

PigBal 4 user manual

Version 2.6

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This publication has been compiled by Alan Skerman, Sara Willis and Brendan Marquardt of Agri-Science Queensland, Department of Agriculture and Fisheries (Queensland), and Eugene McGahan, formerly of FSA Consulting.

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Overview

The original PigBal model was developed by Casey *et al.* (1996). In recent years, the industry identified a need to validate and upgrade the original version of the model. Consequently, Australian Pork Limited (APL) provided funding under Project No 2010/1011.334: Validation and development of the PigBal model – Stage 2, for replicated metabolic pen trials to gather data for the purpose of validating the model. Details of this research were reported by Skerman *et al.* (2013a). Following completion of the model validation, the current version of the model (PigBal 4) was developed by Skerman *et al.* (2013b). PigBal 4 supersedes the original version and all subsequent versions of the model.

The PigBal model uses a mass balance approach to estimate piggery waste production (solids and nutrients) based on detailed dietary data and pig production information entered by the user. It is a Microsoft® Excel spreadsheet model which operates effectively on personal computers (PCs) with Excel 2003 (or later) installed.

PigBal 4 modelling results are typically used for:

- Designing piggery effluent treatment and reuse systems.
- Estimating the energy output and economic viability of piggery biogas collection and reuse systems.
- Estimating piggery GHG emissions for statutory reporting purposes.
- Preparing applications for new and expanding piggery developments.

This manual provides:

- Background information and guidance to assist users in selecting appropriate data to be entered into the various sheets.
- Details of the calculations performed by the model.
- Technical references.

Each chapter of the manual refers to a specific sheet of the spreadsheet model, numbered 1 to 17. Users will generally progress through the sheets in numerical order, entering relevant data into the various sheets. Navigation between the various sheets is achieved by clicking on the macro buttons provided on the menu sheet and each of the other sheets.

Menu

The 'Menu' sheet provides general instructions on how to use the PigBal 4 model in addition to a series of macro buttons to assist the user in navigating between the various sheets. No data entry is required on this sheet which has been reproduced below:

Department of Agriculture and Fisheries

>

PigBal 4
A model for estimating piggery waste production

General instructions:

The user can navigate through the various worksheets, numbered 1 to 17, by clicking on the buttons below.

Additional navigation buttons, as shown to the right, are provided near the upper left-hand corners of the relevant worksheets, to allow the user to move directly to the previous or next worksheets, or to return to this menu worksheet.

Data may be entered in each of the worksheets having black lettered labels, below.

The worksheets having green lettered labels provide output data, graphs and details of some of the model calculations.

Most users will progress through the worksheets in numerical order, entering relevant data in the grey shaded cells, as shown to the right.

All other cells are locked to prevent data entry and to protect the underlying calculations.

All cells with red triangles in the upper-right-hand corners, as shown to the right, contain explanatory comments to assist the user in selecting appropriate input values.

Some of the explanatory comments include typical / default data values and ranges.

The explanatory comments can be viewed by resting the pointer over these cells.

More comprehensive instructions are provided in the user manual (Skerman *et al.*, 2013b).

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Menu


Data entry cell

Explanatory
comments

Menu:

1. Cover	7. Assumptions	13. Diet input
2. User licence	8. Feed details	14. DM DAMP
3. Herd input	9. Water	15. Output summary
4. Growth chart	10. Effluent pre-treatment	16. ERF calculations
5. Herd details	11. Pond design	17. References
6. Deep litter	12. Diet ingredient data	





1. Cover

This sheet provides a general description of the model, an overview of typical uses and details regarding the model development. No data entry is required on this sheet.

Contact details are also provided for technical support purposes.

Technical enquiries about the model should be addressed to Principal Environmental Engineer, Alan Skerman, who can be contacted through the DAF Customer Service Centre, phone 13 25 23 (cost of a local call within Queensland) or +61 7 3404 6999, or by email to alan.skerman@daf.qld.gov.au.

2. User licence

Details of the user licence are provided on this sheet, as outlined below:

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3. Herd input

In this sheet, the user is required to enter data which defines the herd accommodated in the piggery. PigBal 4 calculates the numbers of pigs in the various classes, based on the total number of sows, mortality rates, pig sales data and various performance criteria entered by the user. The calculations cater for farrow-to-finish piggeries as well as specialised breeder and grower units. The calculated pig numbers for each class of pig accommodated in the piggery are shown on the 'Herd details' sheet. Users can override the PigBal 4 calculations by entering known numbers of pigs for the relevant classes on the 'Herd details' sheet.

PigBal 4 allows for the entry of up to six classes of grower pigs between the weaner and finisher stages (inclusive). In general, separate classes should be assigned to groups of pigs that receive different diets, as defined in the 'Diet input' sheet. Names that are meaningful to the user can be assigned to each of these classes; e.g. weaner 1, weaner 2, grower 1, grower 2, finisher 1, finisher 2, porker, baconer, etc. The starting and finishing ages and live weights for each of these pig classes are defined by entering the pig ages and live weights at the ends of each growth stage. In lieu of any other specific data for the piggery being modelled, the pig classes, ages and live weights specified in the National Environmental Guidelines for Piggeries (NEGP, Tucker *et al.*, 2010) as shown in Table 1, may be adopted.

Table 1. Standard pig classes, live weights and ages specified in Table 4.1 of the NEGP (Tucker, *et al.*, 2010).

Pig class	Live weight range (kg. pig ⁻¹)		Age range (weeks)	
	Entry	Exit	Entry	Exit
Gilt	100	160	24	30
Boar	100	300	24	128
Dry sow	160	230		
Lac sow	160	230		
Sucker	1.4	8	0	4
Weaner	8	25	4	10
Grower	25	55	10	16
Finisher	55	100	16	24
Heavy finisher	100	130	24	30

To assist users who may not have the required live weight data for the various grower pig classes, PigBal 4 allows the entry of an average daily live weight gain (ADG), measured from birth to 100 kg live weight. Table 2, which appears in the in-cell explanatory comments built into the model, is intended to assist users in selecting a realistic ADG.

Table 2. Average daily live weight gain (ADG) ratings (birth to 100 kg live weight).

Average daily gain (g. day⁻¹) [Birth to 100 kg live weight]	Rating
550 - 600	fair
600 - 650	average
650 - 700	good
> 700	very good

Pork CRC benchmark values (Campbell, 2013) - Average: 667 g/day, Range: 565 – 764 g/day

Based on the entered ADG value, PigBal 4 uses Equation 1, provided in Appendix A, to calculate predicted live weights at the ends of each of the growth stages previously entered into the model. This equation was developed from standard growth curves published in the Australian pig industry diary (Richards, 2012). The user may choose to enter the live weight values predicted by the model, or some alternative known values, in the 'Herd details' sheet.

The numbers of pigs purchased annually for each of the grower pig classes must be entered in the 'Pig purchases' section of the sheet. In the case of specialised grower piggeries, the user needs to enter the number of weaner pigs purchased or imported annually from an external breeder unit.

PigBal 4 requires the user to enter the pre-weaning and post-weaning mortality rates. The pre-weaning mortality rate is used to calculate the number of sucker pigs that die prior to weaning. PigBal 4 distributes the post-weaning mortality rate, entered by the user, across the various classes of grower pigs, based on the length of time that the pigs spend in each of these classes.

The percentages of grower pigs sold at the end of each of the growth stages are entered in the 'Pig sales' section. In the case of a breeder unit, 100% of the pigs would normally be sold (or exported to an off-site grower unit) at the end of either the sucker or weaner stages.

PigBal 4 also allows for pigs to be sold at multiple live weights to supply a range of markets. For example, some producers may sell 50% of their grower pigs as porkers while retaining the remaining pigs until they reach a heavier bacon weight.

Table 3 provides descriptions, ranges and typical values of the input data for the 'Herd input' sheet.

Table 3. Description, range and average / typical values of data to be entered in the 'Herd input' sheet.

Input data	Description	Range	Average / typical value	Units
Number of sows	Number of breeding female pigs that have been served, including both lactating and dry (gestating) sows.	Variable	Variable	sows
Number of boars	Number of male pigs over 6 months of age intended for use in the breeding herd.	Variable	Variable	boars
Sow culling percentage	Number of sows culled from the herd, expressed as a percentage of the total number of sows in the herd.	40 – 76	56	%
Boar working life	The working life of boars, from selection, generally at approx 6 months of age, to culling.		2	years
Breeder mortalities	% of sows and boars that die annually.	2.5 – 19.1	10.0%	%
Gilt waste rate	% of non-fertile gilts sold.		14%	%
Percent gilts purchased	% of young female pigs purchased from breeding companies, for breeding purposes.	Variable		gilts
Percent boars purchased	% of young male pigs purchased from breeding companies, for breeding purposes.	Variable		%
Farrowing rate	% of sows that farrow after mating.	75 – 90	85%	%
Farrowing index	Average number of farrowings per mated sow annually.	2.24 – 2.42	2.33	farrowings
No of piglets born alive per litter	Average number of live pigs in a litter.	10.3 – 13.7	11.2	piglets
No of piglets stillborn per litter	Average number of fully-formed pigs that are born dead in a litter.	0.7 - 1.2	0.9	piglets
Gilt age at selection / purchase	Age of young female pigs selected from the grower herd, or purchased from breeding companies, for breeding purposes.		24	weeks
Boar age at selection / purchase	Age of young male pigs selected from the grower herd, or purchased from breeding companies, for breeding purposes.		24	weeks
Gilt age at mating	Age of young female pigs when they are first mated.		30	weeks
Sow live weight at mating	Average live weight of sows when they are mated.	130 - 150	140	kg. pig ⁻¹

Input data	Description	Range	Average / typical value	Units
Sow live weight at farrowing	Average live weight of sows when they farrow.	190 - 255	215	kg. pig ⁻¹
Boar live weight at turnoff	Average live weight of boars when they are culled.		300	kg. pig ⁻¹
Backfatter dressed weight	Dressed carcass weight of culled sows, boars and gilts, after processing at the abattoir.		130	kg. pig ⁻¹
Lactation duration	Average time period between farrowing and weaning.	17 - 32	24	days
Pre-weaning mortality	Rate of deaths in sucker pigs, prior to weaning.	5 – 17	11	%
Post-weaning mortality	Rate of deaths in grower pigs, from weaning to finishing.	3 - 7	5	%

Sources: Pork CRC benchmarking results (Campbell, 2013)
 APL Australian pig annual, 2011-2012.

Three macro buttons have been provided near the bottom of the 'Herd input' sheet. By clicking on one of these buttons, the user can enter data for a 1000 sow farrow-to-finish piggery, a 1000 sow breeder unit, or a grower unit receiving weaner pigs from a 1000 sow breeder unit. These standard scenarios are intended to provide a starting point and general reference to assist users in entering appropriate data to realistically model a range of piggery operations.

4. Growth chart

On the 'Growth chart' sheet, PigBal 4 plots the pig age and live weight values entered in the 'Herd input' sheet, along with the predicted growth curve for the selected ADG. Standard growth curves for ADGs ranging from 550 to 700 g. day⁻¹ are also plotted on this chart for comparison purposes. These growth curves, which were derived from data presented by Richards (2012), allow the user to evaluate whether the entered age and live weight values are realistic in comparison with typical growth curves.

In the example provided in Figure 1, the entered age and live weight values (blue triangular markers) closely follow the predicted growth curve (grey line) for the selected ADG value of 640 g. day⁻¹.

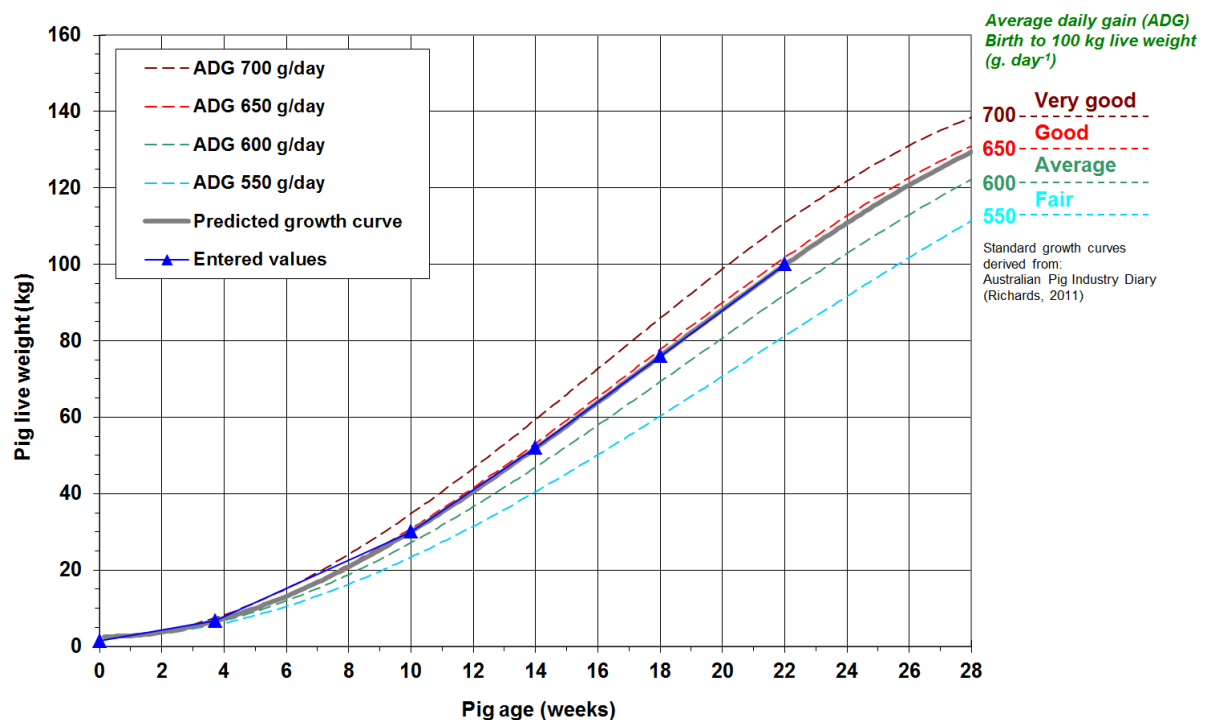


Figure 1. 'Growth chart' example for a selected ADG value of 640 g. day⁻¹ and entered age and live weight values that closely follow the predicted growth curve.

5. Herd details

The 'Herd details' sheet provides the numbers of pigs housed in the piggery at any point in time, calculated by the model, for each of the pig classes entered in the 'Herd input' sheet. On this sheet, the user has an opportunity to override the model calculations and enter known numbers of pigs for each of the classes.

The user is also required to enter the type of manure management system employed in the sheds housing the various classes of pigs. Drop-down lists for each pig class provide 3 choices; viz. 'Flushing', 'Pull plug / Static pit' or 'Deep litter', as briefly described below.

Flushing sheds:

Flushing sheds have relatively shallow concrete channels running under the slatted floors. These channels are flushed at regular intervals (generally ranging from daily to twice weekly), to remove the manure and waste feed from the sheds into external drains or sumps, prior to pre-treatment or discharge into an effluent pond. Flushing is generally carried out by rapidly releasing relatively large quantities of water (or recycled effluent) from flushing tanks located near the ends of the sheds. Alternatively, sheds may be flushed using a high-capacity pump.

Pull plug / Static pit sheds:

Pull plug sheds store manure, waste feed and hosing water in several concrete pits constructed beneath the slatted shed floors. The effluent is generally released by gravity, through individual pipe outlets located in the centre of each pit.

Static pits are relatively large concrete pits, commonly located under the slatted floors of older sheds. They are used to store manure, waste feed and hosing water. The shed effluent is generally released via a sluice gate or valve located at the end of each shed, at intervals up to several weeks.

Deep litter sheds:

Deep litter sheds employ straw, sawdust, rice hulls or an alternative bedding material to absorb the manure excreted by the pigs. These sheds are not cleaned by hosing or flushing. The manure is generally removed from the concrete or compacted earth floor, along with the spent bedding material, after the removal of a batch of pigs, or at regular intervals.

Standard pig units:

The SPU multipliers used for the grower herd are determined using a regression equation based on the average live weights of pigs in each class. This regression equation was developed using the standard SPU multipliers and live weights published in Table 4.1 of the NEGP (Tucker *et al.*, 2010), reproduced in Table 4, below. The regression equation (Equation 2) and a plot of the resulting SPU multipliers (Figure 4) are provided in Appendix A. The standard SPU multipliers outlined in Table 4 are used for the breeder herd.

The 'Herd details' sheet summarises the ages, live weights, and numbers of standard pig units (SPU) for each class of pig, along with the pig purchases, mortalities and sales in terms of both pig numbers and live weight.

Table 4. Standard pig classes, live weights and SPU conversion factors published in Table 4.1 of the NEGP (Tucker *et al.*, 2010).

