks on sloping land to reduce soil erosion and the subsequent vulnerability of nearby surface waters
- Maintaining continuous ground cover land to reduce soil erosion and the subsequent vulnerability of nearby surface waters
- Using sound reuse practices to minimise effluent runoff and deep drainage of nutrients before plants can use them.

These factors are considered when evaluating the vulnerability of each resource. Since different reuse areas on a property have different risk levels depending on site, design and management factors, the site vulnerability assessment needs to be applied separately to each reuse area. A separate reuse area is any area used for spreading effluent or manure that has a different soil type, land use, by-product type (e.g. composted manure V fresh manure), application method or application rate from other areas. For instance, the effluent reuse area might have a high risk level, while the solids area might pose a low risk.

10.1. Soil

The suitability of the soil for effluent and solids reuse depends on a range of factors. Ideally, reuse area soils should have the following properties:

- Loam to medium clay texture (Heavy clay soils require careful management to avoid irrigation runoff and waterlogging)
- Moderately deep to deep
- Not subject to erosion
- Well drained
- Flat to gently sloping
- Slightly alkaline to slightly acidic pH
- Suitable for growing pastures (cut and cart) or forage crops

Texture

Low vulnerability: Soil texture is loam to medium clay.

Medium vulnerability: Soil texture is duplex with a light topsoil and a heavy subsoil or is heavy clay.

High vulnerability: Soil texture is sand or unknown.

Depth

Low vulnerability: Depth of soil is > 1 m.

Medium vulnerability: Depth of soil is 0.5 – 1m.

High vulnerability: Depth of soil is < 0.5 m or unknown.

Slope

Low vulnerability: Slope is < 5% or slope is 5-10% but continuous vegetative cover is constantly maintained over the area or slope is 5-10% but a system of well-designed contour banks is in place to slow the movement of water from the site.

Medium vulnerability: Slope is 5 – 10% or slope is >10% but continuous vegetative cover is constantly maintained over the area or slope is >10% but a system of well-designed contour banks is in place to slow the movement of water from the site.

High vulnerability: Slope is > 10% or unknown.

Soil Dispersion

Low vulnerability: Soil does not disperse on wetting and has a low exchangeable sodium percentage (less than 6%).

Medium vulnerability: Soil disperses on wetting and/or has an exchangeable sodium percentage of 6-15%.

High vulnerability: Soil disperses on wetting and / or has an exchangeable sodium percentage exceeding 15% or the dispersive behaviour and exchangeable sodium percentage of the soil are unknown.

Salinity

Low vulnerability: Soil is in the very low to low salinity class (EC_{se} is less than 1.9 dS/m)

Medium vulnerability: Soil is in the medium salinity class (EC_{se} is 1.9-4.5 dS/m)

High vulnerability: Soil is in the high to extreme salinity class (EC_{se} is over 4.5 dS/m) or soil salinity class is unknown.

Nitrogen

Low vulnerability:	Either soil solution nitrate-N levels at the base of the active root zone are <10 mg/L or are less than measured baseline data.
High vulnerability:	Either soil solution nitrate-N levels at the base of the active root zone are >10 mg/L or are greater than measured baseline data.

These can be converted to soil nitrate-nitrogen concentrations for different soil types as per Table 3

Phosphorus

Vulnerability ratings for phosphorus are based on three methods.

Method 1 involves a check as to whether the Colwell Extractable phosphorus levels exceed certain limits. These limits are based on measured Colwell extractable phosphorus for numerous soils (categorised by clay content and pH). The upper limits (high rating) are one standard deviation above the mean of numerous Colwell extractable phosphorus levels (Redding pers. comm., 2002). However, these limits may not be appropriate for some soil types, such as black vertosols, which may have high levels of Colwell phosphorus in their 'virgin' state.

Method 2 uses guideline limits specifically for acid soils. Some acid soils may require methods involving acid extraction to measure available phosphorus (common in southern NSW and coastal soils). Thus method 2 involves a check as to whether BSES or Bray phosphorus levels exceed certain limits.

