ACIL ALLEN CONSULTING

REPORT TO
**AUSTRALIAN PORK LIMITED**
MARCH 2019

# APL R&D PROGRAMS COST-BENEFIT ANALYSIS

## GILT ENHANCEMENT, PHYSI-TRACE, NUTRITION AND BIOSECURITY / EXOTIC DISEASES

**FINAL REPORT**

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## Ex-post evaluation at Australian Pork Limited

Australian Pork Limited (APL) has systems in place to evaluate R&D at the time of investment (*ex-ante*) and during/after completion of R&D programs (*ex-post*). The *ex-ante* evaluation is integrated into APL's investment processes. The *ex-post* evaluation is conducted separately and use cost-benefit analysis (CBA) based on the Council of Rural RDCs Evaluation Guidelines.

In 2016 a review of APL's R&D evaluation by ACIL Allen found:

— *ex-ante* evaluation could be improved but was sufficiently fit for purpose at that time

— *ex-post* evaluation was not being conducted because CBA was perceived to add limited value.

In 2017 APL commissioned ACIL Allen to complete four new *ex-post* evaluations as part of reactivating the process of evaluating the whole R&D investment program in time. The evaluations were conducted in collaboration with R&D program managers to build greater understanding of, and support for, evaluation within the R&D program.

## Gilt enhancement R&D

ACIL Allen conducted a cost-benefit analysis of key R&D projects relating to gilt enhancement that have been funded by APL. The projects investigated the effects of gilt management, including mating age, mating weight, backfat level, structural integrity and locomotion scores of gilts, as well as other management and potential genetic strategies, on their overall performance and longevity in the breeding herd.

ACIL Allen's approach to assessing the benefits of the R&D projects was to create stylised representations of the lifecycle of a mated gilt/sow under the Base Case and under the "With APL-funded R&D" scenario. In the Base Case, the representative gilt/sow produces 3 parities before being culled. In the "With APL-funded R&D" scenario, it produces 4 parities before being culled, which would be equivalent to an increase of 1 in average parity in the herd.

The key steps in ACIL Allen's approach were:

1. Set out a timeline for a representative mated gilt/sow under the Base Case and another for a representative gilt/sow under the "With APL-funded R&D" scenario. The number of days in each phase of the lifecycle of the gilt/sow was used to calculate the costs of feeding and maintaining the animal. The lifespan of the gilt/sow was used to calculate the average *annual* profit per sow under the Base Case and under the "With APL-funded R&D" scenario.
2. Based on a series of cost and revenue assumptions, ACIL Allen calculated the profit generated by the offspring of the representative gilt/sow across all 3 parities in the Base Case and across all 4 parities

in the "With APL-funded R&D scenario. The calculation took into account differences in average litter size and average carcass weight between the first and subsequent parities.

3. The average annual profit per gilt/sow under the Base Case and under the "With APL-funded R&D" scenario was multiplied by the projected number of sows in the industry each year to 2026/27 and by the proportion of producers with an average of 4 parities per sow and the proportion of producers with an average of 3 parities per sow. The proportion of producers with an average of 4 parities per sow is a proxy for the rate of adoption of the R&D findings across the industry.

The present value (PV) of R&D and extension/implementation costs under a 5 per cent real discount rate was $2.460 million. The PV of incremental industry profits to 2026/27 that is attributable to the APL-funded R&D projects was calculated to be $20.021 million under a 5 per cent real discount rate.

The net benefit or net present value (NPV) to 2026/27 of the APL-funded gilt enhancement R&D projects was thus estimated to be $17.562 million in 2017/18 dollars under a 5 per cent real discount rate. The benefit-cost ratio (BCR) of the gilt enhancement R&D projects was estimated to be 8.14, while the internal rate of return (IRR) was estimated to be 36.7 per cent. The modified internal rate of return (MIRR) was estimated to be 23.4 per cent.

## Physi-Trace R&D

ACIL Allen conducted a cost-benefit analysis of key R&D projects relating to Physi-Trace that have been funded by APL. Physi-Trace uses the trace element signature of pig meat and offal to enable the traceability of all pork products across the whole supply chain from producer to consumer.

The objectives of the Physi-Trace research program were to:

— prove or disprove the ability of physiological identification technologies to provide a rapid and cost effective method to provide source identification validation
— determine the cost to industry of adoption of physiological identification technologies
— determine and develop suitable porcine biological sample collection, identification, transportation, storage and archiving methods and systems
— conduct and document a number of specific trace back trails demonstrating the tracing of exported and wholesale/ retail Australian pork back to the farm of origin.

Physi-Trace potentially enables traceback to farm for fresh pork through the collection, storage and collation of known samples taken at slaughter. A subset of these are analysed for trace element components, with the results stored on a database for subsequent accessing in the event that a trace back is required.

Physi-Trace is expected to generate a range of benefits for the Australian pork industry. For this cost-benefit analysis, ACIL Allen chose to focus on three potential benefit streams:

1. Enabling Australian pork exports to a major market (such as Singapore) to recover more quickly following an incident, such as detection of chemical residues in pork, that causes a disruption of exports to that market.
2. Helping restore consumer confidence in, and therefore sales of, ham and bacon made from Australian pork following the discovery of falsely labelled "Australian" ham and bacon in the domestic market.
3. Facilitating the export of premium branded offal to the Chinese market (once pork export protocols are approved by China).

The present value of all costs associated with Physi-Trace to FY2037 was estimated at $19.80 million in 2017 dollars under a 5 per cent real discount rate. This included R&D costs (for both APL and organisations undertaking the R&D) as well as the costs of maintaining the Physi-Trace database.

The present value of benefits of Physi-Trace to FY2037, across the three benefit streams assessed by ACIL Allen, was estimated at $301.0 million in 2017 dollars under a 5 per cent real discount rate. The breakdown of the benefits was as follows: $87.70 million (Singapore residue scenario), $48.50 (falsely labelled "Australian" ham and bacon scenario) and $164.77 million (premium offal exports to China).

The net benefits or NPV of Physi-Trace was estimated at $281.2 million in 2017 dollars under a 5 per cent discount rate. The BCR of the Physi-Trace R&D program was estimated to be 15.20, while the IRR was estimated to be 48.9 per cent. The MIRR was estimated to be 21.6 per cent.

Excluding future offal exports to China, the NPV of Physi-Trace was estimated at $116.4 million in 2017 dollars under a 5 per cent discount rate. The BCR of the Physi-Trace R&D program was estimated to be 6.88, while the IRR was estimated to be 45.5 per cent. The MIRR was estimated to be 17.9 per cent.

## Nutrition R&D

ACIL Allen conducted a cost-benefit analysis of research projects commissioned and funded by APL that examined the effect of different dietary additives on feed intake of grower and finisher pigs and explored some of the underlying physiological and neuro-endocrinological mechanisms that might be involved. Another strand of research commissioned by APL examined the efficacy of nutritional interventions in enhancing the performance of light weight weaners in order to reduce overall variation at slaughter.

Of the APL-funded nutrition R&D projects assessed by ACIL Allen, lauric acid (LA) was found to be the most promising dietary additive in pig production. While both LA and mineral salts (calcium chloride and sodium triphosphate) reduced average daily feed intake (ADFI), there was a reduction of average daily growth in the pigs fed mineral salts and mineral salts plus LA respectively. On the other hand, pigs fed LA maintained growth similar to that of pigs on the control diet. There was no dietary effect of any of the additives on P2 backfat depth nor on parameters of pork quality.

In addition, while the inclusion of albus lupins reduced feed intake, the growth rate during the last 28 days of growth was adversely impacted. These or other APL projects also found epigallocatechin gallate, n-oleoyethanolamide, boron, vitamin E, cinnamon and omega-3 fatty acids to be ineffective in suppressing feed intake.

At a LA price of $3.50 per kg and assuming a daily feed intake of 3.0 kg, the daily cost of the LA supplement (at 25g/kg) is $0.2625 per pig. The cost per pig over the 28-day finishing period is $7.35.

On the benefits side, the reduction in daily feed intake is worth $0.1233 per pig, assuming daily feed intake of 3.0 kg per pig and feed cost at $380.60 per tonne (being a weighted average of the feed cost in Queensland at $460 per tonne and the feed cost in the rest of Australia at $360 per tonne, with the weights based on March 2018 production figures). The benefit per pig over the 28-day finishing period is $3.45. The net benefit per pig is thus -$3.90. That is, at the current price of LA, the cost of the supplement exceeds its benefit in reduced feed cost.

The present value of total costs (encompassing the cost of the APL nutrition research program between 2011-12 and 2017-18 and the industry cost of the LA supplement between 2017-18 and 2027-28) is $116.6 million in 2017-18 dollars under a 5 per cent real discount rate.

At the current prices of nutritional supplements, the present value of quantified and monetised benefits in reduced feed cost for the pig industry in Australia is projected to be $53.6 million in 2017-18 dollars under a 5 per cent real discount rate.

The NPV of APL's nutrition research program is thus projected to be -$62.9 million in 2017-18 dollars under a 5 per cent real discount rate. The BCR is 0.46. The internal rate of return (IRR) cannot be calculated because the returns to the R&D investment are negative.

## Biosecurity / exotic diseases R&D

Australian agriculture benefits enormously from its freedom from the more devastating epidemic diseases that plague livestock industries in other parts of the world. The introduction of exotic diseases could cause serious production losses to Australia's livestock industries, jeopardise export markets for livestock products and/or have serious public health implications.

ACIL Allen has estimated the potential benefits of the APL R&D on biosecurity and exotic diseases in attenuating the adverse economic impacts of a potential Foot and Mouth Disease (FMD) outbreak in

Australia, drawing on the findings of a 2005 ABARE report and a 2013 ABARES report. FMD was chosen as the focus of the cost-benefit analysis because of its very large potential economic costs and because credible modelling of the disease's potential spread in Australia has previously been undertaken.

Most of the economic costs from a FMD outbreak would arise from revenue losses caused by immediate and prolonged export bans by Australia's FMD-sensitive markets. An FMD outbreak results in trade restrictions on an exporter's livestock products as importing countries try to minimise the risk of introducing the virus.

For Australia, a large exporter of FMD-susceptible products, the loss of export markets is likely to increase the supply of livestock products onto the domestic market. This would significantly reduce domestic prices and result in large losses in producers' revenue. An outbreak can also lead to significant social disruption in the surrounding communities.

The biosecurity/exotic diseases R&D commissioned by APL are expected to assist in the control of a FMD outbreak in Australia by ensuring that the possibility of delayed detection of a FMD outbreak is reduced and that the response to an outbreak is optimised.