Pig class	Start live weight (kg)	Finish live weight (kg)	Average live weight (kg)	SPU multiplier
Gilt	100	160		1.8
Boar	100	300		1.6
Gestating sow	160	230		1.6
Lactating sow	230	160		2.5
Sucker	1.4	8.0	4.7	0.1
Weaner	8.0	25.0	16.5	0.5
Grower	25.0	55.0	40.0	1.0
Finisher	55.0	100.0	77.5	1.6
Heavy finisher	100.0	130.0	115.0	1.8

6. Deep litter

If 'Deep litter' is selected for any of the 'Shed types' in the 'Herd details' sheet, the user needs to specify the type and amount of bedding material added to the relevant shed(s). A drop-down list provides the following alternatives for bedding materials: hardwood sawdust, softwood sawdust/shavings, rice hulls, barley straw, wheat straw and shredded paper. In reality, the choice of bedding material generally depends on the availability and cost of suitable materials in the vicinity of the piggery.

Typical solid and nutrient contents of common deep litter bedding materials are provided in Table 5. These values are used by PigBal 4 to estimate the composition of the spent deep litter and manure removed from the sheds.

Table 5. Typical solid and nutrient contents (% wet basis) of common deep litter bedding materials.

Bedding Materials	TS	VS	Ash	N	P	K
Hardwood sawdust	90.00	90.00	0.00	0.20	0.01	0.05
Softwood sawdust/shavings	90.00	90.00	0.00	0.13	0.01	0.03
Rice Hulls	92.00	87.00	5.00	0.49	0.07	1.21
Barley straw	91.00	85.00	6.00	0.63	0.06	2.16
Wheat straw	89.00	83.15	5.85	0.52	0.36	0.45
Shredded paper	90.00	90.00	0.00	0.00	0.01	0.00

To avoid animal welfare, production and environmental issues, piggery operators need to supply sufficient deep litter bedding material to maintain dry conditions. On average, this requires the addition of approximately 0.5 - 1.0 kg of bedding per pig per day.

7. Assumptions

Table 6 outlines the fixed values used in PigBal 4 calculations. These values cannot be edited by the user. Some references are provided below the table.

Table 6. Fixed values used in PigBal 4 calculations.

Parameter	Units	Value	TS	FS	VS	N	P	K
Carcass composition ¹	g. kg ⁻¹ live weight		300.0	29.0	271.0	25.6	4.5	2.4
Placenta	kg. sow place ⁻¹ . farrowing ⁻¹	3	0.9000	0.0870	0.8130	0.0768	0.0135	0.0072
Milk composition ²	%		20.00%	1.00%	19.00%	0.90%	0.15%	0.07%
Milk fed to suckers	kg. sow place ⁻¹ . day ⁻¹	8	1.6000	0.0800	1.5200	0.0720	0.0120	0.0056
	kg. sow place ⁻¹ . farrowing ⁻¹	208	41.60	2.08	39.52	1.87	0.31	0.15
Suckers	kg. sow place ⁻¹ . farrowing ⁻¹	16.94	5.082	0.491	4.591	0.434	0.076	0.041
Suckers + milk + placenta	kg. sow place ⁻¹ . farrowing ⁻¹	227.94	47.58	2.66	44.92	2.38	0.40	0.19
	kg. sow place ⁻¹ . day ⁻¹	8.77	1.83	0.10	1.73	0.09	0.02	0.01
Gestation period	days	114						
Deep litter moisture content	%	40%						
Shed losses								
Flushing	%		2%	0%	3%	10%	0%	0%
Pull plug / Static pit	%		10%	0%	12%	10%	0%	0%
Deep litter	%		20%	0%	25%	17%	0%	0%

References:

¹ Mahan and Shields (1998), Field *et al.* (1974)

² Hurley (1997), Csapó *et al.* (1996), Lewis A.J. *et al.* (1978), Eliasson and Isberg (2011)

8. Feed details

Feed conversion ratio:

To assist in estimating feed wastage, this sheet includes provision for the user to enter a known average feed conversion ratio (FCR) for the grower pigs, calculated from birth to 100 kg live weight, which is a common turn-off weight. The FCR value is calculated by dividing the total feed fed, by the live weight gain (100 kg – 1.4 kg birth weight). Table 7 provides ratings for a range of FCR values that could be expected in the Australian pork industry. These ratings are also provided in the in-cell explanatory comments. While it is expected that many pig producers will know the average FCR values for their grower pigs, the tabulated values are intended to assist users who don't have detailed knowledge of pork production standards, with the selection of realistic values.

Table 7. Feed conversion ratio (FCR) ratings (birth to 100 kg live weight).

Feed conversion ratio (FCR) (birth to 100 kg live weight)	Rating
< 2.3	very good
2.3 - 2.6	good
2.6 - 2.8	fair
2.8 - 3.0	poor
> 3.0	very poor

Feed wastage:

Feed wastage in piggeries is practically impossible to measure objectively and producers are generally unable to provide accurate, quantitative estimates. However, feed wastage can have a major influence on the characteristics of the waste stream discharged from piggery sheds. For example, McGahan *et al.* (2010) used PigBal modelling to demonstrate that a $\pm 5\%$ variation in feed wastage, from a standard value of 10%, could result in a $\pm 30\%$ variation in total solids and volatile solids production.

To assist users in estimating a realistic feed wastage value, a relationship was developed between feed wastage, the ADG value entered in the 'Herd input' sheet and the FCR value entered on this sheet. This involved the development of Equations 3 to 7, which are included in Appendix A. PigBal 4 uses these equations to determine an estimated feed wastage value, which is shown directly above the table on the 'Feed details' sheet.

Feed wastage values must be entered by the user for each class of pig. Users may choose to enter the calculated value for weaner, grower and finisher pigs. Alternatively, default values are provided in the in-cell explanatory comments.

Feed consumption:

On this sheet, the user may enter either the daily feed ingested per pig for each pig class, or the total annual tonnage of feed fed to each pig class. For many piggeries, the latter figure may be available from feed commodity delivery records.

Alternatively, if these cells are left blank, the default values for the breeder pigs, and the calculated values for the grower pigs (as described below), will be used. Table 8 shows the default feed ingested values for breeder pigs and suckers.

Table 8. Default feed ingested values for breeder pigs and suckers.

Pig class	Feed ingested (kg 'as-fed'. pig ⁻¹ . day ⁻¹)
Gilts	2.50
Boars	2.30
Gestating sows	2.30
Lactating sows	4.50
Suckers ¹	0.85

¹ Includes average 0.8 L. day⁻¹ sow milk + 0.05 kg. day⁻¹ creep.

Estimates of the daily feed ingested and annual feed fed for the grower pigs are provided in the columns labelled 'Calculated / default values'. These values are calculated using Equation 2 (Appendix A), which was derived by fitting a polynomial curve to feed intake data provided by Willis (2013), based on AUSPIG (Davies *et al.*, 1998) modelling. The calculated values may be overridden by entering data in the 'Entered values' column.

It should be noted that all feed intake data is expressed on an 'as-fed' basis, rather than on a 'dry matter' basis. This means that the masses of feed fed include the moisture contents of the diet ingredients.

Annual feed usage values for individual classes of pigs and the whole piggery are provided in the table on the 'Feed details' sheet. FCR values for the whole piggery are provided below the table.

9. Water

The 'Water' sheet in PigBal 4 is not directly used in estimating the piggery manure production. It has been included to assist users in estimating the total water use in the piggery; a very important consideration for planning new or expanding developments and in assessing the environmental foot-print of new and existing piggeries.

PigBal 4 uses Equation 7 (Appendix A), which was developed by Wiedemann *et al.* (2012), to estimate water intake for each class of pig, based on average pig feed intakes.

Drinking water wastage is likely to be influenced by a number of factors including drinker design, environmental factors such as temperature, and a range of pig social/behavioural factors. Wiedemann *et al.* (2012) reported wastage rates of 15 - 42% of the total drinking water supplied, based on determinations made by Li *et al.* (2005), which appear to match observations from Australian piggeries. Consequently, an average drinking water wastage rate of 25% is suggested as a default value for use in PigBal 4. Individual drinking water wastage rates for the various pig classes can be entered into the 'Wastage' column of the 'Water' sheet.

PigBal 4 provides an estimate of the cooling water use, based on recommendations contained in '*Plan it – Build it*' (Taylor *et al.*, 1994). This Australian publication suggests spray cooling water use rates of 300 mL. pig⁻¹. hour⁻¹ for dry sows, boars, grower and finisher pigs, and similar drip cooling rates for farrowing sows. A value of 65 mL. pig⁻¹. hour⁻¹ is suggested for weaners.

PigBal 4 requires the user to enter the average number of hours per year that spray or drip cooling is likely to be used. The default figure is 540 hr per year, which is equivalent to 6 hr per day, over 90 days (3 months).

Known shed flushing and hosing volumes may be entered by the user in the appropriate cells. In some cases, it may be relatively simple to measure the dimensions of flushing tanks to determine the relevant flushing volume. It may be more difficult to measure hosing water without the use of a water meter. Because the hosing and drinking water may be supplied from the same pipeline in many piggeries, it may be difficult or impossible to accurately apportion the appropriate volumes to each use.

In cases where the daily flushing and hosing volumes are unknown or difficult to measure accurately, the user can estimate the shed effluent volume by choosing one of three different shed cleaning systems; *viz.* high flush, medium flush and low flush, from the drop-down list. PigBal 4 estimates the volume of effluent discharged from conventional sheds using the estimated total solids (TS) output (manure + waste feed) from the sheds (calculated on the 'DMDAMP' sheet) and the typical TS concentrations shown in Table 9 for the selected type of shed cleaning system.

Table 9. Typical total solids and volatile solids concentrations for a range of conventional shed cleaning systems.

Cleaning system	TS	VS
High flush	1.0%	0.7%
Medium flush	2.0%	1.4%
Low flush	3.0%	2.1%

Estimates of the moisture contents of the waste feed and manure, and the waste drinking water volume, are subtracted from the total effluent volume to determine the total cleaning (flushing + hosing) volume.

The user is also required to enter the percentage of the total cleaning water (flushing + hosing) obtained from recycled effluent. This is used to calculate the volume of clean (non-recycled effluent) water used for cleaning.

The total clean water volume required for the operation of the piggery is determined by adding the volumes of drinking water intake, waste drinking water, clean water used for shed cleaning and water used for cooling.

10. Effluent pre-treatment

The raw effluent discharged from conventional piggery sheds may be processed in a pre-treatment system, to remove some of the suspended solids and nutrients, prior to discharge into an effluent pond. PigBal 4 allows the user to select, from a drop-down list, one of seven types of pre-treatment system. The pre-treatment options available in the drop-down list are presented in Table 10, along with typical solids and nutrient removal rates.

There is also provision for the user to enter alternative removal rates if more accurate performance data is available, or if an alternative pre-treatment system is being used. If the 'Known pre-treatment removal rates' cells are left blank, the typical values from Table 10 are adopted.

Table 10. Typical percentages of solids and nutrients removed from raw piggery effluent by a range of pre-treatment systems which may be used in the Australian pork industry.

Pre-treatment system	TS	VS	N	P	K	References
Settling Basin	55	70	20	40	3	Kruger <i>et al.</i> (1995)
SEPS	77	82	36	89	4	Payne <i>et al.</i> (2008)
Static rundown screen	20	25	8	11	0	Casey <i>et al.</i> (1996) & Skerman & Collman (2006)
Vibrating screen	20	25	8	11	0	Casey <i>et al.</i> (1996) & Skerman & Collman (2006)
Screw press separator	32	37	37	41	8	McGahan <i>et al.</i> (2002)
Baleen filter screen	30	37	12	17	0	Tucker <i>et al.</i> (2010)
Rotating screen	15	20	5	10	0	Tucker <i>et al.</i> (2010)

PigBal 4 subtracts the solids and nutrients removed by the pre-treatment system from the effluent loading entering the downstream effluent treatment pond. The total masses of separated solids and nutrients are provided on this sheet.

11. Pond design

PigBal 4 provides three options for selecting an appropriate anaerobic pond activity ratio (k) for the piggery site. The first option requires the user to select the Australian state and locality where the piggery is located, from the drop-down lists. PigBal 4 automatically selects a k value for this locality, based on values published in the original PigBal user manual (Casey *et al.*, 1996b), as shown in Appendix B.

In the second option, which is consistent with the approach used in the NEGP (Tucker *et al.*, 2010), the user simply selects a climate type (cool, warm or hot), using the drop-down list. Table 11 provides example localities for these three climate descriptions, along with the corresponding anaerobic activity ratio (k) values, based on Table 12.2 of the NEGP (Tucker *et al.*, 2010).

Table 11. Climate descriptions, anaerobic pond activity ratio (k) values and example locations, based on Table 12.2 of the NEGP (Tucker *et al.*, 2010).

Climate	Anaerobic activity ratio (k)	Example localities
Cool	0.6	Armidale NSW, Southern & central Vic, Southern SA and Tasmania
Warm	0.8	Most of inland NSW, South-East Qld, SA and Southern WA
Hot	1.0	Central & northern Qld, Moree NSW and Goondiwindi Qld

The third option allows the user to enter a known k value for use in the model. The 'user selected' option overrides both of the previously described options.

The anaerobic activity ratio (k) value is multiplied by the volatile solids (VS) loading rate to give an adjusted VS loading rate that accounts for the climate at the piggery site. In this way, the suggested VS loading rates are lower for cooler localities, to account for the reduced biological activity at lower temperatures.

PigBal 4 calculates primary anaerobic pond volumes and dimensions based on three different design concepts, viz. 'conventional large', 'maximum loading' and 'covered anaerobic pond', which may be selected from a drop-down list. Table 12 outlines the recommended baseline VS loading rates and the adjusted VS loading rates for the various combinations of climates and design concepts. These loading rates were obtained by multiplying the anaerobic activity ratios from Table 11, by the baseline loading rates provided in Table 12.

Table 12. Recommended anaerobic pond volatile solids loading rates for the various combinations of design concepts and climates.

Pond design concept	VS loading rate (kg VS. m ⁻³ . d ⁻¹)			
	Baseline	Cool	Warm	Hot
Conventional large	0.10	0.06	0.08	0.10
Maximum loading	0.75	0.45	0.60	0.75
Covered anaerobic pond	0.30	0.18	0.24	0.30

The recommended VS loading rates for the ‘conventional large’ and ‘maximum loading’ options are consistent with the loading rates outlined in Section 12.1.2 of the NEGP (Tucker *et al.*, 2010). While the NEGP does not provide any suggested VS loading rates for covered anaerobic ponds (CAPs), it was considered important for PigBal 4 to provide some guidance on CAP loading rates, given the increasing interest in using this form of technology for the capture and use of biogas. The recommended baseline loading rate for covered anaerobic ponds, shown in Table 12 (300 g VS. m⁻³. day⁻¹) is consistent with current design practice.

The minimum active treatment volume, based on VS loading, is calculated by dividing the VS loading entering the pond, by the suggested adjusted maximum VS loading rate.

In addition to the VS loading rate, the hydraulic retention time (HRT) is an important measure for designing anaerobic ponds. The HRT is calculated by dividing the active treatment volume by the pond inflow value determined in the ‘Water’ sheet. For effective anaerobic treatment, a minimum HRT of 40 days is suggested.

PigBal 4 assumes a sludge accumulation rate of 0.00137 m³ per kg of TS added which is consistent with the value given in the ASABE Standards 2011 (ANSI/ASAE EP403.4 FEB2011 Design of Anaerobic Lagoons for Animal Waste Management). The user is required to enter a pond desludging interval which is generally between two and ten years, depending on the producer’s preferred sludge management practice. Shorter desludging intervals (e.g. 0.5 – 1.0 years) may be appropriate for covered anaerobic ponds equipped with suitable sludge extraction pipes. The desludging interval is used to determine the required sludge storage volume to be provided in the primary anaerobic pond.

PigBal 4 calculates the suggested total pond volume, which is the sum of the suggested active treatment and sludge storage volumes, based on meeting both the suggested VS loading rate and HRT design criteria. The user may then enter a selected total pond volume and PigBal 4 provides the resulting maximum and minimum VS loading rates and HRT values. The maximum VS loading rate occurs when the pond is storing the maximum sludge volume and the minimum VS loading rate occurs when the pond is storing no sludge, such as when it is first commissioned or directly following desludging. Conversely, the maximum HRT occurs when the pond is storing no sludge and the minimum HRT occurs when the pond is storing the maximum sludge volume. If any of

these values fall outside of the suggested ranges, the cells containing the non-compliant values are highlighted and a warning appears.

In order to determine the dimensions of a rectangular-shaped pond, the user is required to enter the total pond storage depth, batter gradient, freeboard, and one of the side dimensions of the pond, measured at the embankment crest. PigBal 4 determines the other relevant dimensions for the proposed pond design, as shown in Figure 2.

If the user selects physically impossible pond dimensions for the required pond volume, resulting in negative dimensions for the pond base, PigBal 4 provides a warning message near the bottom of the sheet.