Method 3 is an alternative method to 1 and 2 and involves measuring extractable phosphorus levels (with the appropriate method) in the reuse areas and comparing these to extractable phosphorus levels in background plots that have not received effluent or solid by-products.

Method 1 (Most Soils)

Low vulnerability:

Clay Content	Soil pH	Colwell Extractable phosphorus Level (mg/kg)
< 30%	< 7	< 15
< 30%	> 7	< 30
> 30%	< 7	< 40
> 30%	> 7	< 45

Medium vulnerability:

Clay Content	Soil pH	Colwell Extractable phosphorus Level (mg/kg)
< 30%	< 7	15 – 30
< 30%	> 7	30 – 60
> 30%	< 7	40 – 75
> 30%	> 7	45 – 85

High vulnerability:

Clay Content	Soil pH	Colwell Extractable phosphorus Level (mg/kg)
< 30%	< 7	> 30
< 30%	> 7	> 60
> 30%	< 7	> 75
> 30%	> 7	> 85

Method 2 (Acid Soils)

Low vulnerability:	Bray phosphorus level < 20 mg/kg BSES phosphorus level < 15 mg/kg for soils with < 30% clay BSES phosphorus level < 65 mg/kg for soils with > 30% clay
Medium vulnerability:	Bray phosphorus level between 20 and 25 mg/kg BSES phosphorus level 15 - 30 mg/kg for soils with < 30% clay BSES phosphorus level 65 - 130 mg/kg for soils with > 30% clay
High vulnerability:	Bray phosphorus level > 25 mg/kg BSES phosphorus level > 30 mg/kg for soils with < 30% clay BSES phosphorus level > 130 mg/kg for soils with > 30% clay

Method 3 (Alternate Method to 1 and 2)

Firstly, obtain baseline available phosphorus levels for the soil on an area that has not received effluent or solids. The extraction method will usually be bicarbonate (e.g. Colwell) but in some cases may be acid extraction. Then measure extractable phosphorus levels in the reuse area.

Low vulnerability	The extractable phosphorus level of the reuse area is less than 150% of baseline data. (Thus if baseline data indicates the level is 30 mg/kg, the trigger level is less than 45 mg/kg).
Medium vulnerability	The extractable phosphorus level of the reuse area is between 150% and 200% of baseline data. (Thus if baseline data indicates the level is 30 mg/kg, the trigger level is between 45 mg/kg and 60 mg/kg).
High vulnerability	The extractable phosphorus level of the reuse area is more than 200% of the baseline data. (Thus if baseline data indicates the level is 30 mg/kg, the trigger level is greater than 60 mg/kg).

If it can be shown from the baseline data that the soil is phosphorus deficient, then the baseline data can be adjusted to 'desirable' phosphorus levels for that particular soil type.

10.2. Surface Water

Overtopping of effluent treatment systems needs to be minimised to protect surface waters. This document only covers the re-use of effluent and solids, however it is acknowledged that the effluent re-use area is linked to the wet weather storage. Thus it is recommended that where appropriate, effluent treatment systems be designed to hold effluent in a 90th percentile wet year for high strength effluent (total nitrogen > 100; total phosphorus > 20) and a 75th percentile wet year for medium strength effluent (total nitrogen 50-100; total phosphorus 10 - 20). These criteria vary between states (e.g In Queensland the treatment system should be designed so that it does not overtop more than once every 10 years on average).

Surface water includes water in dams, reservoirs, rivers, creeks and all other waterways where rainfall is likely to collect. Ideally, reuse areas should be well separated from surface water bodies, particularly those used for sensitive purposes e.g. town water supplies. However, distance is not the only criterion determining the potential for contamination from reuse areas. Design and management factors, particularly the amount and type of vegetative cover, may significantly reduce any potential contamination of surface waters.