ACIL Allen's analysis suggests that the APL R&D in biosecurity / exotic diseases can help reduce the expected total direct economic costs of a FMD outbreak in Australia by $0.92 billion in present value terms over 10 years, from $1.08 billion without APL R&D to $0.16 billion with APL. It does so by preventing a small outbreak from becoming a severe one.

Assuming a 1 per cent annual probability of a FMD outbreak and that APL's R&D contributes 5 per cent to the effectiveness of FMD surveillance and the FMD response once an outbreak has occurred, ACIL Allen estimates that APL's R&D benefits in relation to FMD is approximately $0.46 million a year.

APL R&D in biosecurity / exotic diseases also helps to maintain the disease-free status and reputation of Australian pork, thereby ensuring a price premium in export markets with high income consumers.If 10 per cent of this price premium can be attributed to the APL-funded R&D projects in biosecurity and exotic diseases, then this benefit is valued at approximately $0.46 million per annum (that is, of the same magnitude as the FMD benefit).

The cost of APL's R&D program in biosecurity / exotic diseases, including the cash and in-kind contributions of organisations undertaking the R&D, totalled $984,033. The average annual cost of the R&D between 2013 and 2018 was thus $196,807. For the cost-benefit analysis, a 14 per cent administrative/management cost multiplier was applied.

Comparing the projected FMD benefit of $0.46 million per year against the average R&D cost of $224,360 (inclusive of administrative/management costs) suggests a BCR of approximately 2.0. That is, the benefits of the R&D in terms of FMD alone is projected to be twice the cost of APL's R&D program in biosecurity/exotic diseases. Including the benefits of APL's biosecurity / exotic diseases R&D in ensuring a price premium in key export markets would double the BCR.

# 1 INTRODUCTION

## 1.1 Background

In 2016 ACIL Allen Consulting reviewed evaluation of the R&D program at Australian Pork Limited (APL). The review identified that, historically, evaluation of APL's R&D consisted of:

— *ex-ante* multi-criteria analysis (MCA) of potential projects to select the R&D portfolio each year
— *ex-post* cost-benefit analysis (CBA) of selected projects to demonstrate achievements and inform future investments.

In 2016 we found and recommended the following:

— the *ex-ante* MCA evaluation/investment process was being used and generally seen to be working - but many of the criteria were "stale" and provided limited value for effort
  – **Recommendation 1**: continue and adapt over time to increase cost-effectiveness
— *ex-post* CBA evaluations were not being conducted because questions around selection, data quality, value and use meant there was little support or interest from R&D program managers.
  – **Recommendation 2**: reactivate targeted/participatory CBAs to evaluate portfolio over 3 years as inputs to other processes.

In May 2017 APL agreed to implement Recommendation 1 by conducting CBAs on four programs during 2017/18. Recommendation 2 was held over to be integrated into the R&D program in 20/1819.

## 1.2 This project

The four CBA's were undertaken as a collaboration between APL R&D program managers and ACIL Allen. A collaborative approach was used to build greater understanding of and support for evaluation within the R&D program team. By working collaboratively the required insights were more readily acquired and the implications of the findings directly applied to the programs being evaluated.

The process involved ACIL Allen and the R&D program reviewing the investment portfolio to identify which programs were going to be evaluated based on the following criteria:

— Strategic – targeting programs which had not been evaluated and/or addressed current priorities
— Practical – selecting programs where investments were sufficiently mature to be evaluated
— Rigour/transparency –degree to which investments could be evaluated using CBA guidelines
— Participation – integrating development priorities and interest of program managers.

This process was conducted twice with two programs selected for evaluation each time. Once selected ACIL Allen worked with the relevant program managers to complete the evaluations.

# 2 GILT ENHANCEMENT

ACIL Allen conducted a cost-benefit analysis of key R&D projects relating to gilt enhancement that have been funded by APL. The projects investigated the effects of gilt management, including mating age, mating weight, backfat level, structural integrity and locomotion scores of gilts, as well as other management and potential genetic strategies, on their overall performance and longevity in the breeding herd.

## 2.1 Overview of APL-funded gilt enhancement R&D

The profitability of pork production is significantly affected by the number of parities a sow is kept in the herd before she is culled. Traditionally, the main reasons for sow culling during early parities involved poor reproductive performance, lameness, and other health issues.

Sows that do not produce many litters before culling add considerable costs to the production system. This is because reproductive gilts are expensive to purchase, their litter size is lower than older sows, and the progeny of gilts (that is, offspring from the first parity) tend to be lighter at birth, grow more slowly and weigh less at slaughter compared with the progeny of sows (that is, offspring from the second parity onwards).

In the past several years, APL has funded a series of research projects that aim to improve the selection and management of gilts in order to increase the average number of parities that gilts/sows are kept before culling, which in turn will lead to increased profitability across the industry.

The projects investigated the effects of gilt management, including mating age, mating weight, backfat level, structural integrity and locomotion scores of gilts, as well as other management and potential genetic strategies, on their overall performance and longevity in the breeding herd.

## 2.2 Research projects

### APL Project 2012/2435 – Improvement of sow longevity through identification of early lifetime performance indicators, including the assessment of gonadatrophin response as a suitable selection tool for replacement gilts

*Organisations undertaking the research: Rivalea Australia Pty Ltd, AGBU University of New England*

#### Background

Sow lifetime performance (calculated as the number of pigs produced per-female per day of herd-life) and herd feed conversion (HFC, feed consumed per unit carcass weight produced) are two of the most important economic factors affecting the profitability of pork production worldwide. High sow turnover or replacement rate within a herd leads to a reduction in sow lifetime performance, particularly if replacement rates for early parity sows are high.

Sows that remain in the herd up until at least their 8th or 9th parity have the greatest potential for high sow lifetime performance with older sows also positively contributing to overall HFC. High sow turnover rates result in a higher proportion of younger sows in the herd, and in particular gilts, leading to increases in HFC due to the increased breeder feed consumed and/or the reduced output of pigs sold per year. High sow turnover also has indirect effects on HFC due to a greater proportion of gilt progeny within the herd.

Compared with the progeny from multiparous sows, the progeny of gilts are lighter at birth and weaning and have previously been shown to, gain weight more slowly through to sale and are more susceptible to disease. All of these factors have a substantial impact on progeny feed efficiency and therefore negatively impact overall HFC.

**Project aims**

The project objectives were to:

1. Reduce sow replacement rates in multiplier herds from 60 to 40 per cent by focussing on a novel selection index for replacement gilts
2. Develop specific targets for early lifetime performance parameters that reduce early sow turnover due to poor reproductive performance
3. Assess the use of gonadatrophins at selection as a means of identifying gilts that are less likely to display early reproductive failures, thereby reducing early sow turnover.

**Project method**

The growth performance of almost 9,000 selected gilts at various stages from weaning until selection was monitored as part of the study pertaining to the first and second objectives listed above. Subsequent outcomes in the reproductive herd were assessed to develop relationships between early lifetime performance and subsequent reproductive performance in the breeding herd.

In the gonadotropin study, 563 gilts were injected at about 144 days of age with a low dose (200 i.u.) of PG600® (400 IU of PMSG and 200 IU of hCG; Intervet, Holland). Visual evaluations of the external genitalia of all gilts were undertaken once daily for 7 days following injection. Gilts were assessed by this scoring of the external genitalia as either responders or non-responders, and the subsequent reproductive performance of all gilts was monitored.

**Project findings**

The key results from the study were that there were some early-in-life indicators that were associated with breeder gilts being selected and mated. However, these were not well related to further reproductive outcomes. The early-in-life parameters included:

— Higher pre-weaning gain had the most consistent outcome for improving the probability of gilt selection. Gilts from the lowest 20 per cent of weights at 21 days of age (or <4 kg at 21 days of age) were unlikely to be selected and also had a substantially reduced probability of being mated or farrowing if they were selected. Thus, these females should not be reared as replacement females.
— Increasing weaning age linearly improved the probability of the gilt being selected.
— Increasing the fatness of the gilt will improve the reproductive outcome over her lifetime. There was a linear increase in the likelihood of gilts being mated and farrowing as P2 backfat at selection increased. Fatter gilts at selection were also least likely to be culled by parity 2.
— Gilts born in gilt litters were significantly more likely to be culled without a mating, or due to pregnancy failure in their first gestation, or due to failure to be rebred after their first farrowing. Thus, management of any animals that may be selected from gilt litters is critical.
— Characteristics recorded at selection were the better indicators of subsequent performance outcomes for selected gilts.

**However,** overall, the characteristics of individual gilts recorded early in life or at selection had relatively little impact on reproduction outcomes. Breeding season at birth and, most importantly, farm-specific management practices have a much more significant impact on gilt selection, gilt mating, sow longevity and lifetime performance.

The results of the gonadotropin study revealed that only 48 per cent of gilts exposed to a low dose of gonadotropins at 144 days of age showed a physical response in terms of reddening and swelling of the vulva within 7 days of injection. Parity 1 performance did not differ between Responders and Non-Responders, and overall reproductive performance to parity 3 also did not differ between Responders and Non-Responders.

In conclusion, giving selected gilts a low dose of gonadotropins as PG600 at about 144 days of age did not improve reproductive outcome in the proportion of gilts mated, or subsequent reproductive performance or longevity.

### APL Projects 2012/2436 – Association between gilt structural conformation and implications for lifetime productivity of sows

*Organisation undertaking the research: Australian Pork Farms Group (APFG)*

#### Background

Lameness is recognised as a major contributor to premature removal rates in Australian sow herds impacting on the economic performance of the herd not to mention the associated welfare implications. Premature sow removal rates have been estimated at between 9 per cent and 26 per cent for Australian sow herds for reasons associated with lameness and locomotion issues, second only to reproductive failure.

#### Project method

This study was conducted on a commercial piggery in South Australia and utilised 2,000 maternal line replacement gilts (LWxLR, LR or Hybrid genetic strains) from selection at 25-26 weeks of age until the farrowing of their 4th litter. At selection, at approximately 25-26 weeks of age and at a mean body weight of 116.5±8.85kg bodyweight, gilts destined for future breeding were scored for 18 different traits.

The traits consisted of six body conformation traits, six front limb structural traits, and five rear limb structural traits as well as an overall locomotion score. The traits were scored by two independent and trained scorers. Data was collected on weight and fat depth to parity 4. The structural features of replacements gilts that lead to premature sow removal and culling for lameness as well as associations with productivity traits were assessed.