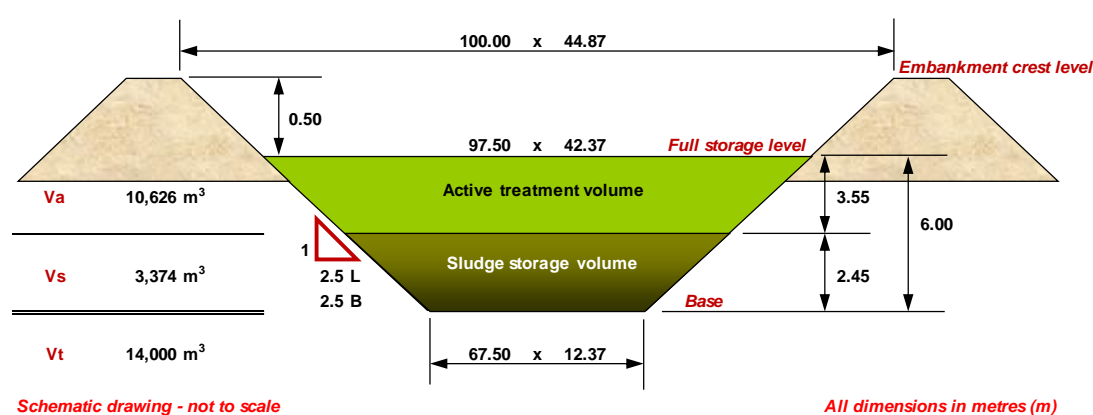


Figure 2. An example of the schematic drawing of the primary anaerobic pond provided on the 'Anaerobic pond design' sheet of PigBal 4.

Secondary treatment / holding ponds

Effluent which overflows from primary anaerobic ponds is unsuitable for direct discharge into the environment or natural watercourses. Overflow from primary ponds should generally be directed into a secondary treatment or holding pond where the effluent is temporarily stored prior to carefully managed irrigation onto land growing crop or pasture. Most conventional piggeries require at least one anaerobic treatment pond and one secondary treatment or holding pond. In some cases, the overflow from the secondary pond may be directed into one or more subsequent ponds (connected in series) for further treatment or to provide additional effluent holding capacity. The final pond in the effluent treatment / storage system may be referred to as a wet weather storage pond.

In general, the second and any subsequent ponds should be designed to store all effluent discharged from the primary pond until the land is sufficiently dry to receive the irrigated effluent, or until agronomic conditions are favourable. In the winter-dominant rainfall areas of southern Australia, secondary / holding ponds may be required to store all effluent discharged from the primary pond for a period of up to six months, from late autumn until early spring. Secondary / holding ponds are generally designed using a (preferably daily) water balance approach, based on limiting overflows from secondary /

holding ponds to a minimum interval of 10 years, on average, using historical rainfall and evaporation data for the piggery site. Various computer models may be used for this purpose. At environmentally sensitive sites, the minimum overflow interval may be increased to further reduce the potential for environmental harm.

12. Diet ingredient data

The 'Diet ingredient data' sheet is essentially a database providing the characteristics of a wide range of feed ingredients used in Australian pig diets. While a range of additional chemical concentrations and other data are provided on this sheet, PigBal 4 only uses the characteristics listed in Table 13 for estimating waste production. Various references for this data are listed at the bottom of the sheet.

Table 13. Diet ingredient characteristics used by PigBal 4.

Characteristic	Abbreviation	Units	Calculation
Dry Matter	DM	%	
Gross Energy	GE	MJ/kg	
Digestible Energy	DE	MJ/kg	
Dry Matter Digestibility	DMD	%	$DMD = DE / GE$
Crude Protein	CP	%	
Nitrogen	N	%	$N = CP / 6.25$
Ash (Fixed Solids)	Ash or FS	%	
Total Phosphorus	Total P	%	
Potassium	K	%	

Nine additional rows (shaded grey) are provided near the bottom of the sheet to allow users to enter data for extra diet ingredients that were not included in the original database.

13. Diet input

On this sheet, the user is required to enter the percentages of each ingredient included in the various diets fed to the pigs accommodated in the piggery. The proportions of each diet ingredient are entered as percentages of the 'as-fed' mass of the total diet for each class of pig. (The 'as-fed' mass, which includes the moisture content of each ingredient, is the feed mass generally used in diet formulation documentation produced by nutritionists and commercial feed companies.) The totals for each diet should add up to 100% and PigBal 4 gives a warning above any diet columns where this is not the case.

If the crude protein concentrations for any of the ingredients included in the diet formulation being entered into the model do not match the standard concentrations shown on the 'Diet input' sheet, alternate crude protein concentrations can be entered in the 'Alternate crude protein' column provided. For diet ingredients such as cereal grains, oilseed meals and animal and fish derived meals, crude protein percentages are commonly reported as a number following the diet ingredient name. For example, "barley 11", "soybean meal 45" and "fish meal 65" contain 11%, 45% and 65% crude protein, respectively. Crude protein levels entered in the 'Alternate crude protein' column override the standard values. The crude protein values are used to determine the nitrogen concentrations of the dietary ingredients, using the relationship outlined in Table 13.

Four standard diets have been incorporated into PigBal 4 for use in cases when detailed dietary data for a particular piggery may not be available for entry into the model. These diets are generally based on grower diets A, B, C and D used in the PigBal validation trial as described by Skerman *et al.* (2013a), with additional diets added for the other classes of pigs (Willis, 2013). Full details of these diets are provided in Appendix C, while the main diet ingredients are summarised below:

Diet A:	wheat, barley
Diet B:	sorghum, wheat
Diet C:	wheat, mung beans, sorghum
Diet D:	barley, wheat, mung beans

Users can enter the standard diet data by clicking on one of the macro buttons provided at the top of the 'Diet input' sheet.

Standard diets A to D include data for suckers, weaners, porkers, growers, finishers, lactating sows, gestating sows and gilts. The gestating sow diet is also used for the boars, while the same sucker diet is used for each of the standard diets A to D.

PigBal 4 selects the standard diet for each class of grower pig, using the end live weights entered on the 'Herd input' sheet, based on the standard live weights outlined in Table 14.

Table 14. Ages and live weights for the pig classes used in formulating standard diets A to D.

Diet	Pig age (weeks)		Pig live weight (kg)	
	Start	End	Start	End
Sucker	2	6	2	14
Weaner	6	10	14	30
Porker	10	14	30	55
Grower	14	18	55	80
Finisher	18		80	100

14. DMDAMP

Barth (1985a) proposed the Digestibility Approximation of Manure Production (DAMP) technique, which was arguably the first method used to predict the organic content of excreted manure from animal production data. This technique used the total digestible nutrient (TDN) content of the feed ingredients in its calculations.

Over time, it became apparent that the DAMP model needed improvement. Sinclair (1997) concluded that the DAMP technique, which used TDN values, was an inadequate means of providing accurate estimates of the basic manure characteristics of TS, VS and FS. van Sliedregt *et al.* (2000) developed a new digestibility model which used the dry matter digestibility (DMD) of each feed ingredient, rather than the TDN value. The DMD approximation of manure production (DMDAMP) predicts the amount of TS, VS and FS excreted by animals using DMD instead of TDN values of individual ingredients (McGahan *et al.* 2000, McGahan and van Sliedregt 2000, van Sliedregt *et al.* 2001). McGahan *et al.* (2001) conducted measurements of manure production at a finisher section (500 finisher pigs) of a 2000 sow commercial piggery to test the developed DMDAMP model.

No data entries are required on the 'DMDAMP' sheet; however, the majority of calculations to determine the ingested feed, waste feed, excreted manure and total waste discharged from the sheds, are carried on this sheet using Equations 10 to 17, as shown in Appendix A.

15. Output summary

No data entries are required on this sheet.

The 'Output summary' sheet provides summaries of the masses of TS, FS, VS, N, P and K in the feed ingested, feed wasted, manure excreted, manure excreted plus waste feed (before shed losses), effluent discharged from conventional sheds, separated solids, effluent discharged to primary pond, deep litter added to sheds and spent litter removed from deep litter sheds.

Stacked bar graphs show the proportions of waste feed and manure TS, FS, VS, N, P and K in the shed effluent. A second set of bar graphs compares the TS, FS, VS, N, P and K in the excreted manure plus the waste feed deposited in the sheds (excluding shed losses) predicted by the model, with the standard values published in the NEGP (Tucker *et al.*, 2010).

16. ERF calculations

The 'ERF calculations' sheet performs the calculations required to determine the baseline methane emissions from the piggery, based on the Carbon Credits (Carbon Farming Initiative) (Destruction of Methane Generated from Manure in Piggeries-1.1) Methodology Determination 2013, which can be downloaded from the Federal Register of Legislation website: <https://www.legislation.gov.au/Details/F2015C00574/Download>.

This methodology involves reducing greenhouse gas emissions from piggeries by installing impermeable covers on anaerobic effluent treatment ponds (or lagoons) to capture the biogas emissions from the pond surface. This abatement activity requires the installation and operation of covers and gas capture and combustion equipment for existing uncovered treatment lagoons or, alternatively, the replacement of conventional lagoons with covered lagoon systems. Piggery operators can use the captured biogas to produce heat and electricity, or destroy it through the use of flares.

Under section 4.3 of the above legislation, the baseline emission for a project is the methane that would have been generated and released from each lagoon included in the project, for each year of the project, in the absence of the abatement activity. The project baseline must be calculated based on the amount of volatile solids (VS) in the effluent stream deposited into each lagoon included in the project. The amount of VS in the effluent stream must be calculated using the PigBal model. Project proponents must input all required data into the PigBal model to calculate VS in accordance with the procedures and requirements set out in the PigBal manual.

PigBal 4 can assist proponents by determining the baseline emissions (volume of methane and the equivalent tonnage of carbon dioxide equivalents [$\text{CO}_2\text{-e}$]) that would be released from the operation of uncovered anaerobic treatment lagoons, in the absence of the project.

Provision has been included on this sheet to enter the current value of the global warming potential of methane (GWP_{CH_4}) specified in the National Greenhouse and Energy Reporting Regulations 2008, <https://www.legislation.gov.au/Details/F2017C00187>. This value is used to calculate the carbon dioxide equivalence value of the estimated methane emissions. The current (May 2018) value is 25; however, this value may change from time to time.

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Appendices

Appendix A – Key equations used in PigBal 4

‘Herd input’ sheet

Based on the entered ADG value, PigBal 4 uses Equation 1 to calculate predicted live weights at the ends of each of the growth stages previously entered into the model. This equation was developed from standard growth curves published in the Australian pig industry diary (Chris Richards and Associates, 2011).

$$\begin{aligned} \text{Live weight} = & (-0.0000300671 \times \text{ADG} + 0.0124897547) \times \text{Age}^3 + (-0.0000008113 \times \text{ADG}^2 + \\ & 0.0020909087 \times \text{ADG} - 0.65050342) \times \text{Age}^2 + (0.000000029 \times \text{ADG}^3 - 0.0000430323 \times \text{ADG}^2 + \\ & 0.0195041468 \times \text{ADG} - 2.587606895) \times \text{Age} + (-0.0000000384 \times \text{ADG}^3 + 0.0000537791 \times \text{ADG}^2 - \\ & 0.0223853981 \times \text{ADG} + 4.991589155) \dots\dots\dots \text{Equation 1} \end{aligned}$$

Where: *Live weight* = pig live weight (kg. pig⁻¹)
ADG = pig average daily live weight gain (g. day⁻¹) [birth to 100 kg live weight]
Age = pig age (weeks)

The predicted growth curve for the selected ADG is plotted along with standard growth curves for a range of ADG values on the ‘Growth chart’ sheet. Figure 3 shows the growth curves predicted using Equation 1 for a range of typical ADG values.

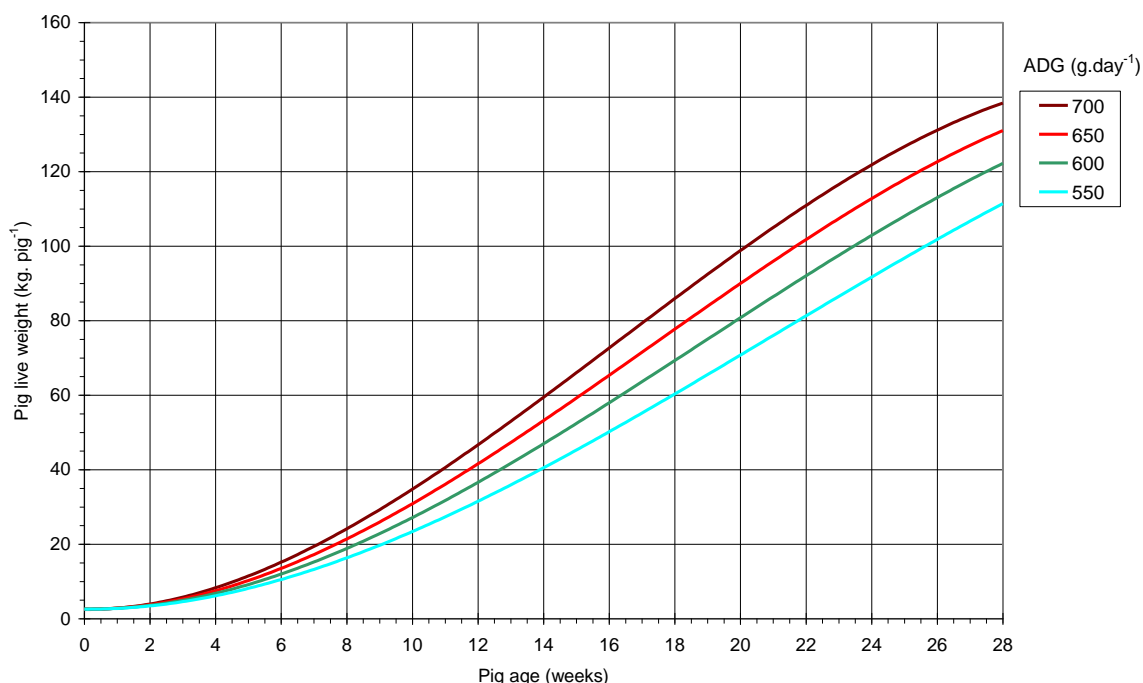


Figure 3. Growth curves predicted using Equation 1 for a range of typical ADG values

'Herd details' sheet

The 'Herd details' sheet includes SPU calculations using the standard SPU factors published in Table 4.1 of the NEGP (Tucker *et al.*, 2010). Two methods are used for selecting the SPU factors for the grower herd. The first method uses the end live weight for each class of pig, while the second method uses a regression equation (Equation 2) developed using the average live weights of pigs in each class. Figure 4 is a plot of this relationship.

$$\text{SPU factor} = 0.0000001837 \times \text{Live weight}^3 - 0.0001685623 \times \text{Live weight}^2 + 0.0329143124 \times \text{Live weight} - 0.0333791203 \dots \text{Equation 2}$$

Where: *SPU factor* = SPU factor (SPU. pig⁻¹)
Live weight = pig live weight (kg. pig⁻¹)

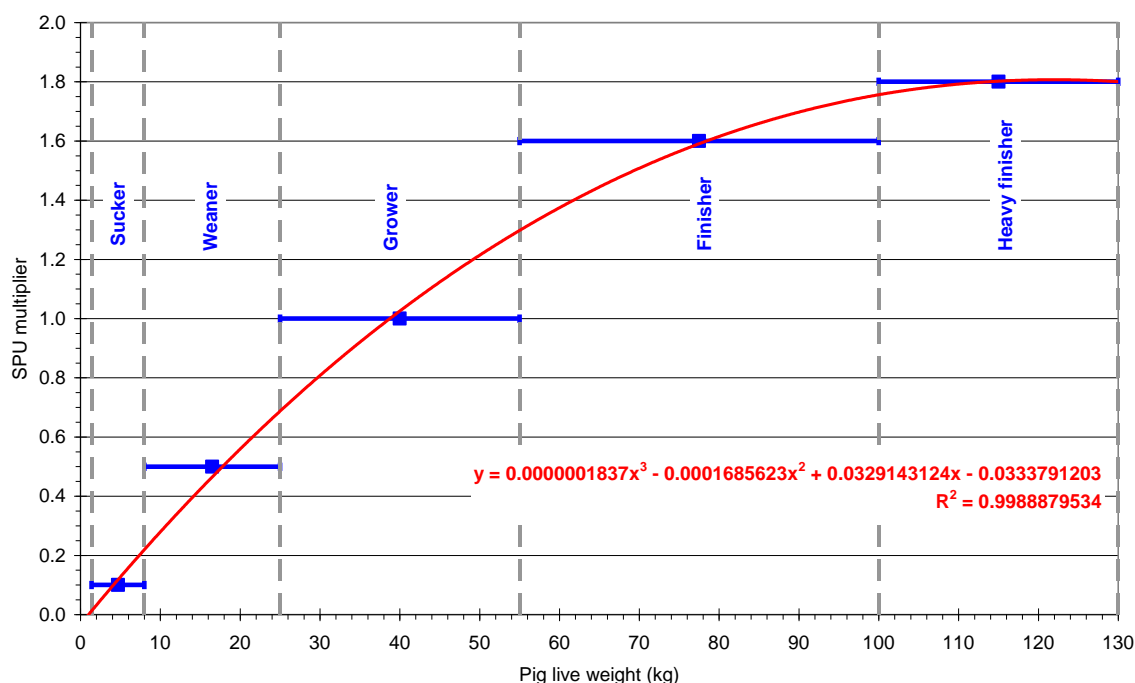


Figure 4. Plot of regression equation developed for determining SPU multipliers, based on average live weights for standard grower pig classes.