Water Quality Protection

Low vulnerability: Reuse area is at least 200 m from a surface water body and effluent irrigations do not cause runoff or is at least 150 m from a surface water body but includes a vegetative buffer at least 25 m wide and effluent irrigations do not cause runoff or is at least 100 m from a surface water body but includes a well-maintained vegetative buffer at least 25 m wide and effluent irrigations do not cause runoff or there is a terminal pond sized to catch the first 12 mm of rainfall runoff plus irrigation water runoff.

Medium vulnerability: Reuse area is between 100 m and 200 m from a surface water body and effluent irrigations do not cause runoff or is at least 75 m from a surface water body but includes a vegetative buffer at least 25 m wide and effluent irrigations do not cause runoff or is at least 50 m from a surface water body but includes a well-maintained vegetative buffer at least 25 m wide and effluent irrigations do not cause runoff.

High vulnerability: Reuse area has no vegetative buffer and is less than 100 m from a surface water body or reuse area has a vegetative buffer but is within 50 m of a surface water body or and effluent irrigations create runoff that is not captured in a terminal pond.

Flood potential

Low vulnerability: Reuse area is above the 1 in 10 year flood line.

Medium vulnerability: Reuse area is above the 1 in 5 year flood line but below the 1 in 10 year flood line.

High vulnerability: Reuse area is below the 1 in 5 year flood line or flooding frequency of reuse area is unknown.

10.3. Groundwater

Ideally, reuse areas should be located on areas with deep groundwater or on those well protected by a layer of clay or be a confined aquifer. The risk to groundwater from effluent reuse depends upon the protection afforded by soil type (e.g. a deep clay blanket may afford good protection, a sandy loam soil provides relatively poor protection) and the geology and type of aquifer (e.g a confined aquifer versus an alluvial aquifer).

The consequences of nutrient or salt leaching to groundwater depend on the quality of the groundwater (e.g. potable water V brackish water). However, re-use practices should not impact on groundwater resources since it is this generation's responsibility to protect groundwater quality for the benefit of future generations.

Depth to Groundwater

Low vulnerability:	Groundwater is at least 20 m below the surface.
Medium vulnerability:	Groundwater is 10 - 20 m below the surface.
High vulnerability:	Groundwater is less than 10 m below the surface or depth to groundwater is unknown.

Soil Type

Low vulnerability:	There is at least 0.5 m of clay above the aquifer or the aquifer is confined.
Medium vulnerability:	There is at least a metre of loam to clay-loam soil above the aquifer.
High vulnerability:	Any other

Water Quality

Low vulnerability:	The groundwater resources in the area are of a quality having no productive use e.g. EC exceeds 8 dS/m.
Medium vulnerability:	Groundwater resources are suitable for stock drinking water or irrigation e.g. EC of up to 8 dS/m & containing less than 100 mg NO_3N/L
High vulnerability:	Groundwater resources are suitable for human consumption. (EC of up to 1.6 dS/m and containing less than 10 mg NO_3N/L) or the quality of groundwater resources is unknown.

Table 7, Table 8 and Table 9 are templates for recording the site vulnerability risk weightings for soil, surface water and groundwater. To complete the tables, a vulnerability weighting of 1, 2 or 3 applies to each sub-category of soil, surface water and groundwater. A low vulnerability attracts a vulnerability weighting of "1", medium vulnerability attracts a vulnerability weighting of "2" and high vulnerability attracts a vulnerability weighting of "3". These numbers are transferred to Table 10, Table 11 and Table 12.