#### Project findings

Retention of sows was affected by weight at first mating. Gilts that were too heavy (≥161kg) or too light (≤110kg) at first mating had a reduced retention to parity 4 than gilts in the 111 to 160 weight range. The main reasons for removal in this study was due to reproductive causes (failure to cycle, early and late pregnancy failure and fecundity) which accounted for 74 per cent of all removals. However, the second largest cause for removal could be attributed to lameness (10 per cent), suggesting that lameness and structural conformation may not be as large an issue as thought in group housed sows.

Undesirable limb conformation could be attributed to 12.6 per cent of all sows removed, predominantly due to lameness. Of these removals, rear limb conformation could be attributed to 78 per cent of removals and front limb conformation only 9 per cent. Rear limbs that were tuned in or out had 123 per cent greater chance of being removed and was associated with 7.8 per cent of all removals.

Turned out hindlimbs was also associated with a poorer locomotion score. Hindlimbs that were considered tucked under a score of ≤3 were 229 per cent more likely to be removed for lameness than preferred leg angles. Similarly, hindlimbs that were post legged were more than twice as likely (183 per cent) to be removed for lameness.

Locomotion score at selection was the best indicator of the likelihood of premature removal of all the traits assessed. Almost all sows (86 per cent) that were removed for lameness, had a locomotion score of ≥5. Given this association and ease of assessment, gilt locomotion could be the most valuable indicator of premature removal for lameness.

Structural conformation had no obvious effects on sow performance. The proportion of pigs born dead was significantly associated with the number of sows culled for structural and lameness reasons. This was correlated with structural angle of the hip. As hip angle decreased (flatter/more horizontal) the incidence of pigs born dead increased.

The investigators believe that much of the premature removal of sows due to lameness and poor conformation prior to parity 4 could be prevented with attention to the structural integrity of replacement gilts, particularly hindlimb conformation and inspection of locomotion in replacement gilts. Good gilt management strategies should receive focus, to ensure that gilts are mated at a reasonable weight but certainly prior to 150kg live weight.

### APL Project 2013/022 – Key differences underlying top and bottom reproductive performers: analysis of management programme data

*Organisations undertaking the research: South Australian Research and Development Institute (SARDI), University of Melbourne, University of Adelaide, Graeme Pope Consultancy, JCR Associates International, DAFF Queensland*

#### Background

A major area of reproductive wastage in sow herds is the premature culling of sows. It is commonly cited that a sow is required to farrow at least three litters in order to generate profit, resulting in a farm average retention of sows to parity three exceeding 70 per cent of the herd inventory. Traditionally, main reasons for sow culling involved poor reproductive performance, lameness, and other health issues. The current self-imposed phase-out of gestation stalls, and subsequent move to group housing in the Australian pork industry may exacerbate or shift these reasons for sow culling.

#### Project aims

The aims of this project were to identify the reasons for low retention of mated gilts to parity three, identify on-farm management differences between herds with low and high retention rates, identify positive and negative influences that impact on sow longevity, develop key management practices to improve gilt and sow retention, and finally to produce case studies promoting key management practices which increase the retention of mated gilts to parity three.

#### Project method

Twenty-two farm participants were recruited to the project from South Australia (12 farms), Queensland (8 farms) and Victoria (2 farms). The first stage of the project involved an in-depth analysis of twelve months of farm performance records that reported on sow population dynamics (parity distribution, replacement rate, reasons for culling) as well as reproductive performance and gilt characteristics.

During stage two, all farm participants were visited, and a questionnaire designed to provide insight into specific aspects of farm management was populated. Finally, six farms (3 from SA and 3 from QLD) were selected based on data collated during stages one and two that showed these participants exhibited high sow retention rates as well as superior reproductive performance. These six farms formed the basis for case studies, showcasing the management of gilts, heat detection and mating strategies, and farrowing house procedures, which were presented during two workshops held in South Australia and Queensland.

Additionally, a seventh case study was produced that included techniques identified by the investigators from published literature not yet taken up or adopted by the farm participants that may increase sow longevity and reproductive output.

### Project findings

Firstly, there were very few farms that achieved a farrowing rate of greater than 85 per cent, signifying that the reproductive performance of the farm participants was sub-optimal. Retention rate averaged 60 per cent and therefore sow longevity may not be as big an issue as first anticipated.

However, replacement rate was high suggesting young sows were being culled at a high rate. The most commonly cited reasons for the culling of young sows were of reproductive nature, and this should not occur in these young animals. A curvilinear relationship was identified between gilt age at first mating and retention to parity three, with a large number of farms falling outside the optimal 210-240-day window.

Additionally, a large number of empty days and often unusual wean to service patterns were observed. Thus, the premature culling of young sows was most likely explained by poor gilt management, heat detection and mating strategies. In addition to this, farrowing house performance was low given the average total numbers of piglets born, however the design of this project did not allow for the identification of reasons for this poor performance.

In order to address high replacement rates, especially by reducing the premature culling of young sows, this project has identified that the management of gilts, heat detection and mating strategies for sows, detection of returns and farrowing house management should all be optimised with the goal of increasing the reproductive performance of Australian herds.

## APL Project 2013/043 – Influence of birth litter size and suckled litter size on gilt ovarian development

*Organisations undertaking the research: University of Adelaide, CHM Alliance Pty Ltd*

### Background

The sub-optimal reproductive performance of sows (i.e. low litter size and reduced farrowing frequency) and insufficient longevity of breeding sows continue to constrain the efficiency and profitability of pig production. This problem persists despite a considerable body of work focussing on post-natal strategies (i.e. gilt management) and lactation strategies (i.e. nutritional interventions) to improve sow longevity. It is, therefore, evident that a new approach to solve reproductive insufficiencies and failures is required.

It is evident in ruminant species that conditions experienced pre-natally determine the reproductive potential and longevity of the breeding female. Further, there is preliminary evidence that the pre- and neo-natal environment affect the fertility and fecundity of gilts. It is, therefore, suggested that improvements in sow reproduction and longevity require optimisation of the pre- and neo-natal environment to ensure that ovarian development and responsiveness to endogenous gonadotrophins are maximised.

### Project aims

The project had two aims:

1. To determine the effect of pre-natal conditions and neonatal conditions on ovarian development and responsiveness to boar stimulation at a young age.
2. To determine whether plasma levels of Anti-Mullerian hormone early in life were predictive of ovarian development and responsiveness to boar stimulation at a young age.

### Project method

To achieve the aims, a total of 101 gilts (Camborough F1 x PIC 400) were selected from birth litters of < 9 (Small) or > 12 (Large). Approximately 24 hours after birth, male pigs were cross-fostered onto small litters to achieve suckled litter sizes of 12. In this way, a two times two factorial arrangement of treatments was created, as follows: birth litter size < 9, suckled litter size 9 (Small – Small); birth litter size < 9, suckled litter size 12 (Small – Large); birth litter size > 12, suckled litter size 9 (Large – Small); birth litter size > 12, suckled litter size 12 (Large –Large).

Gilts were individually identified, and their weights recorded at 24 hours of age, at weaning, 20 weeks of age, and slaughter. The P2 backfat depth was measured at 20 weeks of age. Carcass weight and dressing percentage were also recorded. A blood sample was collected at weaning and 20 weeks of age and assayed to determine levels of anti-mullerian hormone (AMH).

From 20 weeks of age gilts received daily exposure to a mature boar for 14 days. Thereafter, gilts were marketed at normal commercial weights. Ovaries were recovered from each gilt, and the following data collected from each animal: the total number of corpora lutea (CL), number of corpora albicantia (CA) and the total number of surface antral follicles greater than 1 mm in diameter.

**Project findings**

The total number of surface ovarian follicles was unaffected by treatment. However, being born into a large litter and reared in a large litter resulted in a numerical, but not significant, reduction in total surface follicle number at slaughter. The number of corpora lutea present on the ovaries of pubertal gilts was numerically, but not significantly higher, for gilts born in a Large compared to Small litter and for gilts reared in a Large compared to Small litter.

When non-pubertal animals were included in the analysis, there was a tendency (P=0.1) for gilts born in Large litters to contain more CL than those born in Small litters (7.8 ± 1.00 versus 3.8 ± 1.56 CL). There was also a tendency (P < 0.1) for a higher proportion of gilts born in a Large litter and reared in a Small litter to reach puberty compared to gilts born in a small litter and reared in a small litter.

Gestated litter size did not affect AMH levels. However, gilts reared in a Small compared to a Large litter had significantly higher AMH levels at weaning. The incidence of puberty attainment was higher (P < 0.2; 0.62 versus 0.45) for gilts with High AMH levels (> 8.3 ng/ml) compared to Low levels (< 8.3 ng/ml).

There was an interaction between gestation litter size and AMH levels at weaning and between rearing litter size and AMH levels at weaning with regard to the incidence of puberty attainment. Within the large gestated litter size treatment, a higher (P < 0.05) proportion of gilts with High weaning AMH levels reached puberty compared to gilts with Low weaning AMH levels (0.74 versus 0.42). Within the Large lactation litter size, the proportion of gilts reaching puberty tended (P < 0.1) to be higher in animals with a High compared to a Low weaning AMH level (0.63 versus 0.38).

Higher concentrations of anti-mullerian hormone (AMH) at weaning are associated with an increased capacity to exhibit a pubertal response to boar exposure at a young age (140 days). Importantly, this relationship is stronger for gilts born into large gestated litter sizes, with 74 per cent of those gilts with high AMH reaching puberty in response to boar stimulation, compared to only 42 per cent of gilts with low AMH levels.

Similarly, of those gilts reared in large litters, the incidence of puberty attainment was 63 per cent in the cohort of animals with high AMH compared to 38 per cent of the low AMH cohort. This finding supports previous work indicating that early measures of plasma AMH more accurately predict fertility.

The data from the current study, whilst preliminary, also appears to indicate a higher reproductive potential for gilts born into a Large compared to a Small litter, as evident from the numerical improvements in puberty attainment and ovulation rate for these animals. More importantly, it also appears that the capacity of gilts born into large litters to reach their reproductive potential, in terms of their ability to ovulate in response to early boar stimulation, may be impaired when they are reared in a Large litter.

Together, the current data provide support for the use of plasma AMH levels at weaning to identify gilts which are more likely to be responsive to boar stimulation, especially when selecting gilts born into, or reared in, large litters. It also appears that reproductive development and fertility of gilts born into large litters may be improved if they are reared in a smaller litter.

The investigators recommend that additional work is conducted to determine the impact on fertility and reproductive longevity of rearing gilts born in large litters in small litters and selecting gilts based on high AMH levels at weaning (or earlier).