'Feed details' sheet

Estimates of the feed ingested by the grower pigs are calculated using Equation 3, which was derived by fitting a polynomial curve to feed intake data provided by Willis (2013) based on AUSPIG (Davies *et al.*, 1998) modelling. Figure 5 is a graphical representation of this relationship.

$$\text{Feed intake} = -0.0001534 \times \text{live weight}^2 + 0.0453863 \times \text{live weight} + 0.0323195 \dots \text{Equation 3}$$

Where: *Feed intake* = feed ingested (kg 'as-fed'. pig⁻¹. day⁻¹)

live weight = pig live weight (kg. pig⁻¹)

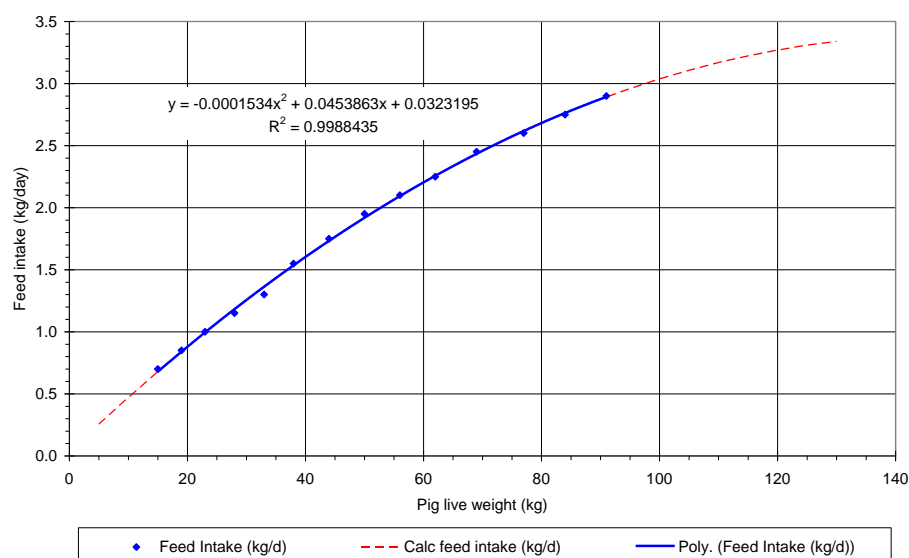


Figure 5. Relationship between feed intake and live weight, developed from data provided by Willis (2013), based on AUSPIG modelling.

To assist users in estimating a realistic feed wastage value, a relationship was developed between feed wastage, the ADG value entered in the 'Herd input' sheet and the FCR value entered on the 'Feed details' sheet. The first step in developing this relationship involved using equations 1 and 3 to develop equation 4, which can be used to calculate feed intake for selected ADG and age values. This relationship has been plotted in Figure 6 for a range of ADG values.

Feed intake =

$$\begin{aligned} & (0.000000000071189 \times \text{ADG}^2 - 0.00000002477377 \times \text{ADG} - 0.000004038661444) \times \text{Age}^4 + \\ & (-0.000000001002912 \times \text{ADG}^2 - 0.000002881954697 \times \text{ADG} + 0.001438856666767) \times \text{Age}^3 + \\ & (-0.000000060875126 \times \text{ADG}^2 + 0.000145742239164 \times \text{ADG} - 0.047938044293907) \times \text{Age}^2 + \\ & (0.000000001800819 \times \text{ADG}^3 - 0.000002774275076 \times \text{ADG}^2 + 0.001272505833082 \times \text{ADG} - \\ & 0.171629578799318) \times \text{Age} + (-0.000000002188792 \times \text{ADG}^3 + 0.000003175842546 \times \text{ADG}^2 - \\ & 0.001355216082386 \times \text{ADG} + 0.304300173002773) \dots \text{Equation 4} \end{aligned}$$

Where: *Feed intake* = Feed ingested by pigs (kg. pig⁻¹. day⁻¹)

ADG = Average daily live weight gain (g. day⁻¹) [birth to 100 kg live weight]

Age = pig age (weeks)

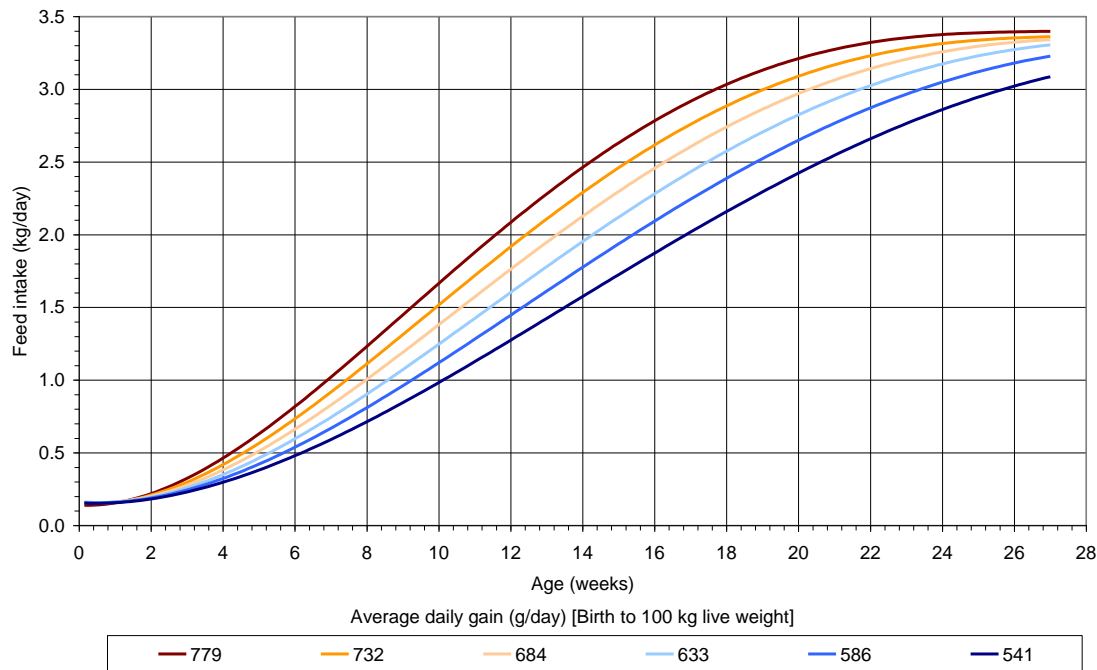


Figure 6. Relationship between feed intake and age at a range of average daily gains, based on Equation 4.

The total feed intake from birth to 100 kg live weight can be determined by integrating the graphs shown in Figure 6 between birth (age = 0 weeks) and the age at which the pigs reach a live weight of 100 kg, which can be calculated using Equation 5. Equation 6 can then be used to determine the total feed intake from birth to 100 kg live weight.

$$Age_{100} = (((100 - 1.4) \times 1000) / ADG) / 7 \dots\dots\dots \text{Equation 5}$$

Where: Age_{100} = Pig age at 100 kg live weight (weeks)
 ADG = average daily live weight gain ($g \cdot day^{-1}$) [birth to 100 kg live weight]

$$\begin{aligned} \text{Total feed intake} = & (((0.000000000071189 \times ADG^2 - 0.00000002477377 \times ADG - 0.000004038661444) \times Age_{100}^5) / 5 + \\ & ((-0.000000001002912 \times ADG^2 - 0.000002881954697 \times ADG + 0.001438856666767) \times Age_{100}^4) / 4 + \\ & ((-0.000000060875126 \times ADG^2 + 0.000145742239164 \times ADG - 0.047938044293907) \times Age_{100}^3) / 3 + \\ & ((0.000000001800819 \times ADG^3 - 0.000002774275076 \times ADG^2 + 0.001272505833082 \times ADG - \\ & 0.171629578799318) \times Age_{100}^2) / 2 + (-0.000000002188792 \times ADG^3 + 0.000003175842546 \times ADG^2 - \\ & 0.001355216082386 \times ADG + 0.304300173002773) \times Age_{100}) \times 7 \dots\dots\dots \text{Equation 6} \end{aligned}$$

Where: Total feed intake = Total feed intake from birth to 100 kg live weight ($kg \cdot pig^{-1}$)
 ADG = average daily live weight gain ($g \cdot day^{-1}$) [birth to 100 kg live weight]
 Age_{100} = Pig age at 100 kg live weight (weeks)

The total feed wasted can be calculated from Equation 7.

$$\begin{aligned} \text{Total feed wasted} &= \text{Total feed fed} - \text{Total feed intake} \\ &= \text{FCR} \times (100 - 1.4) - \text{Total feed intake} \dots \text{Equation 7} \end{aligned}$$

Where: Total feed wasted = Total feed wasted (kg. pig⁻¹) [birth to 100 kg live weight]
 Total feed fed = Total feed intake from birth to 100 kg live weight (kg. pig⁻¹) Eqn 4
 FCR = Feed conversion ratio (birth to 100 kg live weight)

The total feed wastage (%) can be calculated from Equation 8.

$$\text{Total feed wastage} = (\text{Total feed wasted} / \text{Total feed fed}) \times 100 \dots \text{Equation 8}$$

Where: $\text{Total feed wastage}$ = Total feed wastage (%)
 Total feed wasted = Total feed wasted (kg. pig⁻¹) from Equation 6
 Total feed fed = $\text{Total feed wasted} + \text{Total feed intake}$ (kg. pig⁻¹)

Figure 7 is a graph showing the resulting relationship between feed wastage and FCR for a range of ADG values. PigBal uses the equations described above to determine the estimated feed wastage, which is shown directly above the table on the 'Feed details' sheet.

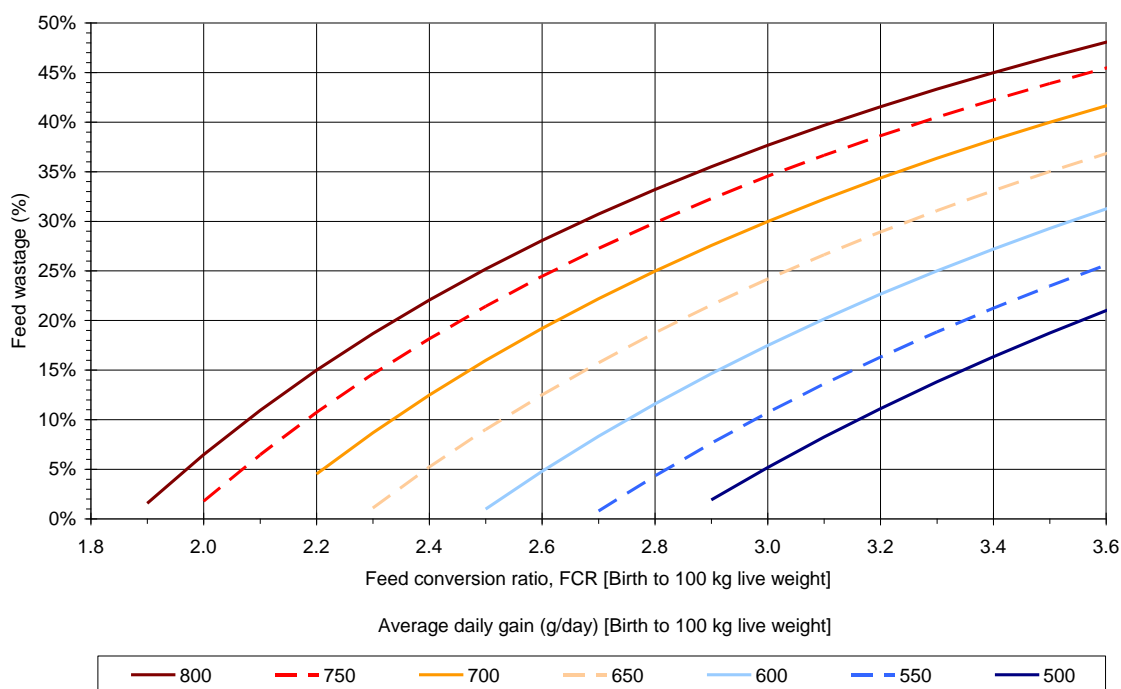


Figure 7. Generalised plot of feed wastage versus feed conversion ratio for a range of ADG values.

‘Water’ sheet

PigBal 4 uses Equation 7, which was developed by Wiedemann *et al.* (2012), to estimate water intake for each class of pig, using the average pig feed intakes entered or calculated on the ‘Feed details’ sheet.

$$WI = FI \times Wf \times Tf \dots\dots\dots \textbf{Equation 9}$$

Where: WI = Water Intake (L. pig⁻¹. day⁻¹)
 FI = Feed intake (kg ‘as-fed’. pig⁻¹. day⁻¹)
 Wf = Water Intake factor, (2.5 for growing pigs, 2.8 for gestating/lactating sows)
 Tf = Temperature factor, (1.6 for lactating sows, 1.2 for all other pigs)

Wiedemann *et al.* (2012) provide the following explanation regarding the development of this equation:

Water use can be particularly variable in response to climate. This makes prediction quite difficult. However, for the purposes of this study a simple predictive formula was developed based on feed intake, with a climate adjustment factor. This formula varied for different classes of pigs based on data from a number of studies. For grower-finisher pigs, the ratio of water intake to feed was taken to be 2.5 after Braude *et al.* (cited in National Research Council, 1998).

For dry sows, the ratio of water intake to feed was taken to be 2.8 after Van der Peet-Schwering *et al.* (cited in Small 2001), who suggested a water to feed ratio of 2.8 : 1 is sufficient for pregnant sows. Mroz *et al.* (1995) suggested that water consumption for lactating sows is at least 40% higher than that of non-lactating sows.

All the available review data were sourced from northern hemisphere countries where ambient temperature is considerably lower than in Australia. To account for this, a factor of 1.2 was used in the drinking water equation for Australian conditions. This factor was derived from the Australian temperature response data in Vajrabukka *et al.* (cited in National Research Council 1998).

‘DMDAMP’ sheet

On this sheet, the following calculations are performed for each diet ingredient, and the results are added to determine total values for each pig class.

$$TS\ ingested = \% \text{ fed weight} \times \text{Ingredient DM\%} \times 100 \dots\dots\dots \text{Equation 10}$$

Where: $TS\ ingested$ = Total solids ingested by pigs (kg TS. 100 kg fed⁻¹)
 $\% \text{ fed weight}$ = ('as-fed' mass of ingredient / mass of total diet) x 100 (%)
(entered on '13. Diet input sheet')
 $Ingredient\ DM\%$ = Dry matter (or total solids) content of each ingredient (%)
(from '12. Diet ingredient data' sheet.

$$FS\ ingested = \% \text{ fed weight} \times \text{Ingredient FS\%} \times 100 \dots\dots\dots \text{Equation 11}$$

Where: $FS\ ingested$ = Fixed solids ingested by pigs (kg FS. 100 kg fed⁻¹)
 $\% \text{ fed weight}$ = ('as-fed' mass of ingredient / mass of total diet) x 100 (%)
(entered on '13. Diet input sheet')
 $Ingredient\ FS\%$ = Fixed solids (or ash) content of each ingredient (%)
(from '12. Diet ingredient data' sheet.

$$VS\ ingested = TS\ ingested - FS\ ingested \dots\dots\dots \text{Equation 12}$$

Where: $VS\ ingested$ = Volatile solids ingested by pigs (kg VS. 100 kg fed⁻¹)

$$N\ ingested = \% \text{ fed weight} \times \text{Ingredient N \%} \times 100 \dots\dots\dots \text{Equation 13}$$

Where: $N\ ingested$ = Nitrogen ingested by pigs (kg N. 100 kg fed⁻¹)
 $\% \text{ fed weight}$ = ('as-fed' mass of ingredient / mass of total diet) x 100 (%)
(entered on '13. Diet input sheet')
 $Ingredient\ N\ \%$ = Nitrogen content of each ingredient (%)
(from '12. Diet ingredient data' sheet.

Similar calculations are performed to determine phosphorus (P) and potassium (K) ingested values.

$$TS\ excreted = TS\ ingested \times (1 - DMD) \dots\dots\dots \text{Equation 14}$$

Where: $TS\ excreted$ = Total solids excreted by pigs (kg TS. 100 kg fed⁻¹)
 $TS\ ingested$ = Total solids ingested by pigs (kg TS. 100 kg fed⁻¹)
(from Equation 10)
 DMD = Dry matter digestibility of each ingredient (%)
(Calculated as Digestible energy (DE) / Gross energy (GE)
on '12. Diet ingredient data' sheet)

The majority of calculations to determine the ingested feed, waste feed, excreted manure and total waste discharged from the sheds, are carried out on the 'DMDAMP' sheet, using a range of equations to provide results in various units. The basic forms of the equations are outlined below, without specific units or conversion factors.