10.4. Risk Assessment Tables

TABLE 7 – VULNERABILITY WEIGHTINGS - SOIL

Resource	Texture (weighting low = 1, med. = 2, high = 3)	Depth (weighting low = 1, med. = 2, high = 3)	Slope (weighting low = 1, med. = 2, high = 3)	Soil Dispersion (weighting low = 1, med. = 2, high = 3)	Salinity (weighting low = 1, med. = 2, high = 3)	Nitrogen (weighting low = 1, med. = 2, high = 3)	Phosphorus (weighting low = 1, med. = 2, high = 3)
Site Vulnerability Weighting						e.g. 2	

TABLE 8 – VULNERABILITY WEIGHTINGS – SURFACE WATER

Resource	Water Quality Protection Weighting (low = 1, medium = 2, high = 3)	Flood Potential Weighting (low = 1, medium = 2, high = 3)
Site Vulnerability Weighting		

TABLE 9 – VULNERABILITY WEIGHTINGS - GROUNDWATER

Resource	Depth to Groundwater Weighting (low = 1, medium = 2, high = 3)	Soil Type Weighting (low = 1, medium = 2, high = 3)	Water Quality Weighting (low = 1, medium = 2, high = 3)
Site Vulnerability Weighting			

Transfer these values to the Risk Assessment Matrix Tables (Table 10, Table 11and Table 12).

11. THE RISK ASSESSMENT PROCESS

11.1. Introduction

This risk assessment process considers the site assessment, the whole farm mass balance, the design and management of the reuse area and the sustainability indicators to decide if adverse environmental impacts are likely. The outcome of the risk assessment process is a risk appraisal for each resource and targeted environmental monitoring to measure sustainability.

In determining the level of risk of a reuse practice, the general principles of sustainable effluent irrigation and manure spreading need to be considered, such as those listed in the *Draft Guidelines for Industry – The Utilisation of Treated Effluent for Irrigation*. These principles are:

Resource Use: Potential resources in effluent, such as water, plant nutrients and organic matter, should be identified, and agronomic systems developed and implemented for their effective use.

Protection of Lands: An effluent irrigation system should be ecologically sustainable. In particular, it should maintain or improve the capacity of the land to grow plants, and should result in no deterioration of land quality through soil structure degradation, salinisation, water logging, chemical contamination or soil erosion.

Protection of Groundwater: Effluent irrigation areas and systems should be located, designed, constructed and operated so that the current or future beneficial uses of groundwater do not diminish as a result of contamination by the effluent or run off from the irrigation scheme or changing water tables.

Protection of Surface Waters: Effluent irrigation systems should be located, designed, constructed and operated so that the surface waters do not become contaminated by any flow from irrigation areas, including effluent, rainfall run off, contaminated sub-surface run off, or contaminated groundwater**.**

Prevention of Public Health Risk: The effluent irrigation scheme should be sited, designed, constructed and operated so as not to compromise public health. In this regard, special consideration should be given to the provision of barriers that prevent human exposure to pathogens and contaminants.

Community Amenity: The effluent irrigation system should be located, designed, constructed and operated to avoid unreasonable interference with any commercial activity or the comfortable enjoyment of life and property off-site, and where possible to add the amenity. In this regard, special consideration should be given to odour, dust, insects and noise.

In addition, an environmental management plan (EMP) or an environmental management system (EMS) will help to assess the environmental risk of an enterprise and any potential environmental impacts will hopefully be addressed. This could be used to provide informed decisions on the level of monitoring needed for a particular enterprise, with a possible reduction in monitoring requirements. An EMP or EMS should provide more information on the level of risk associated with the system, but wouldn't be the only means of determining an appropriate level of monitoring. The level of influence would be determined by the quality of information they contain.

A matrix has been developed to help determine the risk that each effluent or solid by-product area poses to surface water, groundwater and soil. Since different reuse areas on a property have different levels of risk depending on site, design and management factors the matrix needs to be applied to each reuse area. A separate reuse area is any area used for spreading or effluent or manure that has different soil type, land use, by-product type (e.g. composted manure V fresh manure), application method or application rate. For instance, the effluent irrigation area might have a high risk, while the solids area might pose a low risk. Consequently, more stringent monitoring would be needed for the effluent area compared with the solids area.