### APL Project 2014/468 – Optimising gilt progeny performance through gilt development and lactation feeding interventions

*Organisations undertaking the research: CHM Alliance Pty Ltd*

#### Background

Feed cost is the primary variable to the cost of pig production and consequently there has been a considerable emphasis by producers and researchers on improving feed efficiency. High sow replacement rates have a direct effect on herd feed efficiency through increased numbers of gilts being introduced to the herd, with a contributing factor being the reduced output from gilts and the poorer survivability and growth of their progeny compared to progeny of multiparous sows.

Minimisation of sow replacement through optimal gilt development and optimisation of reproductive efficiency will contribute significantly to reduced whole herd feed conversion efficiency. The key to a long reproductive life is to optimise the entry of the gilt into the breeding herd through meeting key weight targets by maintaining an adequate level of nutrition

Previous projects funded by both APL and the Pork CRC have shown that by the time the progeny is on the ground it is often too late to apply interventions, therefore it is important to impact the breeding gilt. The interventions in this project will increase the quality of gilt progeny and will increase lactational feed intake and thus milk supply and therefore improve the growth performance of gilt progeny, leading to a reduction in the variation within the total herd.

#### Project aims

The project objectives are:

— Improve the quality of gilt progeny at birth and subsequent lifetime performance.
— Optimise lactational feed intake of the gilt, and thus milk output and weaning weights.
— Reduce the overall variation in the progeny herd by enhancing gilt progeny.
— Through development, gestation and lactation interventions produce a more robust gilt.

#### Project method

This project was comprised of two components, the first being a 2 x 2 factorial experiment looking at the backgrounding of gilts and their feeding during their first gestation and lactation and the second being an evaluation of the growth response of the progeny from their first litter.

At selection gilts were allocated to one of two treatments, a restricted treatment where they were floor-fed 2.5 kg/hd/d and an ad libitum treatment where they had unrestricted access to a self-feeder. At mating, these groups were further allocated to a restricted treatment featuring a stepped gestation and lactation feeding program and another treatment designed to allow ad libitum intake in lactation.

#### Project results

Reproductive performance through to the third litter was not impacted by the gilt development programme. The impact of a gestation and lactation feeding program designed to give the gilt ad libitum access to feed in order to optimise feed intake during lactation was also minimal with no influence on reproductive performance except for a small but significant increase in stillbirths in the first litter.

The largest impact of treatments was on the age and weight of gilts at first mating, with the gilts receiving feed ad libitum between selection and mating being heavier and younger at mating. However, when assessing the number of gilts that presented for mating, this project found that restrictively fed gilts had a longer length of oestrus and an increased strength of standing reflex.

Progeny performance was not greatly affected by treatment, and when assessing main effects, no difference existed between gilt development and gestation and lactation feeding treatments. An interesting observation occurred when looking at the interaction treatments. Progeny born to gilts that had received a ‘cross-over’ in treatments, i.e. restricted to ad libitum and ad libitum to restricted, had significantly lower birthweights.

The impact on gilt progeny performance from the nutritional interventions within this project were limited. The major impost to a producer within this project is the 'wasted' gilts that did not present for mating within the ad libitum treatment – which is both supported and not supported by other literature. Neither treatment impacted on performance which suggests that both are viable sow management programs. However, the significant difference in birth weights when treatments were crossed suggests that switching between management programs may not be wise.

## 2.3 CBA approach and methodology

### 2.3.1 Overview

The cost-benefit analysis assesses the benefits of the APL-funded R&D relating to gilt enhancement against the R&D and extension/implementation costs.

The benefits of the R&D projects are research findings that, when disseminated to pork producers, increase their profitability by improving their approaches to gilt selection and management so that the average number of parities that mated gilts/sows are kept before culling is increased across the industry.

ACIL Allen's approach to assessing the benefits of the R&D projects is to create stylised representations of the lifecycle of a mated gilt/sow under the Base Case and under the "With APL-funded R&D" scenario. In the Base Case, the representative gilt/sow produces 3 parities before being culled. In the "With APL-funded R&D" scenario, it produces 4 parities before being culled, which would be equivalent to an increase of 1 in average parity in the herd.

The key steps in ACIL Allen's approach are:

3. Set out a timeline for a representative mated gilt/sow under the Base Case and another for a representative gilt/sow under the "With APL-funded R&D" scenario. The number of days in each phase of the lifecycle of the gilt/sow is used to calculate the costs of feeding and maintaining the animal. The lifespan of the gilt/sow is used to calculate the average *annual* profit per sow under the Base Case and under the "With APL-funded R&D" scenario.
4. Based on a series of cost and revenue assumptions, calculate the profit generated by the offspring of the representative gilt/sow across all 3 parities in the Base Case and across all 4 parities in the "With APL-funded R&D scenario. The calculation takes into account differences in average litter size and average carcass weight between the first and subsequent parities.
5. The average annual profit per gilt/sow under the Base Case and under the "With APL-funded R&D" scenario is multiplied by the projected number of sows in the industry each year to 2026/27 and by the proportion of producers with an average of 4 parities per sow and the proportion of producers with an average of 3 parities per sow. The proportion of producers with an average of 4 parities per sow is a proxy for the rate of adoption of the R&D findings across the industry.

### 2.3.2 Timeline of representative gilt/sow in Base Case and 'With APL-funded R&D' scenario

The timeline of a sow/gilt from purchase to cull, in the Base Case and in the 'With APL-funded R&D' scenario, is shown in **Table 2.1**. As explained previously, a gilt/sow produces 3 litters in the Base Case and 4 litters in the 'With APL-funded R&D' scenario.

**TABLE 2.1** TIMELINEOF A SOW/GILT FROM PURCHASE TO CULL

| Day | Baseline | With enhanced gilt longevity |
|---|---|---|
| **168** | **Purchase gilt** | **Purchase gilt** |
| 210 | Gilt pregnant with first litter (Parity 1) | Gilt pregnant with first litter (Parity 1) |
| **324** | **Birth of first litter** | **Birth of first litter** |
| 349 | First litter weaned | First litter weaned |
| 356 | Gilt pregnant with second litter (Parity 2) | Gilt pregnant with second litter (Parity 2) |
| **470** | **Birth of second litter** | **Birth of second litter** |
| 495 | Second litter weaned | Second litter weaned |

| Day | Baseline | With enhanced gilt longevity |
|---|---|---|
| 502 | Gilt pregnant with third litter (Parity 3) | Gilt pregnant with third litter (Parity 3) |
| **616** | **Birth of third litter** | **Birth of third litter** |
| 641 | Third litter weaned | Third litter weaned |
| **648** | **Gilt (sow) culled** | Gilt pregnant with fourth litter (Parity 4) |
| 762 | - | **Birth of fourth litter** |
| 787 | - | Fourth litter weaned |
| **794** | - | **Gilt (sow) culled** |

*SOURCE: ACIL ALLEN CONSULTING*

The key information underpinning the timeline shown in **Table 2.1** are:

— Age of gilt at purchase – 168 days
— Age of gilt when pregnant with the first litter – 210 days
— Duration of pregnancy – 114 days
— Lactation duration – 25 days
— Period from weaning to oestrus – 7 days.

## 2.4 Assessment of costs

### 2.4.1 R&D costs

The costs of the five R&D projects by year from 2013/14 to 2016/17 are shown in **Table 2.2**. They include the salaries, travel and operating costs incurred by the organisations undertaking the R&D. The R&D costs were funded by APL and by the organisations undertaking the R&D (including through in-kind contributions).

**TABLE 2.2** R&D PROJECT COSTS, 2013/14 TO 2016/17

| Project | 2013/14 | 2014/15 | 2015/16 | 2016/17 |
|---|---|---|---|---|
| APL 2012/2435 | $272,987 | $212,782 | $172,083 | - |
| APL 2012/2436 | $24,572 | - | $6,143 | - |
| APL 2013/022 | $67,915 | $106,660 | - | - |
| APL 2013/043 | $140,720 | $65,880 | - | - |
| APL 2014/468 | - | $304,182 | $459,582 | $10,000 |
| **Total** | **$506,193** | **$689,504** | **$637,808** | **$10,000** |

*SOURCE: APL*

For the cost-benefit analysis, a 14 per cent administrative/management cost multiplier was used to determine the total expenditure for APL for the projects that have been commissioned, conducted and reported on. This multiplier was applied on top of the annual R&D costs shown in **Table 2.2**.

### 2.4.2 Implementation and extension costs

The implementation and extension costs incurred by APL to disseminate the results and findings of the four R&D projects to industry are estimated by APL at $10,000 per year from 2013/14 to 2015/16.

## 2.5 Assessment of benefits

The assessment of the benefits of the gilt enhancement R&D program is underpinned by a series of assumptions relating to production costs and revenues. These are set out in Sections 2.5.1 and 2.5.2 below.

### 2.5.1 Production cost assumptions

The assumptions relating to production costs are shown in **Table 2.3**.

**TABLE 2.3** PRODUCTION COST ASSUMPTIONS

| Assumption | Value | Unit | Source |
|---|---|---|---|
| **Gilt purchase** | | | |
| Cost of a replacement gilt (including genetic premium) | $720 | | Ray King |
| **Gilt (sow) feed intake** | | | |
| During preparation of gilt from selection until first mating | 3.00 | kg per day | Ray King |
| During pregnancy | 2.50 | kg per day | Ray King |
| During lactation | 5.50 | kg per day | Ray King |
| Between weaning and oestrus | 3.50 | kg per day | Ray King |
| **Feed intake of growing piglets** | | | |
| Herd feed conversion (HFC) | 3.73 | | Pork CRC (average 2015-16 KPI, Benchmarking Project) |
| Feed conversion ratio (FCR), wean to sale - live weight | 2.44 | | Pork CRC (average 2015-16 KPI, Benchmarking Project) |
| **Production cost** | | | |
| Cost of Production (COP) | $2.83 | per kg HSCW | Pork CRC |
| Feed cost | $433 | per tonne | Pork CRC (average 2015-16 KPI, Benchmarking Project) |
| Non-feed costs as proportion of total costs | 43.00% | | Pork CRC (2015-16 Benchmarking Project) |

*SOURCE: VARIOUS*

### 2.5.2 Revenue assumptions

The assumptions relating to the calculation of revenues are shown in **Table 2.4**.