The amount of FS excreted is calculated by mass balance, as the difference between the amount in the ingested feed and the amount retained by the animal as live weight gain.

$$FS\ excreted = FS\ ingested - FS\ retained \dots\dots\dots \textbf{Equation 15}$$

Where: $FS\ excreted$ = Fixed solids (or ash) excreted by pigs
 $FS\ ingested$ = Fixed solids (or ash) ingested by pigs
 $FS\ retained$ = Fixed solids retained by pigs as live weight gain
= Live weight gain x pig carcass fixed solids composition

The amount of VS excreted is calculated as the difference between TS and FS.

$$VS\ excreted = TS\ excreted - FS\ excreted \dots\dots\dots \textbf{Equation 16}$$

The masses of nutrients (N, P and K) excreted are calculated by mass balance, as the difference between the amount in the ingested feed and the amount retained by the animal as live weight gain.

$$Nutrient\ excreted = Nutrient\ ingested - Nutrient\ retained \dots\dots\dots \textbf{Equation 17}$$

Where: $Nutrient\ ingested$ = Mass of N, P or K ingested
= Mass of feed ingested x Feed N, P or K content
 $Nutrient\ retained$ = Mass of N, P or K retained by pigs as live weight gain
= Live weight gain x pig carcass N, P or K composition

‘ERF calculations’ sheet

The following calculations are performed by PigBal 4 to assist proponents in determining the required baseline emissions for proposed and existing piggery developments. The variables have been described for consistency with the methodology, and cross references for the equation numbers are provided.

$$Q_b = VS \times Bo \times MCF \dots\dots\dots \textbf{Equation 18} \text{ (Equation 1.2, p 7 Methodology)}$$

Where: Q_b = volume of methane that would be released from the operation of uncovered anaerobic treatment lagoons within the project site in the absence of the project, in cubic metres of methane ($\text{m}^3 \text{CH}_4$) at standard conditions, calculated using Equation 1.2.

VS = quantity of Volatile Solids entering the project lagoons, in kilograms, calculated using the PigBal model in accordance with the PigBal Manual.

Bo = the maximum methane-producing capacity from VS , in units of cubic metres of methane per kilogram of VS ($\text{m}^3 \text{CH}_4 \cdot \text{kg VS}^{-1}$). The Bo factor for pigs is 0.45.

MCF = methane conversion factor which reflects that portion of Bo that is achieved under temperature and treatment specifications. For anaerobic lagoons across Australia this is 0.9.

$$E_b = \gamma \times Q_b \dots\dots\dots \textbf{Equation 19} \text{ (Equation 1.1, p 7, Methodology)}$$

Where: E_b = methane emissions from the operation of uncovered anaerobic treatment lagoons within the project site in the absence of the project, in tonnes of $\text{CO}_2\text{-e}$.

$\gamma = 6.784 \times 10^{-4} \times \text{GWP}_{\text{CH}_4}$ the factor for converting cubic metres of methane to tonnes of $\text{CO}_2\text{-e}$ at standard conditions.

GWP_{CH_4} = The global warming potential of methane (CH_4) specified in Table 2.02 of the *National Greenhouse and Energy Reporting Regulations 2008*, currently having a value of 25. This value is used for determining carbon dioxide equivalence of greenhouse gases.

Appendix B – Anaerobic pond activity ratios

Table 15. Anaerobic pond activity ratios (k) for locations throughout Australia.
(Casey *et al.*, 1996)

State / Territory	Locality	Latitude	Longitude	K value	Climate
Australian Capital Territory	Canberra	-35.20	149.10	0.58	Cool
Australian Capital Territory	Gudgenby	-35.45	148.59	0.40	Cool
New South Wales	Albury	-36.05	146.55	0.75	Warm
New South Wales	Ardlethan	-34.21	146.54	0.74	Warm
New South Wales	Armidale	-30.31	151.38	0.61	Cool
New South Wales	Badgerys Creek	-33.52	150.44	0.78	Warm
New South Wales	Balranald PO	-34.38	143.34	0.78	Warm
New South Wales	Baradine Forest	-30.57	149.04	0.82	Warm
New South Wales	Barraba PO	-30.23	150.36	0.73	Warm
New South Wales	Bathurst	-33.25	149.34	0.62	Cool
New South Wales	Bega	-36.40	149.50	0.70	Warm
New South Wales	Bellangry Brie	-31.20	152.35	0.84	Warm
New South Wales	Bellingen PO	-30.27	152.54	0.89	Warm
New South Wales	Berrigan PO	-35.39	145.48	0.73	Warm
New South Wales	Bingara PO	-29.52	150.34	0.87	Warm
New South Wales	Black Spring SF	-33.51	149.44	0.44	Cool
New South Wales	Blayney PO	-33.32	149.16	0.48	Cool
New South Wales	Bombala (Chusan)	-36.54	149.14	0.48	Cool
New South Wales	Bourke	-30.06	145.57	0.99	Hot
New South Wales	Brewarrina	-29.57	146.52	0.96	Hot
New South Wales	Broken Hill	-31.57	141.25	0.84	Warm
New South Wales	Broken Hill Aero	-31.54	141.36	0.83	Warm
New South Wales	Burrinjuck Dam	-35.00	148.36	0.65	Cool
New South Wales	Cabramurra (SMC)	-35.56	148.23	0.33	Cool
New South Wales	Campbelltown	-34.05	150.49	0.77	Warm
New South Wales	Cessnock PO	-32.50	151.21	0.86	Warm
New South Wales	Clarence Heads	-29.26	153.22	0.92	Hot
New South Wales	Cobar	-31.30	145.49	0.89	Warm
New South Wales	Coffs Harbour	-30.19	153.08	0.86	Warm
New South Wales	Collarenebri	-29.33	148.35	0.98	Hot
New South Wales	Condobolin PO	-33.05	147.09	0.82	Warm
New South Wales	Coolah Bowl Club	-31.50	149.43	0.67	Cool
New South Wales	Coolongalook SF	-32.12	152.12	0.77	Warm
New South Wales	Cooma	-36.14	149.07	0.52	Cool
New South Wales	Coonabarabran	-31.16	149.17	0.70	Warm
New South Wales	Coonamble	-30.57	148.24	0.92	Hot
New South Wales	Cootamundra	-34.39	148.02	0.70	Warm
New South Wales	Cowra PO	-33.54	148.42	0.72	Warm
New South Wales	Crookwell PO	-34.28	149.29	0.50	Cool
New South Wales	Cumberland SF	-33.45	151.00	0.78	Warm
New South Wales	Dalkeith	-32.00	149.58	0.72	Warm
New South Wales	Deepwater PO	-29.27	151.50	0.59	Cool
New South Wales	Deniliquin	-35.32	144.58	0.76	Warm
New South Wales	Deniliquin	-35.22	145.03	0.73	Warm
New South Wales	Dubbo	-32.15	148.36	0.82	Warm
New South Wales	Dunedoo	-32.01	149.24	0.76	Warm
New South Wales	Dungog	-32.24	151.46	0.81	Warm
New South Wales	Euston PO	-34.35	142.44	0.75	Warm
New South Wales	Forbes	-33.23	148.00	0.81	Warm
New South Wales	Frogmore PO	-34.16	148.50	0.63	Cool
New South Wales	Gilgandra	-31.42	148.42	0.81	Warm
New South Wales	Glen Innes	-29.44	151.44	0.59	Cool
New South Wales	Glenfield Vet Rs	-33.58	150.54	0.79	Warm
New South Wales	Glenorie	-33.36	151.00	0.78	Warm
New South Wales	Goodooga PO	-29.07	147.27	0.99	Hot

State / Territory	Locality	Latitude	Longitude	K value	Climate
New South Wales	Goulburn	-34.45	149.43	0.62	Cool
New South Wales	Grafton	-29.41	152.56	0.99	Hot
New South Wales	Green Cape	-37.16	150.03	0.66	Cool
New South Wales	Grenfell PO	-33.54	148.10	0.72	Warm
New South Wales	Griffith	-34.71	146.03	0.77	Warm
New South Wales	Griffith Res Stn	-34.17	146.02	0.73	Warm
New South Wales	Gulgong PO	-32.22	149.32	0.70	Warm
New South Wales	Gunnedah	-30.59	150.15	0.86	Warm
New South Wales	Gurnang	-34.00	150.06	0.39	Cool
New South Wales	Guyra PO	-30.13	151.40	0.48	Cool
New South Wales	Harden PO	-34.33	148.22	0.66	Cool
New South Wales	Harrington PO	-31.52	152.42	0.84	Warm
New South Wales	Harwood Sugar Mill	-29.26	153.15	0.90	Hot
New South Wales	Hay	-34.30	144.50	0.78	Warm
New South Wales	Hillston PO	-33.29	145.32	0.82	Warm
New South Wales	Hume Reservoir	-36.06	147.02	0.69	Cool
New South Wales	Inverell	-29.47	151.07	0.71	Warm
New South Wales	Ivanhoe	-32.54	144.18	0.85	Warm
New South Wales	Jerrys Plains PO	-32.30	150.55	0.82	Warm
New South Wales	Jervis Bay	-35.08	150.42	0.77	Warm
New South Wales	Jervis Bay	-35.06	150.48	0.77	Warm
New South Wales	June	-34.52	147.35	0.72	Warm
New South Wales	Katoomba	-33.42	150.18	0.53	Cool
New South Wales	Kempsey West	-31.05	152.50	0.89	Warm
New South Wales	Kendall Forestry	-31.36	152.42	0.82	Warm
New South Wales	Kirkconnell Prison	-33.25	149.50	0.44	Cool
New South Wales	Kulnura (Boots R)	-33.14	151.12	0.73	Warm
New South Wales	Lake Victoria	-34.03	141.16	0.78	Warm
New South Wales	Leeton Soldier C	-34.33	146.25	0.77	Warm
New South Wales	Lismore	-28.48	153.16	0.92	Hot
New South Wales	Lithgow	-33.29	150.09	0.50	Cool
New South Wales	Mathoura SF	-35.49	144.54	0.71	Warm
New South Wales	Menindie	-32.24	142.25	0.86	Warm
New South Wales	Molong	-33.06	148.52	0.64	Cool
New South Wales	Monkstadt	-29.08	151.27	0.82	Warm
New South Wales	Montague Island	-36.15	150.14	0.75	Warm
New South Wales	Moree	-29.28	149.50	0.95	Hot
New South Wales	Moruya Heads	-35.55	150.10	0.71	Warm
New South Wales	Moss Vale PO	-34.33	150.22	0.56	Cool
New South Wales	Moulamein PO	-35.05	144.02	0.77	Warm
New South Wales	Mt Mitchell Aff	-29.39	152.06	0.57	Cool
New South Wales	Mt Victoria	-33.55	150.15	0.50	Cool
New South Wales	Mt Victoria	-33.36	150.15	0.49	Cool
New South Wales	Mudgee	-32.36	149.35	0.68	Cool
New South Wales	Mungindi PO	-28.59	149.00	0.97	Hot
New South Wales	Murrurundi	-31.46	150.50	0.72	Warm
New South Wales	Muswellbrook	-32.15	150.53	0.77	Warm
New South Wales	Nalbaugh SF	-37.04	149.21	0.48	Cool
New South Wales	Naradhan PO	-33.37	146.19	0.79	Warm
New South Wales	Narara (Gosford)	-33.24	151.20	0.77	Warm
New South Wales	Narrabri	-30.19	149.47	0.91	Hot
New South Wales	Narranderra PO	-34.45	146.33	0.80	Warm
New South Wales	Nelson Bay (RSL)	-32.43	152.09	0.86	Warm
New South Wales	Nerriga PO	-35.07	150.05	0.56	Cool
New South Wales	Newcastle	-32.57	151.45	0.84	Warm
New South Wales	Newnes Prison Cp	-33.21	150.15	0.48	Cool
New South Wales	Nimmitabel PO	-36.31	149.17	0.40	Cool
New South Wales	Nowa	-37.43	148.06	0.61	Cool
New South Wales	Nowra Ranas	-34.57	150.32	0.73	Warm
New South Wales	Nyngan	-31.34	147.11	0.86	Warm

State / Territory	Locality	Latitude	Longitude	K value	Climate
New South Wales	Oberon PO	-34.01	149.51	0.41	Cool
New South Wales	Oberon PO	-33.43	149.52	0.45	Cool
New South Wales	Orange PO	-33.17	149.06	0.60	Cool
New South Wales	Parkes PO	-33.08	148.11	0.78	Warm
New South Wales	Peak Hill	-32.42	148.12	0.83	Warm
New South Wales	Pictou	-34.10	150.37	0.72	Warm
New South Wales	Pilliga	-30.21	148.54	0.85	Warm
New South Wales	Port Kembla	-34.28	150.55	0.83	Warm
New South Wales	Port Macquarie	-31.28	152.56	0.82	Warm
New South Wales	Quambone PO	-30.56	147.52	0.91	Hot
New South Wales	Richmond Aero	-33.36	150.42	0.81	Warm
New South Wales	Riverview	-33.50	151.09	0.81	Warm
New South Wales	Scone	-32.05	150.50	0.80	Warm
New South Wales	Seven Hills Exp	-33.43	150.47	0.81	Warm
New South Wales	Smoky Cape	-30.55	153.05	0.93	Hot
New South Wales	Sydney	-33.53	151.12	0.83	Warm
New South Wales	Tamworth	-31.06	150.59	0.84	Warm
New South Wales	Taralga PO	-34.24	149.49	0.50	Cool
New South Wales	Taree Radio Stn	-31.54	152.29	0.84	Warm
New South Wales	Temora	-34.26	147.32	0.70	Warm
New South Wales	Tenterfield	-29.03	152.00	0.66	Cool
New South Wales	Tibooburra	-29.26	142.00	0.99	Hot
New South Wales	Tocumwal PO	-35.49	145.34	0.74	Warm
New South Wales	Trangie (Exp Fm)	-31.59	147.57	0.80	Warm
New South Wales	Tullamore PO	-32.38	147.34	0.79	Warm
New South Wales	Tumbarumba PO	-35.47	148.01	0.53	Cool
New South Wales	Urana	-35.20	146.16	0.77	Warm
New South Wales	Wagga	-35.07	147.22	0.76	Warm
New South Wales	Wagga Aero	-35.06	147.30	0.69	Cool
New South Wales	Walcha	-31.00	151.36	0.52	Cool
New South Wales	Walgett	-30.01	148.07	0.94	Hot
New South Wales	Wallangarra PO	-28.55	151.56	0.64	Cool
New South Wales	Wallangra (Stat)	-29.15	150.54	0.79	Warm
New South Wales	Wallerawang SF	-32.36	151.48	0.75	Warm
New South Wales	Warralga	-29.33	150.34	0.80	Warm
New South Wales	Wauchope SF	-31.28	152.44	0.85	Warm
New South Wales	Wellington	-32.33	148.57	0.79	Warm
New South Wales	Wentworth	-34.06	141.55	0.82	Warm
New South Wales	White Cliffs PO	-30.51	143.05	0.94	Hot
New South Wales	Willcannia	-31.34	143.23	0.92	Hot
New South Wales	Williamstown Aero	-32.48	151.50	0.81	Warm
New South Wales	Woolbrook PO	-30.58	151.21	0.54	Cool
New South Wales	Wyalong PO	-33.56	147.15	0.75	Warm
New South Wales	Yarras (Mt Seav)	-31.23	152.15	0.81	Warm
New South Wales	Yass	-34.51	148.56	0.59	Cool
New South Wales	Yenda PO	-34.15	146.11	0.79	Warm
New South Wales	Young PO	-34.19	148.18	0.66	Cool
Northern Territory	Alice Springs	-23.50	133.53	1.00	Hot
Northern Territory	Avon Downs Homestd	-20.02	137.29	1.26	Hot
Northern Territory	Barrow Creek PO	-21.30	133.54	1.22	Hot
Northern Territory	Borroloola	-16.05	136.20	1.37	Hot
Northern Territory	Brunette Downs	-18.39	135.57	1.34	Hot
Northern Territory	Cape Don Light	-11.19	131.46	1.40	Hot
Northern Territory	Charlotte Waters	-25.55	134.55	1.06	Hot
Northern Territory	Croker Island	-11.09	132.35	1.39	Hot
Northern Territory	Curtain Springs	-25.19	131.45	1.03	Hot
Northern Territory	Daly Waters	-16.15	133.22	1.39	Hot
Northern Territory	Darwin	-12.28	130.50	1.44	Hot
Northern Territory	Elcho Island	-11.55	135.45	1.41	Hot
Northern Territory	Finke PO	-25.35	134.34	1.11	Hot