When interpreting monitoring data there will be considerable variations due to climatic conditions (e.g. wet years, drought) and subsequent effects on crop yields and therefore nutrient uptakes, cropping regime (rotations) and general soil dynamics. Thus, monitoring data should be viewed in terms of trends in the context of the forward management plan (10 – 15 years), which is regularly reviewed (every 3 – 5 years). Single monitoring points that exceed trigger levels do not signify an unsustainable system. Averages or trends (3 – 5 years) need to be used to assess sustainability, with the view of utilising all the nutrients applied in the long term. This includes the utilisation of stored phosphorus after re-use has ceased.

11.2. Risk Assessing the Site

The following matrix combines the site vulnerability assessment with the design and management risk assessment to provide an overall risk assessment of effluent and solids reuse. **Transpose information from Section 6.4, Table 2, Table 7, Table 8 and Table 9 into Table 10, Table 11 and Table 12 to complete the matrix. Multiply each site vulnerability weighting by each Design and Management Risk Weighting to obtain an overall risk assessment for the site (see example in Table 10).**

The overall level of risk calculated for each site resource (soil, surface water and groundwater) is used to design the appropriate monitoring (targeted monitoring) or change to design and management.

Risk weighting of 1, 2, 3, 4, 6 & 9 are possible. Ratings of 1 and 2 require minimal monitoring and/or change to design and management. Ratings of 3, 4 & 6 attract moderate levels of monitoring and/or changes to design and management. A rating of 9 requires intensive monitoring and/or changes to design and management. It is important to realise that if a rating of 4 is calculated for groundwater and a rating of 9 is calculated for soil, moderate monitoring and/or change would be warranted for the groundwater and intensive monitoring and/or change would be warranted for the soil.

It is recommended that the risk assessment process be trialed prior to implementation. Ideally, this trialing should include a range of case studies on theoretical and real case piggeries and feedlots to demonstrate how the assessment process would work and the outcomes that it would deliver in terms of the assessed risk and the resultant monitoring requirements. The proposed risk assessment process should be evaluated by applying it to some existing licensed piggeries and feedlots.

Theoretical example risk assessments for a piggery and two feedlots can be found in the accompanying Resource Manual.

TABLE 10. RISK ASSESSMENT MATRIX - SOIL

Design and Management Criteria	Design & Management Risk Weighting (Low = 1, medium = 2, high = 3)	Texture	Depth	Slope	Soil Dispersion	Salinity	Nitrogen	Phosphorus
							2	
Nutrients in manure and effluent Size of land area and Application rate Application method	3						6	

TABLE 11. RISK ASSESSMENT MATRIX – SURFACE WATER

Design and Management Criteria	Design & Management Risk Weighting (Low = 1, medium = 2, high = 3)	Site Vulnerability Weighting	
		Water Quality Protection	Flood Potential
Nutrients in manure and effluent Size of land area and Application rate Application method			

TABLE 12. RISK ASSESSMENT MATRIX - GROUNDWATER

Design and Management Criteria	Design & Management Risk Weighting (Low = 1, medium = 2, high = 3)	Site Vulnerability Weighting		
		Depth	Soil Type	Water Use
Nutrients in manure and effluent Size of land area and Application rate Application methods				

Based on the Risk Rating from Table 10, Table 11 and Table 12 an evaluation of the likely amount of monitoring or change to the design and management that would be required can be determined (See Section12).

12. TARGETED MONITORING

Table 10, Table 11 and Table 12 (Section 11.2) identify the level of overall risk to soils, surface water and groundwater, respectively. Monitoring and/or improved design and management should be undertaken in accordance with the risk level.

When monitoring is used to observe trends, it is worth noting that considerable variations can be obtained via the sampling method and laboratory used for analysis. In addition, time of sampling is important. Soil samples should be collected at the end of the main growing season when the plants have had time to take up the applied nutrients.

12.1. Soils

Where the risk of soil related impacts is low (rating of 1-3) and at least 3 years of annual monitoring shows that the system is sustainable, it is suggested that soils from reuse areas should be monitored at least every three years. Those in a low risk category will not need to monitor effluent quality *unless* they are already undertaking this monitoring (which is the reason for being in this category).