**TABLE 2.4** REVENUE ASSUMPTIONS

| Assumption | Value | Unit | Source |
|---|---|---|---|
| **Litter size and survival rate** | | | |
| Number born alive per litter (Parity 1) | 10.70 | | Pork CRC (average 2015-16 KPI, Benchmarking Project) |
| Number born live per litter (Parity 2 onwards) | 11.40 | | Pork CRC (average 2015-16 KPI, Benchmarking Project) |
| Survival rate to weaning (Parity 1) | 88.40% | | |
| Survival rate to weaning (Parity 2 onwards) | 88.40% | | |
| **Carcass weight** | | | |

| Assumption | Value | Unit | Source |
|---|---|---|---|
| Carcass weight (Parity 1) | 76.20 | kg | Yoder, C, Lawrence, S, Duttlinger, V and Shaffer, C. Parity differences in reproductive performance and progeny performance. PureTek Genetics, Technical report - March1, 2014: |
| Carcass weight (Parity 2 and beyond) | 78.60 | kg | Pork CRC (average 2015-16 KPI, Benchmarking Project) |
| Carcass weight of culled sow (after 3 parities) | 187.50 | kg | Ray King |
| Carcass weight of culled sow (after 4 parities) | 210.00 | kg | Ray King |
| **Carcass price** | | | |
| Price of prime baconers | $3.65 | per kg CW | APL *Eyes & Ears* Issue #734 |
| Price of backfatters (cull sow) | $2.20 | per kg CW | APL *Eyes & Ears* Issue #734 |

*SOURCE: VARIOUS*

The assumed carcass weight for the Parity 1 offspring is based on the finding in Yoder, C, Lawrence, S, Duttlinger, V and Shaffer, C. *Parity differences in reproductive performance and progeny performance. PureTek Genetics, Technical report – March 1, 2014* that progeny of gilts took 177.2 days to slaughter whereas the progeny of older sows took only 174 days, a significant delay of 3.2 days, which would be equivalent to 2.4 kg carcass weight (assuming growth at about 1000g/day at the end of the growth stage).

The assumption of a 2.4 kg difference in carcass weight between gilt progeny (from Parity 1) and sow progeny (from Parity 2 onwards) is a conservative one. Other studies have indicated a greater difference in carcass weight. For example, Craig and Collins (2016) found a 3.6 kg difference in live weight (equivalent to about 2.7 kg in carcass weight). In a paper submitted for publication in the *Journal of Animal Science*, Craig (2017) showed that gilt progeny carcasses were 4.6 kg lighter than sow progeny carcasses.

### 2.5.3 CBA calculations

The key calculations of the cost-benefit analysis, based on the production cost and revenue assumptions set out in Sections 2.5.1 and 2.5.2, are shown in **Table 2.5**.

**TABLE 2.5** CBA CALCULATIONS

| | Base Case | With APL-funded R&D |
|---|---|---|
| **Gilt/sow feed costs per parity** | | |
| During preparation of gilt for first mating | $54.56 | $54.56 |
| During pregnancy | $123.41 | $123.41 |
| During lactation | $59.54 | $59.54 |
| Between weaning and oestrus | $10.61 | $10.61 |
| Gilt/sow feed costs across 3 (4) parities | $635.21 | $828.76 |
| Gilt/sow non-feed costs | $479.20 | $587.17 |
| Sale price of culled sow | $412.50 | $462.00 |
| Net cost of gilt/sow<br>*( = gilt purchase price + gilt/sow feed and non-feed costs – sale price of culled sow)* | $1,421.91 | $1,673.93 |

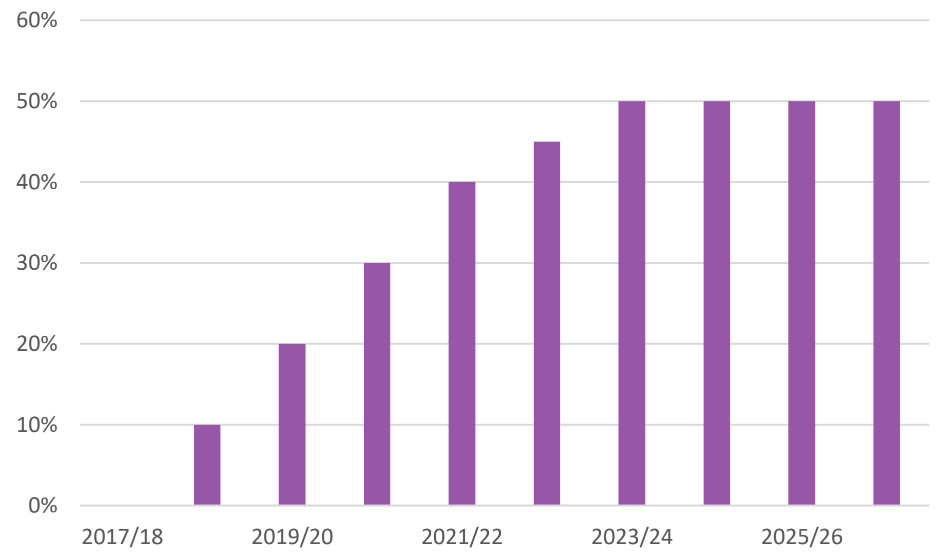
| | Base Case | With APL-funded R&D |
|---|---|---|
| **Total number of offspring that survive to market** | | |
| Parity 1 | 9.5 | 9.5 |
| Parity 2 and Parity 3 (and Parity 4) | 20.2 | 30.23 |
| **Profit per offspring** | | |
| Parity 1 | $62.59 | $62.59 |
| Parity 2 and Parity 3 (and Parity 4) | $64.56 | $64.56 |
| Profits across 3 (4) parities | $1,893.26 | $2,543.87 |
| **Profit per gilt/sow** | | |
| Net profit per gilt/sow<br>*( = profits across all parities – net cost of gilt/sow)* | $471.34 | $869.94 |
| Profit rate per sow per year<br>*( = net profit per gilt/sow / time elapsed between gilt purchase and cull)* | $265.49 | $399.91 |

*SOURCE: ACIL ALLEN CONSULTING*

For this cost-benefit analysis, it is assumed that in the counterfactual (that is, without the APL-funded research in gilt enhancement), the progressive increase in the proportion of producers with 4 parities per sow instead of 3 parities would be delayed by 10 years. That is, the APL-funded research has brought forward the benefits of improved gilt selection by a decade.

It is assumed that there are 240,000 sows each year to 2026/27 across the Australian pork industry. The assumed proportion of producers with an average of 4 parities per sow (as opposed to an average of 3 parities per sow) between 2017/18 and 2026/27 is shown in **Figure 2.1**. This increase is due to the dissemination and implementation of the findings from the five APL-funded gilt enhancement R&D projects, which is expected to significantly improve the gilt selection and management practices of producers.

**FIGURE 2.1** PROPORTION OF PRODUCERS WITH AN AVERAGE OF 4 PARITIES PER SOW, 2017/18 TO 2026/27

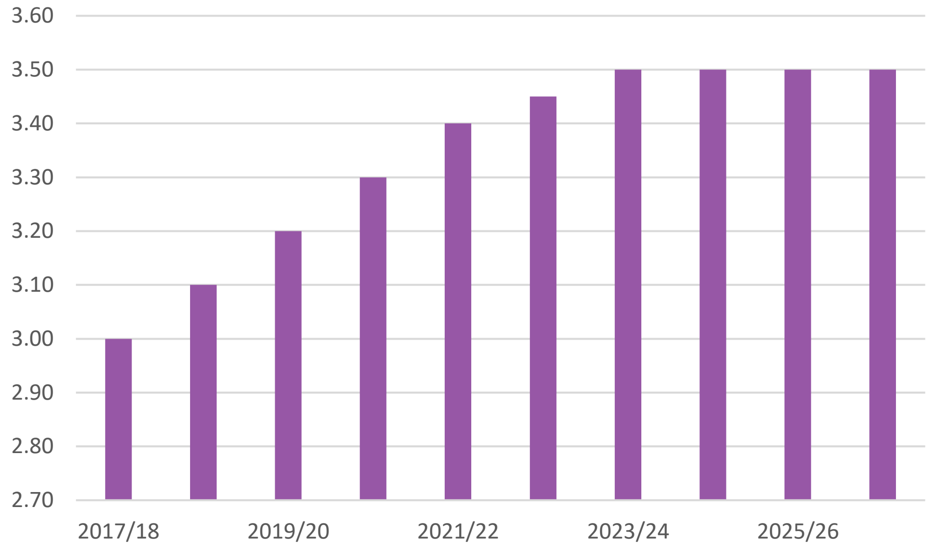



*SOURCE: ACIL ALLEN CONSULTING*

The uptake of research project findings is assumed to be relatively quick due to the concentrated nature of the industry (which is dominated by two very large producers, who are heavily involved in the R&D projects).

The projected average number of parities per gilt/sow across the industry between 2017/18 and 2026/27 is shown in **Figure 2.2**.

**FIGURE 2.2** AVERAGE NUMBER OF PARITIES PER SOW ACROSS THE INDUSTRY, 2017/18 TO 2026/27




*SOURCE: ACIL ALLEN CONSULTING*

### 2.5.4 Social and environmental benefits

The APL-funded gilt enhancement R&D projects are expected to enhance the profitability and economic viability of the pig meat industry in Australia. This will lead to more economically and socially resilient communities across Australia where pig farming and/or pork processing is a key component of the local economy, with positive impacts on the physical and mental health of community members.

The gilt enhancement R&D projects are not expected to generate significant environmental benefits in Australia. It will have little impact on Australia's natural capital, that is, air, water, land (soil, sub-soil assets, space and landscape) and habitats (including ecosystems, flora and fauna).

## 2.6 CBA results

### 2.6.1 Present value of costs

The present value (PV) of R&D and extension/implementation costs to 2021/22 and to 2026/27 under a 5 per cent real discount rate is $2.460 million.