State / Territory	Locality	Latitude	Longitude	K value	Climate
Northern Territory	Goulburn Is Sound	-11.39	133.23	1.42	Hot
Northern Territory	Groote Eylandt	-13.59	136.28	1.33	Hot
Northern Territory	Hooker Creek	-18.20	130.38	1.35	Hot
Northern Territory	Inverway Stn	-17.50	129.39	1.31	Hot
Northern Territory	Katherine	-14.18	132.28	1.39	Hot
Northern Territory	Katherine PO	-14.28	132.16	1.41	Hot
Northern Territory	Larrimah PO	-15.35	133.13	1.39	Hot
Northern Territory	Maningrida	-12.03	134.14	1.36	Hot
Northern Territory	Middle Point	-12.27	131.17	1.39	Hot
Northern Territory	Millingimbi	-12.06	134.54	1.36	Hot
Northern Territory	Newcastle Waters	-17.22	133.25	1.39	Hot
Northern Territory	Noonamah	-12.35	131.05	1.38	Hot
Northern Territory	Oenpelli	-12.20	133.04	1.43	Hot
Northern Territory	Port Keats Mission	-14.14	129.34	1.36	Hot
Northern Territory	Ringwood Stn	-23.50	134.57	1.07	Hot
Northern Territory	Roper River Mission	-14.44	134.44	1.43	Hot
Northern Territory	Snake Bay	-11.25	130.40	1.39	Hot
Northern Territory	Tempe Downs	-24.23	132.26	1.03	Hot
Northern Territory	Tennant Creek	-19.39	134.12	1.29	Hot
Northern Territory	Victoria River	-16.24	131.00	1.44	Hot
Northern Territory	Wave Hill	-17.29	130.57	1.39	Hot
Northern Territory	Wonarah	-19.54	136.20	1.30	Hot
Northern Territory	Yirrkala Mission	-12.15	136.55	1.37	Hot
Northern Territory	Yuendumu	-22.16	131.48	1.12	Hot
Queensland	Adavale	-25.55	144.36	1.09	Hot
Queensland	Atherton	-17.16	145.29	0.98	Hot
Queensland	Ayr	-19.35	147.24	1.18	Hot
Queensland	Baralaba PO	-24.11	149.49	1.10	Hot
Queensland	Barcaldine	-23.34	145.17	1.14	Hot
Queensland	Beaudesert Shire	-27.48	153.00	0.94	Hot
Queensland	Biloela	-24.24	150.30	0.98	Hot
Queensland	Birdsville	-25.55	139.22	1.15	Hot
Queensland	Blackall	-24.25	145.28	1.11	Hot
Queensland	Bollon	-28.02	147.29	1.00	Hot
Queensland	Boulia	-22.55	139.54	1.26	Hot
Queensland	Bowen	-20.01	148.14	1.21	Hot
Queensland	Brisbane	-27.28	153.02	1.00	Hot
Queensland	Bulburin (Forest)	-24.32	151.28	0.88	Warm
Queensland	Bundaberg	-24.52	152.21	1.04	Hot
Queensland	Burketown	-17.44	139.33	1.33	Hot
Queensland	Bustard Head	-24.02	151.45	1.07	Hot
Queensland	Cairns	-16.55	145.47	1.24	Hot
Queensland	Caloundra (Sig)	-26.48	153.09	1.00	Hot
Queensland	Cambooya	-27.43	151.52	0.79	Warm
Queensland	Camooeal	-19.55	138.07	1.29	Hot
Queensland	Cape Capricorn	-23.30	151.14	1.07	Hot
Queensland	Cape Cleveland	-19.11	147.02	1.24	Hot
Queensland	Cape Moreton	-27.02	153.25	1.00	Hot
Queensland	Cardwell	-18.16	146.02	1.16	Hot
Queensland	Casino PO	-28.52	153.03	0.98	Hot
Queensland	Charleville	-26.24	146.15	1.04	Hot
Queensland	Charters Towers	-20.06	146.16	1.18	Hot
Queensland	Childers	-25.15	152.16	1.04	Hot
Queensland	Clermont	-22.49	147.38	1.09	Hot
Queensland	Cloncurry	-20.43	140.30	1.34	Hot
Queensland	Coen	-13.56	143.12	1.26	Hot
Queensland	Coen Aero	-13.46	143.07	1.31	Hot
Queensland	Collinsville	-20.33	147.50	1.13	Hot
Queensland	Consuelo	-24.48	148.00	0.85	Warm
Queensland	Cooktown	-15.26	145.15	1.30	Hot

State / Territory	Locality	Latitude	Longitude	K value	Climate
Queensland	Coolangatta Aero	-28.10	153.30	0.95	Hot
Queensland	Crohamhurst	-26.49	152.50	0.92	Hot
Queensland	Cronulla	-25.24	151.24	1.06	Hot
Queensland	Croydon	-18.13	142.42	1.41	Hot
Queensland	Croydon PO	-18.12	142.15	1.41	Hot
Queensland	Cunnamulla	-28.16	145.49	1.04	Hot
Queensland	Cunnamulla	-28.04	145.41	1.03	Hot
Queensland	Dalby	-27.11	151.16	0.91	Hot
Queensland	Donors Hill	-18.43	140.33	1.35	Hot
Queensland	Double Is Point	-25.56	153.11	1.03	Hot
Queensland	Emerald	-23.37	148.10	1.11	Hot
Queensland	Fairview	-15.33	144.19	1.30	Hot
Queensland	Gatton	-27.33	152.17	0.96	Hot
Queensland	Gayndah	-25.38	151.36	1.00	Hot
Queensland	Georgetown	-18.18	143.32	1.29	Hot
Queensland	Girard SF	-28.54	152.18	0.68	Cool
Queensland	Gladstone	-23.51	151.15	1.09	Hot
Queensland	Goondiwindi	-28.33	150.19	0.95	Hot
Queensland	Gympie	-26.11	152.40	0.98	Hot
Queensland	Hayman Island	-20.03	148.54	1.24	Hot
Queensland	Herberton	-17.24	145.28	0.96	Hot
Queensland	Heron Island	-23.26	151.55	1.17	Hot
Queensland	Hughendon	-20.51	144.12	1.21	Hot
Queensland	Imbil Forest	-26.28	152.40	0.98	Hot
Queensland	Injune	-25.51	148.33	0.93	Hot
Queensland	Innisfail	-17.32	146.02	1.17	Hot
Queensland	Ipswich	-27.37	152.46	0.99	Hot
Queensland	Iron Range Aero	-12.47	143.18	1.28	Hot
Queensland	Isisford PO	-24.15	144.26	1.15	Hot
Queensland	Julia Creek PO	-20.40	141.45	1.30	Hot
Queensland	Kalpower Res	-24.42	151.18	0.89	Warm
Queensland	Killarney	-28.20	152.18	0.76	Warm
Queensland	Kingaroy	-26.32	151.50	0.82	Warm
Queensland	Kingaroy PO	-26.32	151.32	0.84	Warm
Queensland	Lady Elliot Is	-24.07	152.43	1.15	Hot
Queensland	Longreach	-23.27	144.15	1.16	Hot
Queensland	Low Isles	-16.23	145.34	1.33	Hot
Queensland	Mackay Sugar	-21.10	149.13	1.08	Hot
Queensland	Mapoon	-11.58	141.54	1.44	Hot
Queensland	Mareeba	-17.01	145.25	1.13	Hot
Queensland	Maryborough	-25.32	152.42	1.04	Hot
Queensland	Mein	-13.15	142.50	1.32	Hot
Queensland	Miles	-26.40	150.11	0.94	Hot
Queensland	Millaroo	-20.03	147.17	1.18	Hot
Queensland	Mitchell	-26.29	147.58	0.93	Hot
Queensland	Mitchell River Miss	-15.28	141.45	1.38	Hot
Queensland	Monto PO	-24.51	151.01	0.96	Hot
Queensland	Moreton	-12.27	142.38	1.31	Hot
Queensland	Mornington Island	-16.42	139.12	1.44	Hot
Queensland	Mt Isa PO	-20.44	139.28	1.29	Hot
Queensland	Mt Morgan	-23.39	150.23	1.04	Hot
Queensland	Mt Surprise	-18.09	144.19	1.17	Hot
Queensland	Mungindi PO	-28.59	149.00	0.97	Hot
Queensland	Musgrave	-14.47	143.30	1.30	Hot
Queensland	Nanango	-26.40	152.00	0.82	Warm
Queensland	Normanton	-17.40	141.05	1.40	Hot
Queensland	Ormiston Redland	-27.35	153.16	0.95	Hot
Queensland	Palmerville	-16.00	144.05	1.32	Hot
Queensland	Palmerville	-15.49	144.05	1.30	Hot
Queensland	Pine Islet	-21.39	150.13	1.19	Hot

State / Territory	Locality	Latitude	Longitude	K value	Climate
Queensland	Pineapple Rsh St	-26.38	152.56	0.93	Hot
Queensland	Pittsworth	-27.43	151.39	0.84	Warm
Queensland	Pomona (Como)	-26.12	152.55	0.97	Hot
Queensland	Port Douglas	-16.29	145.28	1.22	Hot
Queensland	Proserpine PO	-20.24	148.35	1.17	Hot
Queensland	Quilpie	-26.37	144.16	1.11	Hot
Queensland	Richmond	-20.43	143.08	1.26	Hot
Queensland	Rockhampton	-23.23	150.30	1.14	Hot
Queensland	Roma	-26.35	148.48	0.98	Hot
Queensland	Roseberry SF	-28.29	152.55	0.89	Warm
Queensland	Samford (CSIRO)	-27.22	152.53	0.91	Hot
Queensland	Sandgate	-27.20	153.05	0.97	Hot
Queensland	Sandy Cape	-24.50	153.17	1.11	Hot
Queensland	Sandy Cape	-24.44	153.13	1.09	Hot
Queensland	Somerset Dam	-27.06	152.35	0.95	Hot
Queensland	Southport	-27.57	153.27	0.97	Hot
Queensland	Springsure	-24.07	148.05	1.06	Hot
Queensland	St George	-28.02	143.35	0.99	Hot
Queensland	St George PO	-28.02	148.35	1.01	Hot
Queensland	St Lawrence	-22.21	149.31	0.96	Hot
Queensland	Stanthorpe	-28.40	151.57	0.69	Cool
Queensland	Surat	-27.10	149.04	0.98	Hot
Queensland	Tambo	-24.53	146.15	1.02	Hot
Queensland	Tamborine	-27.53	153.08	0.81	Warm
Queensland	Taroom PO	-25.39	149.48	1.00	Hot
Queensland	Tewantin PO	-26.23	153.02	1.01	Hot
Queensland	Texas PO	-28.51	151.11	0.87	Warm
Queensland	Thargomindah	-28.00	143.49	1.07	Hot
Queensland	Theodore lwsc	-24.57	150.04	1.05	Hot
Queensland	Thursday Island	-10.35	142.13	1.39	Hot
Queensland	Toorak Field Stn	-21.02	141.48	1.24	Hot
Queensland	Toowoomba	-27.33	151.58	0.79	Warm
Queensland	Townsville	-19.14	146.51	1.24	Hot
Queensland	Twin Hills	-21.57	146.59	1.16	Hot
Queensland	Urandangie	-21.37	138.19	1.24	Hot
Queensland	Urbenville SF	-28.28	152.33	0.79	Warm
Queensland	Wallangarra PO	-28.55	151.56	0.64	Cool
Queensland	Warwick	-28.14	152.00	0.82	Warm
Queensland	Westwood	-23.37	150.10	1.02	Hot
Queensland	Willis Island	-16.18	150.00	1.32	Hot
Queensland	Windorah	-25.26	142.39	1.15	Hot
Queensland	Winton	-22.24	143.02	1.24	Hot
Queensland	Yeppoon	-23.06	150.42	1.07	Hot
Queensland	Yuleba	-26.37	149.23	0.95	Hot
South Australia	Adelaide	-34.56	138.36	0.80	Warm
South Australia	Angorichina	-31.05	138.45	0.83	Warm
South Australia	Berri	-34.17	140.36	0.77	Warm
South Australia	Bundaleer Forest	-33.17	138.35	0.66	Cool
South Australia	Cape Borda	-35.45	136.35	0.64	Cool
South Australia	Cape De Couedie	-36.04	136.42	0.64	Cool
South Australia	Cape Northumberland	-38.04	140.40	0.59	Cool
South Australia	Cape Willoughby	-35.51	138.07	0.66	Cool
South Australia	Ceduna	-32.08	133.40	0.77	Warm
South Australia	Clare	-33.50	138.37	0.66	Cool
South Australia	Cleve PO	-33.42	136.30	0.76	Warm
South Australia	Coober Pedy	-29.01	134.45	1.00	Hot
South Australia	Cook PO	-30.37	130.25	0.86	Warm
South Australia	Elliston	-33.39	134.53	0.75	Warm
South Australia	Ernabella	-26.17	132.08	0.95	Hot
South Australia	Euduna	-34.11	139.05	0.66	Cool

State / Territory	Locality	Latitude	Longitude	K value	Climate
South Australia	Farina	-30.04	138.17	0.94	Hot
South Australia	Fowlers Bay	-31.59	132.34	0.78	Warm
South Australia	Georgetown PO	-33.22	138.24	0.73	Warm
South Australia	Hawker PO	-31.53	138.25	0.82	Warm
South Australia	Kadina	-33.58	137.43	0.77	Warm
South Australia	Kapunda PO	-34.21	138.55	0.71	Warm
South Australia	Keith	-36.06	140.21	0.70	Warm
South Australia	Kimba PO	-33.09	136.25	0.76	Warm
South Australia	Kingscote	-35.40	137.38	0.67	Cool
South Australia	Kyancutta	-33.08	135.34	0.79	Warm
South Australia	Kybybolite	-36.54	141.00	0.59	Cool
South Australia	Lameroo PO	-35.20	140.31	0.70	Warm
South Australia	Leigh Creek	-30.28	138.26	0.93	Hot
South Australia	Loxton	-34.27	140.34	0.74	Warm
South Australia	Lucindale PO	-36.59	140.22	0.65	Cool
South Australia	Maitland PO	-34.23	137.40	0.72	Warm
South Australia	Maralinga	-30.09	131.35	0.89	Warm
South Australia	Marree	-29.39	138.04	0.97	Hot
South Australia	Meningie	-35.23	138.58	0.68	Cool
South Australia	Minnipa Seed Farm	-32.50	135.10	0.80	Warm
South Australia	Mount Gambier	-37.50	140.46	0.59	Cool
South Australia	Mt Barker	-35.04	138.52	0.59	Cool
South Australia	Mt Burr Forest	-37.33	140.26	0.59	Cool
South Australia	Mt Crawford For	-34.43	138.57	0.56	Cool
South Australia	Murray Bridge	-35.07	139.17	0.73	Warm
South Australia	Myponga	-35.24	138.28	0.58	Cool
South Australia	Naracoorte PO	-36.58	140.44	0.63	Cool
South Australia	Neptune Island	-35.21	136.07	0.71	Warm
South Australia	Nonning	-32.31	136.30	0.80	Warm
South Australia	Nuriootpa Viticu	-34.29	139.01	0.65	Cool
South Australia	Oodnadatta	-27.33	135.28	1.06	Hot
South Australia	Parafield Plant	-34.46	138.38	0.76	Warm
South Australia	Parndana East	-35.47	137.21	0.61	Cool
South Australia	Port Augusta	-32.30	137.46	0.90	Hot
South Australia	Port Augusta Stn	-33.32	137.46	0.90	Hot
South Australia	Port Lincoln	-34.44	135.52	0.73	Warm
South Australia	Port Pirie	-33.11	138.00	0.87	Warm
South Australia	Price	-34.18	138.00	0.76	Warm
South Australia	Renmark PO	-34.11	140.45	0.82	Warm
South Australia	Rennick	-37.50	140.59	0.57	Cool
South Australia	Robe	-37.11	139.45	0.62	Cool
South Australia	Roseworthy	-34.32	138.44	0.75	Warm
South Australia	Serviceton	-36.22	140.59	0.63	Cool
South Australia	Snowtown PO	-33.47	138.13	0.75	Warm
South Australia	Stirling West	-35.00	138.43	0.55	Cool
South Australia	Strathalbyn	-35.16	138.54	0.68	Cool
South Australia	Streaky Bay	-32.48	134.13	0.81	Warm
South Australia	Tailem Bend	-35.16	139.27	0.74	Warm
South Australia	Tarcoola	-30.41	134.33	0.88	Warm
South Australia	Turretfield Res	-34.33	138.50	0.72	Warm
South Australia	Victor Harbour	-35.33	138.37	0.71	Warm
South Australia	Waikerie (Lands)	-34.11	139.59	0.80	Warm
South Australia	Wanbi	-34.46	140.18	0.71	Warm
South Australia	Warooka PO	-34.59	137.25	0.73	Warm
South Australia	Whyalla PO	-33.02	137.35	0.85	Warm
South Australia	Woomera	-31.12	136.48	0.89	Warm
South Australia	Yongala	-33.02	138.45	0.65	Cool
South Australia	Yudjapinna	-32.08	137.09	0.87	Warm
South Australia	Yunta PO	-32.35	139.34	0.76	Warm