Where there is a medium risk of soil impacts (rating of 4 or 6) and at least 3 years of monitoring data show that the system is sustainable, it is suggested that soils from reuse areas should be sampled and analysed at least every two years. Effluent and solids quality (if reused on-site) should also be analysed annually.

Where there is a high risk of soil impacts (rating of 9), annual soil monitoring is imperative. Effluent and solids quality (if reused on-site) should also be analysed annually.

Table 13 includes recommended soil monitoring parameters in order to determine sustainability. Additional monitoring may be required for agronomic purposes. The monitoring results should be compared with the limits for sustainability indicators given in Section 8. Where the triggers for further investigation are reached, further analysis is needed. Table 14 and Table 15 include recommended effluent and solids monitoring parameters.

The quantity of effluent and solids applied to land will need to be measured by everyone, except those relying on a mass balance calculation to demonstrate sustainability.

Crop yields will need to be measured by everyone, except those relying on a mass balance calculation that shows that they are sustainable.

12.2. Surface Water

Surface water quality monitoring is not suggested as a relevant measure of sustainability for piggeries and cattle feedlots, as they are not direct discharge industries (e.g. sewage treatment plants) and generally rely on land application for the reuse of by-products. To be able to achieve any meaningful results from a monitoring perspective, surface water monitoring would require sophisticated equipment and trained operators.

Piggeries and cattle feedlots are required to comply with relevant codes of practice for their design and management, such as appropriate buffers, vegetative filter strips or terminal ponds. If an enterprise attracts a high rating, remedial action in the form of improved design and/or management of the reuse area is warranted.

12.3. Groundwater

Groundwater quality monitoring would be warranted for anyone attracting a high rating (9). Ideally this would include sampling and analysis from bores upslope and downslope of reuse areas. Electrical conductivity and nitrate-nitrogen should be determined. On very sandy soils, total P should also be measured. If a moderate risk weighting is attracted for groundwater, monitoring would not be required, provided nutrient and salt risk weightings for the soil are low.

TABLE 13 – RECOMMENDED SOIL ANALYSIS PARAMETERS

Soil test parameter	Depth (Down profile)	Justification
pH		Influences nutrient availability
EC_{se} (Can measure $EC_{1:5}$ and convert to EC_{se})$^{+}$	0.0 – 0.1 m 0.2 – 0.3 m 0.5-0.6 m OR base of root zone	Measure of soil salinity
Nitrate-N	0-0.1 m 0.2-0.3 m 0.5-0.6 m OR base of root zone	Measure of nitrogen available for plant uptake
Available phosphorus (Colwell or Olsen or Bray or BSES or Lactate or Calcium Chloride or Other)	0-0.1 m 0.5-0.6 m OR base of root zone*****	Measure of phosphorus available for plant uptake
P sorption capacity or phosphorus Sorption Index	0 –0.6 m OR 0 – base of root zone******	Essential if applying more than 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 0.5-0.6 m or base of root zone	Needed to calculate ESP, EKP and Ca: Mg which have important implications for soil structure

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

***** Only check available P levels annually at 0.5 – 0.6 m (or base of root zone) if a sandy soil, otherwise every 5 years.

****** Measurement of P sorption capacity to 0.6 m or the base or the root zone is desirable before reuse and every 5 years after initial application.

Measuring chloride as 50 – 60 cm (or base of root zone) may also be warranted if further investigations of salinity are required.