### 2.6.2 Present value of benefits

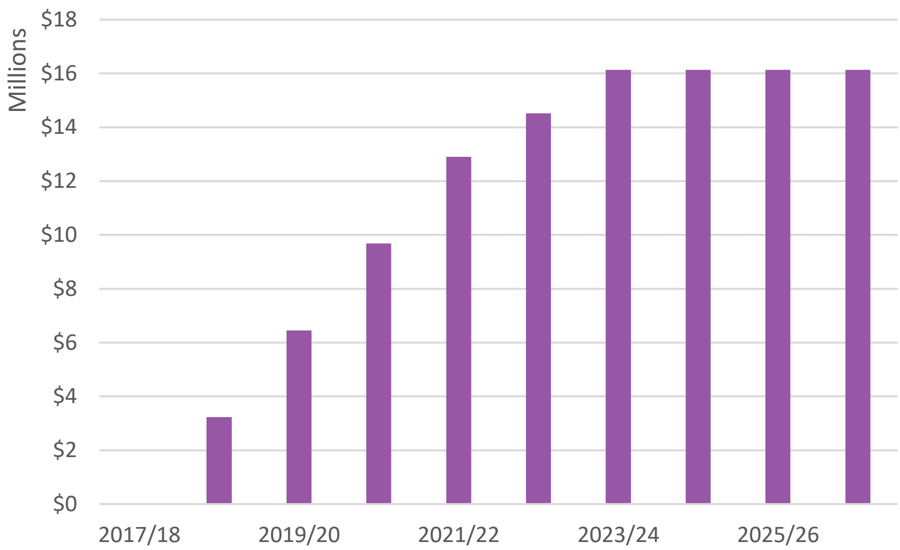
The PV of benefits to 2021/22 in terms of incremental industry profits above those in the Base Case is $26.572 million under a 5 per cent real discount rate.

The PV of benefits to 2026/27 in terms of incremental industry profits above those in the Base Case is $80.085 million under a 5 per cent real discount rate. The projected year-by-year incremental industry profits are shown in **Figure 2.3**. The PV of benefits to any timeframe beyond 2026/27 is the same as that to 2026/27 as it is assumed (as explained previously) that the APL-funded research has brought forward the benefits of improved gilt selection by a decade, so benefits beyond that time frame cannot be attributed to the research.

It is conservatively assumed that 25 per cent of the incremental industry profits is attributable to the APL-funded R&D program. The rest is attributed to research funded by the Pork CRC, to consultants and to other sources and entities that have contributed to improvements in gilt selection and management.

The PV of incremental industry profits to 2021/22 attributable to the APL-funded R&D projects is thus $6.643 million under a 5 per cent real discount rate. The PV of incremental industry profits to 2026/27 attributable to the APL-funded R&D projects is $20.021 million under a 5 per cent real discount rate.

**FIGURE 2.3** AVERAGE NUMBER OF PARITIES PER SOW ACROSS THE INDUSTRY, 2017/18 TO 2026/27




*SOURCE: ACIL ALLEN CONSULTING*

### 2.6.3 Net present value

The net benefit or net present value (NPV) to 2021/22 of the APL-funded gilt enhancement R&D projects is estimated to be $4.183 million in 2017/18 dollars under a 5 per cent real discount rate.

The NPV to 2026/27 of the APL-funded gilt enhancement R&D projects is estimated to be $17.562 million in 2017/18 dollars under a 5 per cent real discount rate.

The NPV is calculated by subtracting the PV of incremental costs from the PV of incremental benefits.

### 2.6.4 Benefit-cost ratio

The benefit-cost ratio (BCR) to 2021/22 of the gilt enhancement R&D projects is estimated to be 2.70. The BCR to 2026/27 of the gilt enhancement R&D projects is estimated to be 8.14.

The BCR is calculated by dividing the PV of incremental benefits by the PV of incremental costs.

### 2.6.5 Internal rate of return

The internal rate of return (IRR) of the gilt enhancement R&D projects to 2021/22 and 2026/27 is estimated to be 24.4 per cent and 36.7 per cent respectively. The modified internal rate of return MIRR) to 2021/22 and 2026/27 is estimated to be 18.9 per cent and 23.4 per cent respectively.

## 2.7 Sensitivity analysis

To test the robustness of the central CBA results, sensitivity analysis was taken to ascertain the impact of changes in key assumptions and parameters on the BCR. The results are reported for the 10-year analytical timeframe (that is, to FY2027).

### Carcass weight difference between parities

In the CBA, it was assumed that there was a 2.4 kg difference in carcass weight between Parity 1 and subsequent parities (76.2 kg versus 78.6 kg). If this weight difference was 50 per cent greater (3.6 kg instead of 2.4 kg), the BCR would increase from 8.14 to 8.29. Conversely, if the weight difference was 50 per cent smaller (1.2 kg instead of 2.4 kg), the BCR would decrease to 7.99.

### Feed cost

In the CBA, it was assumed that feed cost was $433 per tonne. If the feed cost was 25 per cent higher (at $541.25 per tonne), the BCR would decrease from 8.14 to 7.79. Conversely, the BCR would increase to 8.49 if the feed cost was 25 per cent lower (at $324.75 per tonne).

### Carcass price

In the CBA, it was assumed that the price of prime baconers was $3.65 per kg carcass weight and the price of backfatters (culled sows) was $2.20 per kg carcass weight. If both prices were 25 per cent higher (reflecting, for example, stronger demand for pork), the BCR would increase from 8.14 to 14.77. Conversely, if both prices were 25 per cent lower, the BCR would decrease to 1.51. This shows that the BCR is highly sensitive to pork prices.

### Number of sows across whole industry

The CBA assumed that there would be 240,000 sows across the Australian pork industry each year. If the number was 25 per cent higher (300,000 sows instead of 240,000), the BCR would increase from 8.14 to 10.17. Conversely, if the number was 25 per cent lower (180,000 sows a year), the BCR would decrease to 6.10.

### Proportion of ‘3 parity’ and ‘4 parity’ sows

In the CBA, it was assumed that the proportion of ‘4 parity’ sows in the industry (as opposed to ‘3 parity’ sows) would increase by 10 per cent each year from zero in FY2018 to 40 per cent in FY2022 and then increase by 5 per cent each year over the following two years before flatlining at 50 per cent.

If the proportion of ‘4 parity’ sows were to increase by 15 per cent each from zero in FY2018 to 60 per cent in FY2022 before flatlining (reflecting more rapid and ultimately greater adoption of the R&D findings), the BCR would increase from 8.14 to 10.72.

Conversely, if the proportion of ‘4 parity’ sows were to increase by only 5 per cent each year from zero in FY2018 to 40 per cent in FY2026 before flatlining (reflecting slower and ultimately lower adoption of the R&D findings), the BCR would decrease to 5.09.

## 2.8 References

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# 3 PHYSI-TRACE

ACIL Allen conducted a cost-benefit analysis of key R&D projects relating to Physi-Trace that have been funded by APL. Physi-Trace uses the trace element signature of pig meat and offal to enable the traceability of all pork products across the whole supply chain from producer to consumer.

## 3.1 Background

### 3.1.1 Pork supply chain integrity system

From 2006 onwards, APL had been working with all sectors of the Australian pork industry and government to develop the Pork Supply Chain Integrity Program (including PigPass System). This joint APL/ Department of Agriculture, Fisheries and Forestry (DAFF) initiative to develop and implement the National Livestock Identification System – Pork (NLIS-P) was aimed at enabling the industry to meet the National Traceability Performance Standards endorsed by Commonwealth and State governments for disease control purposes.

A catalyst was a number of residue detections in Singapore in 2005-06 and more generally integrity issues in other countries at that time, specifically melamine residues in Chinese products (milk) and dioxin residues in Irish pork. The Program aimed to improve product integrity programs and systems to underpin Australia's pork export certification.

The key drivers for assurance on pork integrity and traceability include:

— increasing global concern over food safety
— maintaining Australia's competitive advantage in new and existing export markets based on its pig herd health status
— recall in the event of an integrity issue in the domestic or overseas market
— protection against bioterrorism
— underpinning Australian pork brands by assuring the integrity and traceability of Australian pork.

The Pork Supply Chain Integrity System has 7 parts:

1. Property Identification Codes for all properties where pigs are held (a State Government administered system)
2. Pig Tattoo code applied as a pig slap brand (or if an approved NLIS ear tag is used by some producers, this must be printed with the property identification code) for all movements of pigs (a State Government administered system)
3. PigPass National Vendor Declaration (NVD). The PigPass System integrates with the National Livestock Identification Scheme (NLIS), Australia's multi-species livestock identification and traceability system.

4. On-farm quality assurance program to validate the PigPass NVD and verify compliance with industry standards and government requirements.
5. PigPass NVD links with the abattoir system to provide correlation between the pig and the carcase. For export abattoirs, this is generally the GS1 bar coding of carcasses and cartons post-slaughter.
6. Processor QA programs (DAWR responsible for ante-mortem inspection and verification of post-mortem inspection and processor hygiene practices for export establishments and state regulated programs for domestic establishments)
7. Validation programs – State and Federal compliance programs (including on-farm audits)

### 3.1.2 Physi-Trace concept

In November 2008, a meeting of the National Consultative Committee for the NLIS-P project endorsed a pilot project to assess the potential of physiological technologies to validate pig/ pork traceability systems.

Specifically, the Physi-Trace research project aimed at assessing the potential of Physi-Trace to:

- validate the PigPass system for traceability
- enable rapid traceback in event of a food safety incident
- authenticate 'Product of Australia'

The underlying concept behind Physi-Trace is that food, such as pigmeat, can be fingerprinted through trace element analysis of pork samples and that individual test samples can then compared with a database of analysed samples to ascertain the likely origins of the test samples

In particular, the feed (of which the major components are of plant origin and hence local geology), feed supplements (possibly plant or even mineral based origin), local water and environment all contribute to the trace elements in the final meat product.

It is therefore possible to construct a profile of trace elements present in the food. This profile is essentially a pattern of elements present and is unique, in a similar way to a physical fingerprint. This pattern of elements or 'elemental fingerprint', is a representation of what the food is and provides an indication of where it has come from.

The objectives of the Physi-Trace research program were to:

- prove or disprove the ability of physiological identification technologies to provide a rapid and cost-effective method to provide source identification validation
- determine the cost to industry of adoption of physiological identification technologies
- determine and develop suitable porcine biological sample collection, identification, transportation, storage and archiving methods and systems
- conduct and document a number of specific trace back trials demonstrating the tracing of exported and wholesale/ retail Australian pork back to the farm of origin.

Physi-Trace potentially enables traceback to establishment, kill date and tattoo through samples taken at slaughter, collated and analysed for trace element components with the results stored on a database for subsequent accessing in the event that traceability (traceback and traceforward) is required. Physi-Trace could thus become a key aspect of future validation of traceability programs.

## 3.2 Research projects

### 3.2.1 Early Physi-Trace R&D – 2008 to 2009

The early phase of the Physi-Trace research program was conducted in two stages:

- **Stage 1**: Proof of Concept: demonstrate inter tattoo and intra tattoo variations using the Physi-Trace technology with pork samples collected from an abattoir. Stage 1 was begun in June 2008 and completed in September 2008.
- **Stage 2**: Stage 2 involved all other participating pork export abattoirs. It was begun in December 2008 and completed in June 2009.