State / Territory	Locality	Latitude	Longitude	K value	Climate
Tasmania	Bicheno	-41.53	148.18	0.57	Cool
Tasmania	Bothwell	-42.23	147.01	0.40	Cool
Tasmania	Bridport PO	-41.00	147.24	0.55	Cool
Tasmania	Bronte Park	-42.08	146.30	0.33	Cool
Tasmania	Burnie	-41.06	145.54	0.52	Cool
Tasmania	Bushy Park	-42.42	147.02	0.49	Cool
Tasmania	Bushy Park (Hops)	-42.43	146.53	0.47	Cool
Tasmania	Butlers Gorge	-42.17	146.16	0.31	Cool
Tasmania	Cape Bruni	-43.29	147.08	0.45	Cool
Tasmania	Cape Sorell	-42.12	145.10	0.49	Cool
Tasmania	Cradle Valley	-41.38	145.57	0.27	Cool
Tasmania	Cressy Research	-41.43	147.05	0.46	Cool
Tasmania	Currie	-39.56	143.50	0.54	Cool
Tasmania	Deloraine	-41.32	146.40	0.40	Cool
Tasmania	Devonport East	-41.11	146.22	0.51	Cool
Tasmania	Eddystone Point	-41.00	148.21	0.56	Cool
Tasmania	Erriba	-41.27	146.07	0.33	Cool
Tasmania	Grove Research	-42.59	147.06	0.45	Cool
Tasmania	Hastings Chalet	-43.25	146.53	0.43	Cool
Tasmania	Hobart	-42.55	147.20	0.51	Cool
Tasmania	Hobart Airport	-42.50	147.32	0.51	Cool
Tasmania	Hythe	-43.25	146.04	0.44	Cool
Tasmania	Lake St Clair	-42.06	146.13	0.31	Cool
Tasmania	Launceston	-41.25	147.08	0.54	Cool
Tasmania	Launceston Aero	-41.33	147.13	0.47	Cool
Tasmania	Low Head	-41.04	146.48	0.51	Cool
Tasmania	Maatsuyker Is	-43.41	146.17	0.42	Cool
Tasmania	Maydena	-42.46	146.36	0.40	Cool
Tasmania	Miena	-41.59	146.44	0.25	Cool
Tasmania	Oatlands	-42.18	147.22	0.41	Cool
Tasmania	Orford PO	-42.34	147.52	0.52	Cool
Tasmania	Pats River	-40.06	148.01	0.56	Cool
Tasmania	Port Davey	-43.20	145.57	0.45	Cool
Tasmania	Redpa	-40.56	144.45	0.48	Cool
Tasmania	Risdon	-42.48	147.20	0.52	Cool
Tasmania	Ross (Ellinthorp)	-42.00	147.19	0.45	Cool
Tasmania	Rossarden	-41.39	147.44	0.38	Cool
Tasmania	Scottsdale (Kraft)	-41.09	147.31	0.48	Cool
Tasmania	Sheffield	-41.23	146.20	0.42	Cool
Tasmania	Smithton PO	-40.51	145.08	0.51	Cool
Tasmania	St Helens	-41.20	148.15	0.53	Cool
Tasmania	Stanley	-40.46	145.18	0.52	Cool
Tasmania	Swansea	-42.08	148.04	0.52	Cool
Tasmania	Tasman Island	-43.15	148.00	0.41	Cool
Tasmania	Tewkesbury Res	-41.14	145.42	0.38	Cool
Tasmania	Waratah	-41.27	145.32	0.30	Cool
Tasmania	Wynyard Aeradio	-41.00	145.42	0.46	Cool
Tasmania	Zeehan PO	-41.53	145.20	0.41	Cool
Victoria	Aberfeldy	-37.42	146.22	0.36	Cool
Victoria	Alexandra PO	-37.12	145.43	0.58	Cool
Victoria	Ararat	-37.17	142.56	0.58	Cool
Victoria	Aspendale (CSIRO)	-38.02	145.06	0.63	Cool
Victoria	Avoca	-37.05	143.29	0.60	Cool
Victoria	Bairnsdale	-37.50	147.38	0.59	Cool
Victoria	Ballan (Fiskville)	-37.36	144.12	0.50	Cool
Victoria	Ballarat	-37.33	143.52	0.51	Cool
Victoria	Beechworth	-36.22	146.43	0.78	Warm
Victoria	Benalla	-36.33	145.59	0.67	Cool
Victoria	Bendigo	-36.46	144.16	0.66	Cool
Victoria	Beulah PO	-35.57	142.25	0.70	Warm

State / Territory	Locality	Latitude	Longitude	K value	Climate
Victoria	Birchip PO	-35.59	142.54	0.70	Warm
Victoria	Bogong	-36.48	147.14	0.50	Cool
Victoria	Boort	-36.06	143.42	0.71	Warm
Victoria	Brighton East	-37.56	145.01	0.65	Cool
Victoria	Camperdown	-38.14	143.10	0.59	Cool
Victoria	Cann River Forest	-37.34	149.09	0.62	Cool
Victoria	Cape Otway	-38.51	143.31	0.57	Cool
Victoria	Cape Schanck	-38.30	144.53	0.59	Cool
Victoria	Casterton (Clim)	-37.35	141.24	0.61	Cool
Victoria	Charlton	-36.16	143.21	0.68	Cool
Victoria	Clunes	-37.18	143.47	0.54	Cool
Victoria	Clunes PO	-37.24	143.48	0.54	Cool
Victoria	Colac	-38.20	143.35	0.57	Cool
Victoria	Corryong Forest	-36.12	147.54	0.61	Cool
Victoria	Creswick For Sch	-37.25	143.54	0.53	Cool
Victoria	Dookie	-36.20	145.42	0.71	Warm
Victoria	Durridwarrah	-37.49	144.13	0.53	Cool
Victoria	Echuca	-36.08	144.45	0.72	Warm
Victoria	Erica State Forest	-38.00	146.24	0.53	Cool
Victoria	Essendon Airport	-37.44	144.54	0.62	Cool
Victoria	Euroa	-36.46	145.33	0.67	Cool
Victoria	Forrest SF	-38.32	143.43	0.52	Cool
Victoria	Gabo Island	-37.34	149.55	0.66	Cool
Victoria	Geelong	-38.09	144.21	0.63	Cool
Victoria	Gellibrand For	-38.32	143.32	0.52	Cool
Victoria	Hamilton	-37.45	142.02	0.55	Cool
Victoria	Heathcote PO	-36.56	144.42	0.61	Cool
Victoria	Heywood For Off	-38.08	141.38	0.57	Cool
Victoria	Horsham	-36.43	142.12	0.67	Cool
Victoria	Jeparit PO	-36.08	141.59	0.71	Warm
Victoria	Kerang	-35.42	143.54	0.73	Warm
Victoria	Kyabram	-36.19	145.03	0.64	Cool
Victoria	Kyneton PO	-37.15	144.27	0.49	Cool
Victoria	Lake Eildon	-37.14	145.55	0.61	Cool
Victoria	Leongatha	-38.29	145.57	0.59	Cool
Victoria	Lismore PO	-37.58	143.21	0.59	Cool
Victoria	Longerenong	-36.42	142.18	0.64	Cool
Victoria	Macedon State Nr	-37.25	144.34	0.48	Cool
Victoria	Maffra	-37.58	146.59	0.61	Cool
Victoria	Maldon	-37.00	144.06	0.60	Cool
Victoria	Mangalore Aero	-36.54	145.10	0.64	Cool
Victoria	Maryborough	-37.03	143.44	0.63	Cool
Victoria	Melbourne	-37.50	145.00	0.66	Cool
Victoria	Mildura	-34.12	142.09	0.81	Warm
Victoria	Mitta Mitta	-36.32	147.22	0.59	Cool
Victoria	Mornington	-38.12	145.00	0.66	Cool
Victoria	Mount Eliza	-38.12	145.06	0.66	Cool
Victoria	Mt Buffalo	-36.47	146.46	0.35	Cool
Victoria	Mt St Leonard	-37.36	145.30	0.48	Cool
Victoria	Myrtleford	-36.33	146.44	0.62	Cool
Victoria	Nhill	-36.21	141.39	0.65	Cool
Victoria	Numurkah	-36.06	145.24	0.72	Warm
Victoria	Olsons Bridge	-38.29	146.19	0.48	Cool
Victoria	Omeo	-37.06	147.36	0.47	Cool
Victoria	Omeo	-37.06	147.86	0.48	Cool
Victoria	Orbost	-37.42	148.27	0.60	Cool
Victoria	Ouyen	-35.06	142.18	0.76	Warm
Victoria	Portland	-38.21	141.36	0.59	Cool
Victoria	Portsea Quarantine	-38.19	144.42	0.61	Cool
Victoria	Powelltown	-37.52	145.45	0.56	Cool

State / Territory	Locality	Latitude	Longitude	K value	Climate
Victoria	Rainbow PO	-35.54	142.00	0.72	Warm
Victoria	Rochester	-36.21	144.42	0.69	Cool
Victoria	Rubicon Sec	-37.20	145.52	0.47	Cool
Victoria	Rutherglen	-36.03	146.28	0.66	Cool
Victoria	Rutherglen Exp F	-36.06	146.36	0.64	Cool
Victoria	Sale	-38.06	147.04	0.62	Cool
Victoria	Scoresby	-37.52	145.14	0.62	Cool
Victoria	Seymour	-37.02	145.08	0.65	Cool
Victoria	Shepparton	-36.23	145.24	0.70	Warm
Victoria	St Arnaud	-36.37	143.16	0.64	Cool
Victoria	Stawell	-37.06	142.48	0.65	Cool
Victoria	Swan Hill	-35.21	143.34	0.75	Warm
Victoria	Tanjil Bren	-37.48	146.12	0.44	Cool
Victoria	Tatura Res Stn	-36.26	145.16	0.65	Cool
Victoria	Terang	-38.12	142.54	0.57	Cool
Victoria	Tidal River	-39.02	146.19	0.60	Cool
Victoria	Tooradin	-38.12	145.24	0.58	Cool
Victoria	Wail	-36.31	142.10	0.66	Cool
Victoria	Walpeup	-35.08	142.02	0.73	Warm
Victoria	Wangaratta	-36.21	146.19	0.68	Cool
Victoria	Warragul PO	-38.10	145.56	0.60	Cool
Victoria	Warrnambool	-38.23	142.29	0.57	Cool
Victoria	Watsonia (Loyola)	-37.42	145.05	0.63	Cool
Victoria	Werribee	-37.54	144.40	0.62	Cool
Victoria	Wilsons Prom	-39.01	146.28	0.58	Cool
Victoria	Wilsons Promont	-39.08	146.25	0.58	Cool
Victoria	Woods Point	-37.35	146.15	0.43	Cool
Victoria	Woohlpooer	-37.20	142.09	0.57	Cool
Victoria	Yallourn Sec	-38.11	146.22	0.58	Cool
Victoria	Yarrawonga	-36.01	146.01	0.73	Warm
Western Australia	Albany	-35.02	117.52	0.70	Warm
Western Australia	Anna Plains	-19.11	121.37	1.35	Hot
Western Australia	Balladonia	-32.28	123.52	0.78	Warm
Western Australia	Bencubbin	-30.48	117.51	0.86	Warm
Western Australia	Beverley	-32.06	116.54	0.81	Warm
Western Australia	Booylgoo	-27.45	119.55	0.99	Hot
Western Australia	Boyup Brook PO	-33.50	116.23	0.69	Cool
Western Australia	Bridgetown	-33.57	116.07	0.67	Cool
Western Australia	Brookton PO	-32.22	117.01	0.76	Warm
Western Australia	Broome	-17.57	122.14	1.37	Hot
Western Australia	Bunbury	-33.20	115.38	0.78	Warm
Western Australia	Busselton	-33.39	115.21	0.76	Warm
Western Australia	Camballin	-17.58	124.06	1.48	Hot
Western Australia	Cape Leeuwin	-34.22	115.08	0.78	Warm
Western Australia	Cape Leveque	-16.24	122.55	1.38	Hot
Western Australia	Cape Naturaliste	-33.32	115.01	0.76	Warm
Western Australia	Carnamah	-29.50	115.53	0.92	Hot
Western Australia	Carnamah	-29.41	115.53	0.93	Hot
Western Australia	Carnarvon	-24.52	113.38	1.08	Hot
Western Australia	Cashmere Downs	-28.57	119.35	1.01	Hot
Western Australia	Chapman Res Stn	-28.28	114.46	0.94	Hot
Western Australia	Collie	-33.22	116.09	0.69	Cool
Western Australia	Coolgardie	-30.57	121.10	0.85	Warm
Western Australia	Corrigin PO	-32.20	117.52	0.77	Warm
Western Australia	Cossack	-20.50	117.12	1.34	Hot
Western Australia	Cue	-27.25	117.54	1.06	Hot
Western Australia	Cunderdin	-31.39	117.14	0.85	Warm
Western Australia	Dallwallinu	-30.17	116.39	0.90	Hot
Western Australia	Denmark Res Stn	-34.56	117.20	0.67	Cool
Western Australia	Derby	-17.18	123.38	1.44	Hot

State / Territory	Locality	Latitude	Longitude	K value	Climate
Western Australia	Donnybrook	-33.44	115.49	0.73	Warm
Western Australia	Donnybrook PO	-33.34	115.49	0.76	Warm
Western Australia	Dwellingup	-32.44	116.04	0.67	Cool
Western Australia	Eclipse Is	-35.11	117.53	0.69	Cool
Western Australia	Errabiddy	-25.27	117.11	1.18	Hot
Western Australia	Esperance	-33.51	121.53	0.75	Warm
Western Australia	Esperance Downs	-33.36	121.48	0.73	Warm
Western Australia	Eucla	-31.43	128.52	0.81	Warm
Western Australia	Fitzroy Crossing	-18.11	125.35	1.44	Hot
Western Australia	Forrest	-30.52	128.06	0.81	Warm
Western Australia	Gascoyne Junction	-25.03	115.13	1.21	Hot
Western Australia	Geraldton	-28.46	114.36	0.96	Hot
Western Australia	Geraldton Met	-28.48	114.42	0.94	Hot
Western Australia	Giles	-25.02	128.18	1.12	Hot
Western Australia	Goomaling PO	-31.18	116.49	0.84	Warm
Western Australia	Halls Creek	-18.16	127.46	1.31	Hot
Western Australia	Halls Creek	-18.14	127.40	1.39	Hot
Western Australia	Hamelin Pool	-26.26	114.11	1.07	Hot
Western Australia	Hyden PO	-32.27	118.52	0.77	Warm
Western Australia	Kalamunda PO	-32.00	116.04	0.78	Warm
Western Australia	Kalgoolie	-30.45	121.28	0.89	Warm
Western Australia	Kalumburu	-14.18	126.38	1.40	Hot
Western Australia	Karridale	-34.13	115.05	0.69	Cool
Western Australia	Katanning	-33.42	117.33	0.71	Warm
Western Australia	Kellerberrin	-31.38	117.43	0.84	Warm
Western Australia	Kimberley Res Stn	-15.47	128.42	1.44	Hot
Western Australia	Kojonup PO	-33.50	117.09	0.67	Cool
Western Australia	Kondinin PO	-32.30	118.16	0.79	Warm
Western Australia	La Grange Mission	-18.41	121.46	1.38	Hot
Western Australia	Lake Grace	-33.07	118.28	0.76	Warm
Western Australia	Laverton	-28.38	122.25	0.98	Hot
Western Australia	Leonora	-28.53	121.19	1.03	Hot
Western Australia	Madura Motel	-31.54	127.00	0.86	Warm
Western Australia	Mandora Homestead	-19.45	120.51	1.37	Hot
Western Australia	Mandurah	-32.32	115.43	0.84	Warm
Western Australia	Manjimup	-34.14	116.09	0.63	Cool
Western Australia	Marble Bar	-21.11	119.44	1.47	Hot
Western Australia	Mardie	-21.12	115.57	1.33	Hot
Western Australia	Margaret River	-33.57	115.04	0.72	Warm
Western Australia	Meekatharra	-26.36	118.29	1.09	Hot
Western Australia	Menzies	-29.41	121.02	0.92	Hot
Western Australia	Merredin Agr Rs	-31.29	118.17	0.83	Warm
Western Australia	Merredin Shire	-31.29	118.11	0.82	Warm
Western Australia	Mingenew	-29.11	115.26	0.97	Hot
Western Australia	Moora Shire Council	-30.38	116.00	0.85	Warm
Western Australia	Morawa PO	-29.13	116.00	0.95	Hot
Western Australia	Mount Barker	-34.38	117.40	0.63	Cool
Western Australia	Mt Magnet	-28.04	117.51	1.06	Hot
Western Australia	Mullewa	-28.33	115.30	1.00	Hot
Western Australia	Mundiwindi	-23.50	120.10	1.13	Hot
Western Australia	Mundrabilla	-31.51	127.51	0.86	Warm
Western Australia	Muresk	-31.45	116.40	0.81	Warm
Western Australia	Murgoo	-27.22	116.26	1.05	Hot
Western Australia	Narembreen	-32.06	118.24	0.81	Warm
Western Australia	Narrogin	-32.56	117.10	0.71	Warm
Western Australia	Norseman PO	-32.12	121.47	0.81	Warm
Western Australia	Nullagine	-21.53	120.06	1.25	Hot
Western Australia	Nyang Wogoola	-23.00	115.00	1.36	Hot
Western Australia	Ongerup PO	-33.58	118.28	0.69	Cool
Western Australia	Onslow Aero	-21.40	115.07	1.29	Hot