TABLE 14 – RECOMMENDED EFFLUENT ANALYSIS PARAMETERS

Test parameter	Justification
Total-N or TKN	Measure of nitrogen applied for mass balance calculations
Ammonium-N	Measure of nitrogen available or potentially lost as ammonia volatilisation
Nitrate-N	Measure of nitrogen immediately available for plant uptake
Total P	Measure of phosphorus applied for mass balance calculations
Electrical conductivity and Chloride	Measure of effluent salinity
Sodium Adsorption Ratio (SAR)	Measure of effluent sodicity

TABLE 15 – RECOMMENDED SOLIDS ANALYSIS PARAMETERS

Test parameter	Justification
Dry Matter	To calculate nutrient applied
Total-N or TKN	Measure of nitrogen applied for mass balance calculations
Ammonium-N	Measure of nitrogen available or potentially lost as ammonia volatilisation
Nitrate-N	Measure of nitrogen immediately available for plant uptake
Total P	Measure of phosphorus applied for mass balance calculations
Organic Carbon	Influences soil stability
Electrical conductivity and Chloride	Measure of solids salinity

13. REVIEW OF FORWARD MANAGEMENT PLAN

Where interpretation of the monitoring results and/or the risk assessment identifies a need to improve performance, the **Forward Management Plan** would be reviewed. This is the stage where the design and management of the reuse system is evaluated to find ways to reduce the potential risk to the environment. Once changes are implemented, the risk assessment process must be repeated to decide the new level of risk and the appropriate monitoring regime to complement the revised level of risk.

14. CONCLUSIONS AND RECOMMENDATIONS

This section details conclusions from the study and highlights gaps in information related to effluent and solids reuse for piggeries and cattle feedlots. There is currently a significant amount of work being undertaken both in Australia and overseas. It is anticipated that the findings of these studies will improve the general understanding of reuse. Recommendations are also made for possible future research to better understand the processes.

The study has identified sustainability indicators for a number of parameters: nitrogen, phosphorus, salinity and sodicity. For these sustainability indicators, trigger values have been identified to assist industry in reviewing their effluent and manure reuse forward plans. The monitoring and review of these sustainability indicators will assist industry with operating environmentally sustainable operations.

With regard to the specific indicators developed the following recommendations are made:

- For nitrate-nitrogen, a limit of 10 mg/L below the active root zone is suggested only as a trigger for further investigation. Other matters to consider when determining the sustainability of the reuse practice in terms of nitrogen include the risk of nitrate moving off-site in surface water and groundwater, the quality (value) of the groundwater and the amount of deep drainage of the soil of the reuse area. These need to be evaluated as part of the risk assessment of the reuse area.
- For phosphorus it is recommended that storage of phosphorus be allowed based on the calculated storage capacity from the phosphorus sorption isotherm, at a soil solution concentration of 0.5 mg/L. This soil solution concentration level however needs to be reviewed based on the recent work of Redding. It would be possible to generate appropriate soil solution concentration levels for different soil types and regions from currently available data. Another test that offers potential is the simple test for estimating phosphorus buffer capacity (PBC) that was developed by Burkitt *et al.* (2002). Their methods provided a simple and accurate method for estimating PBC. This work requires further investigation to ascertain whether the data can be used to provide simple indices for determining phosphorus sustainability of a range of soil types, not only in NSW, but for the cropping soils of Australia in general.
- If a reuse area is used to store phosphorus it must be good cropping land and a plan must be in place to continually crop the area after effluent or solids reuse has ceased to remove the stored phosphorus as it is released. The phosphorus storage capacity of the reuse area should also be determined by measuring a P sorption isotherm every five years.

A risk assessment process has also been developed. This risk assessment process considers the site assessment, the whole farm mass balance, the design and management of the reuse area and the sustainability indicators to decide if adverse environmental impacts are likely. The outcome of the risk assessment process is a risk appraisal for each resource and targeted environmental monitoring to measure sustainability. Theoretical example risk assessments for a piggery and two feedlots can be found in the accompanying Resource Manual.

No recommendations are made concerning the application (or not) of Load Based Licensing to piggeries and cattle feedlots and the application of the currently existing Load Calculation Protocol to piggeries and cattle feedlots. This process needs to be negotiated between the industries involved and the NSW EPA.