Stage 1, the proof of concept investigation, demonstrated that there was the potential for the identification of the "farm" and "kill lot" based on the trace metal assemblage of a brisket sample. This characteristic trace metal assemblage is a result of both the food and water inputs and the general growing environment of the pig.

Specifically Stage 1:

- developed a robust method for the determination of trace elements in pork meat
- demonstrated that it is possible to discriminate pork meat based on its tattoo and kill date
- demonstrated that there is potential for geographical discrimination of pork samples
- provided what could be a foundation for a robust system for the establishment of 'unknown' pork samples origin.

The specific objectives of Stage 2 were to:

- establish if it is possible to discriminate pork meat samples obtained from different countries
- establish if it is possible to identify the growing region for a pork sample
- establish if a specific plant/kill lot can be identified for a pork meat sample
- test the developed analytical and interpretational protocols through a blind retail based trace back investigation
- investigate if it is possible to develop a protocol for the linking of pork offal samples to a pork meat sample.

Stage 2 demonstrated that Physi-Trace is a proven technology that can:

- provide a means for detection of substitution, that is, it is possible to discriminate fresh pork samples obtained from different countries. Discriminant analysis carried out on this dataset correctly classified 100 per cent of samples on cross-validation.
- discriminate samples based on their state (within Australia) of origin.
- discriminate fresh pork meat samples with respect to the tattoo code and therefore the kill lot.

The cost of Stage 1 and Stage 2 in this early phase of the Physi-Trace research program was $384,400.

### 3.2.2 Physi-Trace R&D since 2010

The list of Physi-Trace projects that have been funded by APL since 2010 are shown in **Table 3.1**. The project budgets include the cash and in-kind contributions from the organisations undertaking the R&D. The total R&D costs for these projects total $3.17 million.

**TABLE 3.1** APL-FUNDED PHYSI-TRACE R&D PROJECTS, FROM 2010 ONWARDS

| Project code and title | RO | IP assignment | Budget | Start date | Completion date |
|---|---|---|---|---|---|
| 2010/0001 - Investigation into the potential use of Trace Elements and Stable Isotopes in the Traceability of Pork Offal and its relationship to the Pork Meat Physi-Trace Database | TSW Analytical Pty Ltd | APL | $406,040 | 30/01/2010 | 30/06/2013 |
| 2010/0003 - Physi-Trace Stage III | TSW Analytical Pty Ltd | APL | $258,656 | 01/10/2010 | 07/06/2011 |
| 2010/0004 - Pork Supply Chain Integrity/ Physi-Trace Singapore Demonstration Project | TSW Analytical Pty Ltd | $0 Company Funds assume APL IP | $30,225 | 20/03/2010 | 30/06/2010 |
| 2011/1035.408 - Physi-Trace IIIa: Integration & Business Rules | TSW Analytical Pty Ltd | APL | $140,054 | 12/09/2011 | 31/01/2012 |
| 2011/1035.436 - Physi-Trace: National Livestock Traceability Performance Standards | UWA | APL | $245,663 | 28/06/2012 | 30/06/2013 |

| Project code and title | RO | IP assignment | Budget | Start date | Completion date |
|---|---|---|---|---|---|
| 2013/2131 - Physi-Trace: Retailer Standard Compliance & Logistics and Implementation Plan | Food Science Solutions/UWA | 68.62 APL%/7.63% UWA/23.75% | $320,580 | 14/01/2014 | 20/09/2014 |
| 2014/491 - CIC - Physi-Trace verification and traceback studies | Food Science Solutions | APL | $23,127 | 25/07/2014 | 02/11/2014 |
| 2015/006 - Physi-Trace: Industry Implementation | Food Science Solutions | APL | $1,231,272 | 16/02/2015 | 30/06/2017 |
| 2015/061 - Information Management and Data Analysis Tool for Physi-Trace | Food Science Solutions | APL | $102,783 | 15/06/2015 | 01/10/2015 |
| 2015/071 - Physi-Trace Liver – Investigation into the relationship of the element signatures of pork liver with raw pork meat | Food Science Solutions | APL | $145,650 | 02/05/2016 | 09/12/2016 |
| 2015/2210 - Physi-Trace Sampling | Food Science Solutions | work completed under purchase order - no contract | $14,625 | 17/08/2015 | |
| 2015/2218 - Assessment of the association of the Physi-Trace profile of a liver sample with the Physi-Trace profile of livers of known origin | Food Science Solutions | APL | $22,120 | 04/01/2016 | 27/05/2016 |
| 2016/2224 - Assessment of the status of Physi-Trace sampling regime | Food Science Solutions | APL | $9,405 | 31/10/2016 | 14/02/2017 |
| 2016/2241 - Information Management and Data analysis Tool for Physi-Trace Manual | Food Science Solutions | APL | $220,888 | 12/05/2017 | 10/02/2018 |

*SOURCE: APL*

The major recent investment by APL in Physi-Trace was project APL 2015/006. The objectives of this project were to:

— establish a current raw meat database by populating the database with trace element profiles of samples collected from all export abattoirs and two domestic abattoirs

— establish a current processed meat (ham and bacon) database by populating the database with trace element profiles of samples collected from Australia and at least four known international sources

— continue maintenance and development of Physi-Trace program infrastructure, and to ensure full integrity of Physi-Trace logistics.

Concurrent with Project 2015/006, project APL 2015/061 was initiated by Pork CRC and later supported by APL. Prior to this project, skilled scientists were required to generate and interrogate data to successfully trace pork meat samples to their property of origin. This project was to develop an automated interpretative tool for Physi-Trace to ensure rapid and robust traceability. The final report for this project provides the protocol for analysis of samples and interpretation of the source of these samples

The software developed by the project takes inexperienced users or authorised Physi-Trace personnel through all phases of quality assurance and control of raw data generated by sophisticated analytical equipment. As such, it represents a viable first attempt to enable an inexperienced user to undertake complex and often intuitive data correction typically undertaken by more experienced users and to do this work in a fraction of the time taken even by an experienced user.

The Australian pork industry also wanted to be able to trace pork liver samples back to its source of origin. Project 2015/071 was initiated by APL to develop a model to correlate the elemental signature of liver back to the Physi-Trace fresh meat database. The investigators in this project have been able to produce a series of “correction factors” for transforming data for pork liver samples into “equivalent” data that can be compared with data for pork meat.

This “normalized” pork liver data can be used with greater than 90 per cent success to accurately trace pork liver back to the producer of origin. Furthermore, the “normalised” pork liver data can be used with approximately 86 per cent success rate to accurately trace individual pork liver data from a specific tattoo back to the equivalent meat tattoo.

A more recent project (APL 2016-17/2224) in this suite of Physi-Trace projects was a small project designed to assess the status of the Physi-Trace sampling regime to ascertain whether unknown raw meat samples selected by individual abattoirs could be traced back to the farm of origin.

The project showed that samples using the Physi-Trace raw pork meat database could only be traced back to a relevant abattoir, at best. The Physi-Trace program should therefore not be used as a standalone technology; rather, it should be used with other external information for trace back purposes. The final report for this project also presented a number of options for the next phase of the Physi-Trace program.

## 3.3 Assessment of potential benefits

Physi-Trace is expected to generate a range of benefits for the Australian pork industry. For this cost-benefit analysis, ACIL Allen has chosen to focus on three potential benefit streams:

1. Enabling Australian pork exports to a major market (such as Singapore) to recover more quickly following an incident, such as detection of chemical residues in pork, that causes a disruption of exports to that market.
2. Helping restore consumer confidence in, and therefore sales of, ham and bacon made from Australian pork following the discovery of falsely labelled “Australian” ham and bacon in the domestic market.
3. Facilitating the export of premium branded offal to the Chinese market.

Each of these benefit streams and ACIL Allen’s modelling approach are discussed below.

### 3.3.1 Singapore residue scenario

Physi-Trace, in conjunction with the PSCIP/PigPass system, is expected to benefit the Australian pork industry by assisting a rapid re-entry into a market in the event of a “market collapse”. Physi-Trace enables a potential problem to be isolated to Australia or to another supplying country, with the production region and the kill lot within Australia identified in the former case. It could lower the volume of product that is isolated during investigation and subsequently stored or sold to lower value markets.

To estimate the above benefit of Physi-Trace, based on past actual incidents, ACIL Allen has constructed a scenario where pork exports to Singapore are disrupted due to the discovery of residues of a banned chemical or substance in a consignment of Australian pork exports to that country. It is assumed that the probability of such an incident occurring in any given year is 20 per cent (that is, one incident every 5 years, on average).

Singapore is by far the most important export market for Australian pork. In 2016, 37,733 tonnes of pork was exported (out of a total production of 394,678 tonnes)[1], of which 39 per cent was destined for the Singapore market. For the purpose of this modelling exercise, it is assumed that exports to Singapore would remain at the same level in future years.

[1] Data from APL Import, Export and Domestic Production Report May 2017

It is assumed that exports to Singapore would cease for **3 months** without Physi-Trace in the event of such an incident, but for only **2 weeks** with Physi-Trace due to the rapid identification of the source of the contaminated pork shipment.

During the period of disruption, the exports to Singapore would be diverted to the Australian domestic market. It is assumed that, without Physi-Trace, the sudden increase in the domestic supply would lower the price of pork received by producers by about $0.40/kg, from **$3.50 per kg to $3.10 per kg** over the three-month period.[2]

The key assumptions in this scenario are summarised in **Table 3.2**.

**TABLE 3.2** KEY ASSUMPTIONS – SINGAPORE RESIDUE SCENARIO

| Assumption | Assumed value |
|---|---|
| Annual domestic production (based on 2016 data) | 394,678 tonnes |
| Annual exports (based on 2016 data) | 37,733 tonnes |
| Proportions of exports bound for Singapore | 39% |
| Probability of an incident in a given year | 20% |
| Market loss without Physi-Trace | 3 months |
| Market loss with Physi-Trace | 2 weeks |
| Price in Australian market before incident | $3.50 / kg |
| Price in Australian market during incident | $3.10 / kg |

*SOURCES: VARIOUS (SEE FOOTNOTES IN BODY OF REPORT)*

Based on the above assumptions, the expected annual benefits of Physi-Trace is estimated to be $7.04 million in 2017 dollars.

### 3.3.2 Falsely labelled "Australian" ham and bacon scenario

In this scenario, ham or bacon that is labelled as being made from Australian pork is discovered to be made from imported pork instead, leading to a loss of consumer confidence in the provenance and authenticity of ham/bacon made from local pork.