State / Territory	Locality	Latitude	Longitude	K value	Climate
Western Australia	Peak Hill	-25.48	118.43	1.12	Hot
Western Australia	Pearce Aerodrome	-31.40	116.00	0.87	Warm
Western Australia	Pemberton Forest	-34.27	116.01	0.67	Cool
Western Australia	Perth	-31.59	115.50	0.85	Warm
Western Australia	Perth Guildford	-31.55	115.58	0.85	Warm
Western Australia	Perth Regional	-31.57	115.51	0.88	Warm
Western Australia	Pingelly	-32.32	117.05	0.75	Warm
Western Australia	Port George IV	-15.25	124.43	1.35	Hot
Western Australia	Port Hedland	-20.23	118.37	1.35	Hot
Western Australia	Port Hedland	-20.19	118.03	1.34	Hot
Western Australia	Ravensthorpe	-33.35	120.03	0.75	Warm
Western Australia	Rawlinna	-31.00	125.15	0.84	Warm
Western Australia	Rottne Island	-32.00	115.30	0.87	Warm
Western Australia	Salmon Gums Res	-32.59	121.39	0.74	Warm
Western Australia	Sandstone	-27.59	119.17	0.98	Hot
Western Australia	Southern Cross	-31.13	119.19	0.84	Warm
Western Australia	Swan Upper	-31.45	116.06	0.84	Warm
Western Australia	Three Rivers	-25.08	119.10	1.12	Hot
Western Australia	Troughton Island	-13.45	126.09	1.45	Hot
Western Australia	Turkey Creek	-17.02	128.12	1.46	Hot
Western Australia	Flaming Head	-21.48	114.06	1.21	Hot
Western Australia	Wagin PO	-33.18	117.20	0.73	Warm
Western Australia	Wandering	-32.40	116.41	0.71	Warm
Western Australia	Watheroo	-30.17	116.04	0.82	Warm
Western Australia	Wiluna	-26.36	120.13	1.05	Hot
Western Australia	Winning Pool	-23.09	114.01	1.26	Hot
Western Australia	Wittenoom Gorge	-22.18	118.18	1.36	Hot
Western Australia	Wokalup	-33.08	115.53	0.80	Warm
Western Australia	Wongan Hills RF	-30.53	116.43	0.83	Warm
Western Australia	Wyalkatchem	-31.12	117.24	0.85	Warm
Western Australia	Wyndham	-15.28	128.06	1.54	Hot
Western Australia	Yalgoo	-28.20	116.41	1.02	Hot
Western Australia	Yampi Sound	-16.06	123.36	1.45	Hot
Western Australia	York PO	-31.53	116.46	0.83	Warm

Appendix C – Details of standard diets A - D

Table 16. Percentages of ingredients (% as-fed) for standard sucker, weaner and porker diets A to D.

Ingredient	Sucker	Weaner				Porker			
	Diets A-D	Diet A	Diet B	Diet C	Diet D	Diet A	Diet B	Diet C	Diet D
Cereal Grains									
Barley 11					40.00				40.00%
Sorghum 10			49.90	10.00			49.90%	10.00%	
Wheat 13.5	5.0410	80.63	23.50	53.07	22.62	80.63%	23.50%	53.07%	22.62%
Wheat Extruded	1.5000								
Legumes									
Mung Beans				10.00	20.00			10.00%	20.00%
Oilseed Meals									
Canola Meal		10.00	10.00	10.00	8.10	10.00%	10.00%	10.00%	8.10%
Soybean Meal 48	0.2850	1.10	6.50	11.20	1.00	1.10%	6.50%	11.20%	1.00%
Soya protein (HP 300)	0.1250								
Yeast Products									
Nupro	0.3500								
Animal & Fish products									
Blood meal, spray/ring	0.3000	2.60	2.80		0.10	2.60%	2.80%		0.10%
Fishmeal 62	0.7500								
Meat & bone meal	0.1750	2.90	3.90	0.00	2.80	2.90%	3.90%		2.80%
Milk, chocolate milk powder	0.5000								
Milk, whey powder	0.5000								
Fats									
Tallow									
Vegetable oil	0.3000	0.90	1.80	2.60	3.40	0.90%	1.80%	2.60%	3.40%
Minerals									
Choline Chloride	0.0025								
Dicalphos				1.21				1.21%	
Limestone		1.00	0.71	1.00	1.00	1.00%	0.71%	1.00%	1.00%
Salt	0.0100	0.20	0.20	0.20	0.20	0.20%	0.20%	0.20%	0.20%
Zinc Oxide	0.0300								
Synthetic amino acids									
L-Lysine HCL	0.0265	0.36	0.36	0.36	0.36	0.36%	0.36%	0.36%	0.36%
DL-Methionie	0.0005	0.05	0.07	0.07	0.09	0.05%	0.07%	0.07%	0.09%
L-Threonine	0.0045	0.05	0.05	0.08	0.12	0.05%	0.05%	0.08%	0.12%
Vitamin/mineral premixes									
Breeder premix									
Grower premix		0.20	0.20	0.20	0.20	0.20%	0.20%	0.20%	0.20%
Weaner premix	0.0350								
Enzymes									
Phyzyme (500 FTU OR 100g dose)		0.01	0.01	0.01	0.01	0.01%	0.01%	0.01%	0.01%
Toxin Binders									
Biofix	0.0200								
Acidifiers									
Biotronic SE (Biomim)	0.0300								
Other Additives									
Betaine (Betafin)	0.0150								
Additional ingredients									
Sow milk	90.0000								
Totals:	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 17. Percentages of ingredients (% as-fed) for standard grower and finisher diets A to D.

Ingredient	Grower				Finisher			
	Diet A	Diet B	Diet C	Diet D	Diet A	Diet B	Diet C	Diet D
Cereal Grains								
Barley 11	10.00	10.00	10.00	45.00	15.00	21.30	26.60	46.42
Sorghum 10		55.00	10.00			53.00	10.00	0.00
Wheat 13.5	76.87	16.45	51.75	24.87	70.58	10.00	43.11	27.90
Legumes								
Mung Beans			10.00	20.00			10.00	20.00
Oilseed Meals								
Canola Meal	3.40	8.20	10.00	0.50	9.80	10.00	7.20	0.00
Soybean Meal 48	2.00	2.00	4.20	2.00	0.00	0.00	0.00	0.00
Animal & Fish products								
Blood meal, spray/ring	2.30	2.30		0.00	0.50	1.40		0.50
Meat & bone meal	3.30	4.20	0.00	3.30	1.70	1.90	0.00	3.30
Fats								
Tallow				0.20				
Vegetable oil	0.20	0.30	1.10	2.00	0.00	0.00	0.00	0.00
Minerals								
Choline Chloride	0.02	0.00		0.07			0.01	0.08
Dicalphos			0.64		0.59	0.53	0.72	
Limestone	1.00	0.68	1.42	1.00	1.00	1.00	1.45	1.00
Salt	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Synthetic amino acids								
L-Lysine HCL	0.35	0.35	0.35	0.34	0.35	0.35	0.35	0.18
DL-Methionie	0.06	0.05	0.05	0.16	0.01	0.05	0.05	0.13
L-Threonine	0.09	0.06	0.08	0.15	0.06	0.06	0.10	0.08
Vitamin/mineral premixes								
Grower premix	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Enzymes								
Phyzyme (500 FTU OR 100g dose)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Totals:	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 18. Percentages of ingredients (% as-fed) for standard lactating sow, dry (gestating) sow and gilt diets A to D. (Boar diet is the same as for gestating sows).

Diet Ingredient	Lactating sow				Dry sow				Gilts			
	Diet A	Diet B	Diet C	Diet D	Diet A	Diet B	Diet C	Diet D	Diet A	Diet B	Diet C	Diet D
Cereal Grains												
Barley 11	21.65	17.60	16.25	45.00	50.00	29.70	30.00	50.00	50.00	30.12	25.00	50.00
Sorghum 10		20.00	10.00			52.92	10.00			55.00	10.00	
Wheat 13.5	62.81	45.40	50.59	24.93	39.77		39.50	24.55	40.68		39.51	21.97
Legumes												
Mung Beans			10.00	20.00			10.00	20.00			10.00	20.00
Oilseed Meals												
Canola Meal	3.65	5.45	4.55		4.05	12.00	5.20		3.10	9.70	9.65	2.65
Soybean Meal 48	1.00	1.00	1.00	1.00							1.00	
Animal & Fish products												
Blood meal, spray/ring	1.70	1.85										
Fishmeal 62				1.25								
Meat & bone meal	2.55	2.10		2.35	2.65	1.40		1.40	3.10	2.55		1.50
Hay & Straw												
Lucerne meal/crumbles	2.50	2.50	2.50	1.25	1.25	1.25	1.30	1.25				
Fats												
Vegetable oil	1.40	1.20	1.30	1.75					0.85	0.25	0.95	1.20
Minerals												
Choline Chloride	0.04	0.04	0.04	0.05	0.03	0.03	0.04	0.09	0.07	0.03	0.04	0.11
Dicalphos	0.19	0.36	0.72		0.23	0.66	1.50	0.80	0.15	0.42	1.50	0.76
Limestone	1.00	1.00	1.39	1.00	1.00	1.00	1.50	1.00	1.00	0.90	1.50	1.00
Salt	0.40	0.40	0.40	0.40	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Synthetic amino acids												
L-Lysine HCL	0.37	0.37	0.45	0.25	0.12	0.13	0.06		0.32	0.33	0.15	0.09
DL-Methionie			0.02	0.01					0.02			0.02
L-Threonine	0.04	0.03	0.10	0.06					0.01			
Vitamin/mineral premixes												
Breeder premix	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Enzymes												
Phyzyme (500 FTU OR 100g dose)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Toxin Binders												
Biofix	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.10	0.10	0.10	0.10
Other Additives												
Betaine (Betafin)	0.20	0.20	0.20	0.20	0.10	0.10	0.10	0.10				
Totals:	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Glossary of terms

Ash (fixed solids)	The quantity of total solids remaining after the volatile solids component of a material is driven off or burnt by heating the material to 600°C for 1 hour. The ash or fixed solids component of a material is the non-organic component which is not readily biodegradable.
Average daily gain (ADG)	The total weight gain of the pig divided by the number of days that the weight gain was measured over, generally expressed in with the units g. day ⁻¹ . In PigBal 4, this term is used to refer to live weight gain (rather than dressed weight gain), measured over the period from birth to the time when the pig grows to a live weight of 100 kg. ADG is often expressed as an average for a group of pigs.
Backfatter	Culled breeding pig sold for meat; usually refers specifically to a culled sow, but is sometimes used in reference to boars.
Baconer pig	Pigs within a variable weight-range (typically 65 - 80kg dressed weight, 85 – 105 kg live weight) which are sold for meat to serve the requirements of a particular market desiring heavier pigs.
Boar	Male pig over 6 months of age selected for use in the breeding herd, from either the grower herd or elsewhere.
Breeder piggery	A unit where breeding stock are kept, along with sucker pigs, which are raised to weaner weight prior to transfer off-site to a grower piggery.
Conventional piggery	These typically house pigs within steel or timber framed sheds with corrugated iron or sandwich panel roofing and walls made from preformed concrete panels, concrete blocks, corrugated iron or sandwich panel (or some combination of these), sometimes with shutters or nylon curtains depending on the ventilation system. A fully environmentally controlled shed has enclosed walls with extraction fans and cooling pads providing ventilation and climate control. Conventional sheds have a concrete base, often with concrete under-floor effluent collection pits or channels. The flooring is usually partly or fully slatted, and spilt feed, water, urine and faeces fall through the slats into the underfloor channels or pits. These are regularly flushed or drained to remove effluent from the sheds. Sheds without slatted flooring usually include an open channel dunging area which is cleaned by flushing or hosing. (NEGP, Tucker <i>et al.</i> , 2010)
Creep	Highly palatable, easily digested feed offered to piglets while suckling, and for the first week post-weaning.

Deep litter piggery	A housing system in which pigs are typically accommodated within a series of hooped metal frames covered in a waterproof fabric, similar to the plastic greenhouses used in horticulture. However, skillion-roof sheds and converted conventional housing may also be used. Deep litter housing may be established on a concrete base or a compacted earth floor. Pigs are bedded on straw, sawdust, rice hulls or similar loose material that absorbs manure, eliminating the need to use water for cleaning. The used bedding is generally removed and replaced when the batch of the pigs is removed, or on a regular basis. (NEGP, Tucker <i>et al.</i> , 2010)
Desludging	Removing settled solids from the bottom of an effluent pond.
Dressed weight	The dressed weight refers to the whole body weight of a pig slaughtered in an abattoir and passed as suitable for human consumption by a meat inspector after bleeding, removal of hair, scurf, toenails, ears eyelids/lashes, tongue, kidneys and kidney fat, and evisceration of all internal, digestive, respiratory, excretory and reproductive organs.
Farrow to finish piggery	Operation in which pigs are raised on-site from birth through all subsequent growth stages, culminating in sale to market.
Farrowing	Production of a litter of one or more live or dead pigs.
Feed conversion ratio (FCR)	The total weight of air-dry feed (as-fed weight) fed to a pig or group of pigs, divided by the weight gain over a given period. In PigBal 4 the FCR generally refers to the weight of feed fed to a group of pigs, over the period from birth to the time when the pig or pigs achieve a live weight of 100 kg.
Finisher pig	A grower pig over 70 kg live weight, which is in the final production phase before sale to market at a pre-defined finishing weight (typically approximately 100kg).
Fixed solids (ash)	The quantity of total solids remaining after the volatile solids component of a material is driven off or burnt by heating the material to 600°C for 1 hour. The fixed solids or ash component of a material is the non-organic component which is not readily biodegradable.

Flushing sheds	Flushing sheds have relatively shallow concrete channels running under the slatted floors. The channels are flushed regularly (generally daily to twice weekly) to remove the manure and waste feed from the sheds into drains or sumps, prior to pre-treatment or discharge into an effluent pond. Flushing is generally carried out by rapidly releasing relatively large quantities of water (or recycled effluent) from flushing tanks located near the ends of the sheds. Alternatively, sheds may be flushed using a high-capacity pump.
Gestating sow	Impregnated sow (also referred to as a “dry” or non-lactating sow), prior to reaching the farrowing stage.
Gilt	Young female pig that has not been mated, selected for use in the breeding herd, from either the on-site grower herd or following purchase from another herd.
Grower pig	Any pig between weaning and sale or transfer to the breeding herd, sold for slaughter or killed for rations.
Grower piggery	Operation in which weaner pigs are sourced from other units (such as breeder piggeries) to be “grown out” to a pre-defined finishing weight before sale to market.
Lactating sow	A sow that has given birth to a litter of piglets, and is producing milk to feed the piglets.
Manure	Faeces plus urine.
Parity	The number of litters a sow has carried, including the current pregnancy e.g. a second parity sow is either in pig, suckling or has just weaned her second litter.
Porker pig	Market pigs between approximately 30 and 55 kg dressed weight (40 – 70 kg live weight).
Pull plug sheds	Pull plug sheds store manure, waste feed and hosing water in several concrete pits constructed beneath the slatted shed floors. The effluent is generally released by gravity, through individual pipe outlets located in the centre of each pit.
Run-down screen	A screen comprised of finely spaced stainless steel bars held on an incline by a steel frame. When effluent is poured onto the screen, the liquid and fine solids pass through, while the larger solids are retained on the screen before falling onto a solids collection vessel or bunk.

Screw press	A cylindrical screen with a screw-conveyor in the centre. The conveyor presses the solids against the screen to remove moisture. The conveyor also moves solids from one end of the press to the other, to a collection area.
Sedimentation	The process of settling entrained solids from an effluent stream through the influence of gravity. A sedimentation system may be a pond, basin or terrace that discharges to a holding pond or evaporation system.
SEPS	A Sedimentation and Evaporation Pond System (SEPS) is an effluent treatment system consisting of two or three long, narrow, shallow, trafficable earthen channels, designed to settle out solids and store effluent. Each channel is designed to receive effluent for a six to twelve month period. At the end of this time, another channel is activated and the liquid is drained or siphoned from the first channel, allowing the settled solids to dry prior to removal.
Sow	A breeding female pig that has been served; term refers to both lactating and “dry” (gestating) sows.
Static pit sheds	Static pit sheds are commonly older sheds which store manure, waste feed and hosing water in concrete pits located under the slatted floors. The effluent is generally released via a sluice gate or valve located at the end of each shed, at intervals up to several weeks.
Stillborn piglet	A piglet which is deceased at time of delivery.
Standard pig unit (SPU)	One standard pig unit (SPU) has a manure volatile solids production rate equivalent to a standard grower pig with a live weight of 40 kg.
Sucker	A pig which is in a growth stage between birth and weaning.
Total solids (TS)	The dry matter content of a compound.
Volatile solids (VS)	The quantity of total solids burnt or driven off when a material is heated to 600°C for 1 hour. Volatile solids is a measure of the biodegradable organic solids content of a material.
Weaner pig	Pig which has been removed from the lactating sow and fed a solid/semi-solid diet, up to a maximum live weight of approximately 30 kg.
Weaning	The time at which piglets are removed from the lactating sow and introduced to solid/semi-solid feed.