Currently licensed piggeries and cattle feedlots in NSW have collected significant monitoring data. This collected information could be used to trial the developed risk assessment process. As part of this current study, two theoretical risk assessments have been completed to further explain how the process would work. A further trial of the risk assessment process could include a range of case studies on real piggeries and feedlots to demonstrate how the assessment process would work and the outcomes that it would deliver in terms of the assessed risk and the resultant monitoring requirements. This would allow the process to be evaluated for both the piggery and feedlot industries.

The Load Calculation Protocol proposes a 15 year forward management plan with a review of the plan every 3 years to ensure that future planned application rates will continue to achieve sustainable assimilation. FSA Environmental agrees that there is a need for a plan for managing nutrients for reuse. Review via monitoring results at least every three years is necessary to judge performance. Plans for proposed reuse need to be made after considering monitoring results. Whether a 15 year forward management plan is strictly needed is debatable. The main priority is to have a forward plan in place that is regularly reviewed and updated in light of monitoring results.

The cattle feedlot industry agrees with the 15 year forward management plan. The recommendation is that if the pig industry wishes, they adopt a 5-year forward management plan that is reviewed annually.

The general recommendations of sustainable reuse practices presented in the report can apply to most industries that reuse their by-products in a land application system. Inherent differences however will apply for industries that generate larger volumes of water compared to both the piggery and cattle feedlot industries. These, and any other inherent differences would need to be considered when investigating sustainability indicators for other industries.

It is recommended that EPA review their monitoring requirements for piggeries and cattle feedlots. The level of monitoring required should be based on the level of environmental risk as determined by the risk assessment process. The level of environmental risk specific should also determine the parameters measured.

The authors believe that a defined path for upgrading Codes of Practice and Guidelines is lacking, with many of these documents being outdated and/or very conservative because of a lack of knowledge ‘Precautionary Principle’. This is however, changing with many of the more recently produced codes for intensive animal industries planning 5-year reviews and upgrades of the publications. It would be beneficial that as part of current and future research (APL and MLA), relevant, peer reviewed findings be included in regular upgrades of codes and guidelines. This is most likely to be successful if national codes and guidelines exist for the industries. This process can proceed, as the feedlot industry currently has a National Code and the pig industry is developing a National Guideline.

The sustainability indicators identified from this project are considered to be the best available at the time of project completion. However, due to the significant work being undertaken currently in this area, particularly by the piggery and feedlot industries, it is recommended that they be regularly reviewed to ensure they remain relevant.

The authors advise that it is important that the NSW EPA and operators of piggeries and cattle feedlots recognise that it is extremely difficult to develop tools for determining and demonstrating sustainability and indicators of sustainability that adequately cover all situations. It is probable that situations will arise where the tools for determining sustainability overstate the likely risk to the environment.

Similarly, while the best-bet indicators of sustainability have been identified in this project, these may occasionally provide an inaccurate assessment of environmental impact. Consequently, where a significant level of environmental risk or impact is identified, it is critical to confirm that the result is accurate through further examination.

15. REFERENCES

ANZECC 1992. "Australian Water Quality Guidelines for Fresh and Marine Waters".

National Research Council. 1984. Nutrient Requirements of Beef Cattle, National Academy Press, Washington DC, Sixth Revised Edition.

Redding, M.R. 2002. Queensland Department of Primary Industries. Personal communication.

Rengasamy, P. and J. Bourne 1997. "Managing Sodic, Acidic and Saline Soils", Cooperative Research Centre for Soil & Land Management, Glen Osmond.

Reuter, D.J. and Robinson, J.B. (eds). 1997. "Plant Analysis – An Interpretation Manual." CSIRO Publishing, Collingwood, Victoria.

Skerman, A. 2000. "Reference Manual for the Establishment and Operation of Beef Cattle Feedlots in Queensland", Queensland Cattle Feedlot Advisory Committee (FLAC), Department of Primary Industries, Queensland, Information Series QI99070.

Streeten, T.A. and McGahan, E.J (eds). 2000. Environmental Code of Practice for Queensland Piggeries. Department of Primary Industries, Queensland.