According to APL, in 2016 Australians consumed 529,742 tonnes of pig meat. Data from the NSW Department of Primary Industry shows that the average Australian consumed 9.8 kg of fresh pork in 2015[3]. It is thus estimated that Australians consume approximately 296,500 tonnes of ham and bacon each year, of which an estimated 70 per cent are made from imported pork. It is assumed that Australian producers receive $3.50 per kg for pork that is made into ham and bacon.

Without Physi-Trace, it is assumed that the hypothesised incident would lead to an immediate **20 per cent** fall in the sales of ham and bacon made from Australian pork, which would take **3 years** to recover fully. During this period, some consumers who hitherto bought ham and bacon made from Australian pork would switch to ham and bacon made from imported pork, while others would stop purchasing ham and bacon altogether.

With Physi-Trace, by enabling the rapid identification of the source country of the falsely labelled ham and bacon and thereby helping to (partially) restore consumer faith and confidence, it is assumed that there would be an immediate **10 per cent** fall in the sales of ham and bacon made from Australian pork, which would take **1 year** to recover fully.

The key assumptions in this scenario are summarised in **Table 3.3**.

[2] This assumption was based on advice from Rob Smits Research and Innovation Manager at Riverlea Australia.
[3] See http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/578747/pork-industry-overview-2015.pdf

**TABLE 3.3** KEY ASSUMPTIONS – FALSELY LABELLED "AUSTRALIAN" HAM AND BACON SCENARIO

| Assumption | Assumed value |
|---|---|
| Probability of incident in any given year | 5% |
| Net annual consumption of pork in Australian (2016) | 529,742 tonnes |
| Australian population in 2015 | 23.80 million |
| Per-capita annual fresh pork consumption (2015) | 9.80 kg |
| Average farm-gate price of bacon and ham | $3.50 / kg |
| Imports share of ham and bacon consumed in Australia | 70% |
| Immediate loss in sales of ham and bacon produced from Australian pork - without Physi-Trace | 20% |
| Immediate loss in sales of ham and bacon produced from Australian pork - with Physi-Trace | 10% |
| Time taken for sales to recover completely - without Physi-Trace | 3 years |
| Time taken for sales to recover completely - with Physi-Trace | 1 year |

*SOURCE: VARIOUS (SEE FOOTNOTES IN BODY OF REPORT)*

Under the above assumptions, Physi-Trace will reduce the losses to Australian producers in foregone sales to ham and bacon processors from $93.40 million to $15.57 million during the course of an incident. Assuming that the probability of such an incident occurring in any given year is **5 per cent** (that is, an incident every 20 years, on average), the expected annual benefit of Phys-Trace is estimated to be $3.89 million in 2017 dollars.

### 3.3.3 Offal exports to China

According to the UK's Agriculture and Horticulture Development Board, global pork shipments to China reached 1.6 million tonnes in 2016. The European Union supplied approximately two-thirds of China's imported pork, led by the UK, Germany, Spain and Denmark. However, EU producers are likely to see increasing competition from the US and Brazil in the future.

Pig offal is very popular with Chinese consumers and features prominently in such classic Chinese dishes as stewed bung, or pork intestines, and pork liver soup. There is also strong demand for parts of the animal that Westerners do not readily consume, such as whole pig heads and trotters.

In 2015, Spain exported €76.3 million of pig offal to China, an increase of 24 per cent over 2013. British exports of offal to the Chinese market increased by 18 per cent from 2011 to 2013 to 41,123 tonnes.

Australia does not currently export pork to China due to the lack of a pork export protocol. Given the low value of offal in Australia and the strong demand for offal in China, there appears to be an opportunity for future exports of premium branded Australian offal to China.

As noted previously, 394.678 tonnes of pig meat was produced in Australia in 2016. It is estimated that offal constitutes approximately 7.5 per cent of total pig meat production by weight.[4] The price of offal in Australia is currently $1.24 per kg.[5]

According to Evan Bittner, an industry-sponsored University of Melbourne PhD student completing a dissertation on potential Australian pork exports to China, the price of offal in the Chinese market is currently approximately A$2.00 per kg, and premium branded offal from Australia that leverages the country's "clean and green" image could potentially fetch up to A$6.00 per kg. However, the success of such a product would be predicated on the availability of a trace back system such as Physi-Trace that would enable the source of the product to be authenticated, given the serious problem of counterfeiting in the Chinese market.

4 Source: Rob Smits. Riverlea
5 Source: Rob Smith, Riverlea

It is assumed that offal exports to China would commence in 2022 with **5 per cent** of Australian offal production exported to that market. In the next few years, it is assumed that the proportion increases by 5 per cent each year until it reaches **25 per cent** in 2026, and then remains at that level thereafter.

It is assumed that the price of offal exported to China would be **A$5.00 per kg** with Physi-Trace and **A$2.00 per kg** without Physi-Trace (both in 2017 dollars). The cost of developing the export protocol for the Chinese market would be incurred under both cases.

The key assumptions underpinning the analysis are summarised in **Table 3.4**.

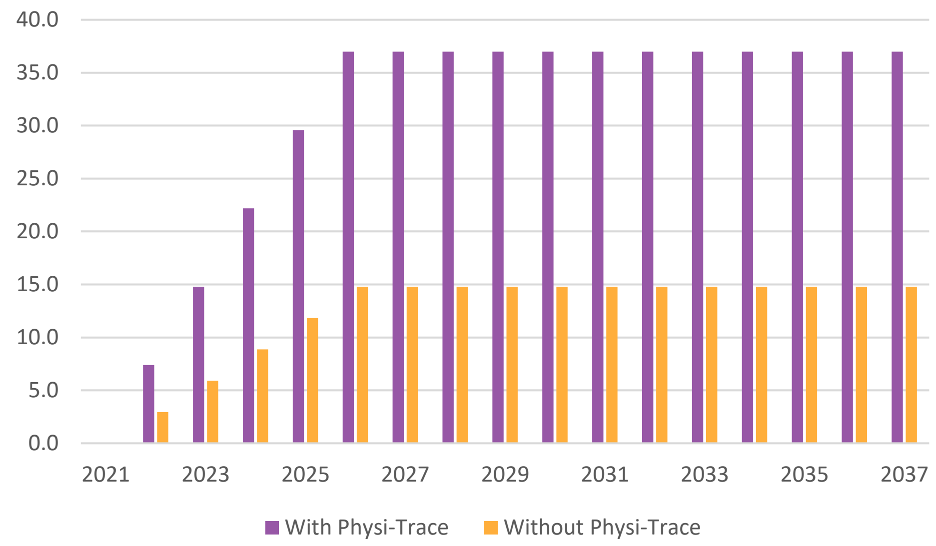
**TABLE 3.4** KEY ASSUMPTIONS – EXPORT OF PREMIUM BRANDED OFFAL TO CHINA

| Assumption | Assumed value |
|---|---|
| Offal as proportion of total pig meat production | 7.5% |
| Price of offal in Australia | $1.24 / kg |
| Price of Australian offal exported to China – with Physi-Trace | A$5.00 / kg |
| Price of Australian offal exported to China – without Physi-Trace | A$2.00 / kg |
| Cost per offal trace for country of origin | $100 |
| Average export volume per offal trace | 500 kg |
| Incremental cost of developing export protocol for Chinese market (compared with base case without Physi-Trace) | $0 |

*SOURCE: VARIOUS (SEE FOOTNOTES IN BODY OF REPORT)*

Under the above assumptions, the projected value of Australian offal exports to China with and without Physi-Trace is shown in **Figure 3.1**. There is an annual benefit in excess of $20 million from the use of Physi-Trace, once the market to China has been established to accept 25 per cent of Australian offal production.

**FIGURE 3.1** PROJECTED VALUE OF AUSTRALIAN OFFAL EXPORTS TO CHINA, FY2018 TO FY2037 ($M, 2017 DOLLARS)




*SOURCE: ACIL ALLEN CONSULTING*

### 3.3.4 Social and environmental benefits

By enabling Australian pork exports to a major market to recover more quickly following an incident, by helping restore consumer confidence in ham and bacon made from Australian pork following the discovery of falsely labelled "Australian" ham and bacon in the domestic market, and by facilitating the export of premium branded offal to the Chinse market, Physi-Trace will enhance the profitability and economic viability of the pig meat industry in Australia.

This will lead to more economically and socially resilient communities across Australia where pig farming and/or pork processing is a key component of the local economy, with positive impacts on the physical and mental health of community members.

Physi-Trace is not expected to generate significant environmental benefits in Australia. It will have little impact on Australia's natural capital, that is, air, water, land (soil, sub-soil assets, space and landscape) and habitats (including ecosystems, flora and fauna).

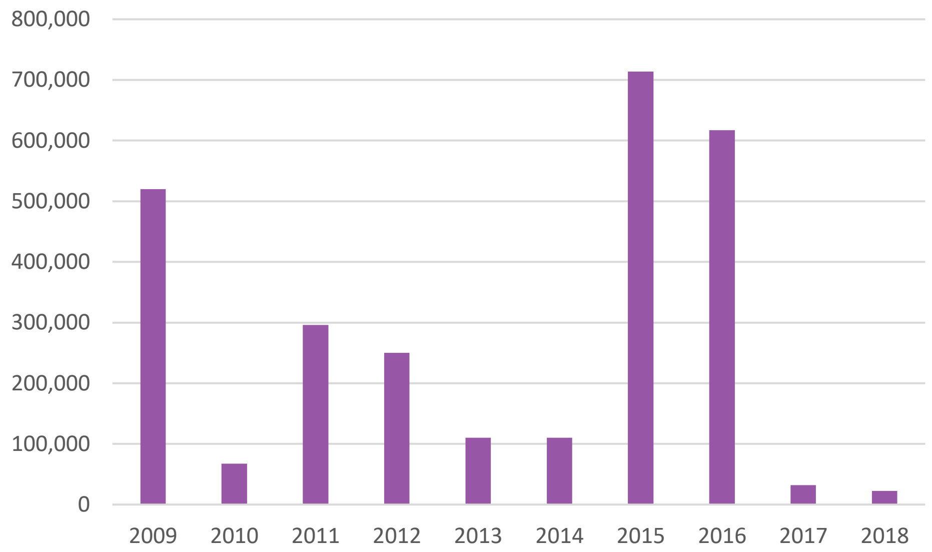
## 3.4 Assessment of costs

### 3.4.1 Physi-Trace R&D costs

The annual costs of the Physi-Trace R&D projects listed previously in Section 3.2 are shown in **Figure 3.2**. It is assumed that the R&D cost of each project is distributed evenly across the relevant financial years of the project.

The annual R&D costs vary considerably from year to year, ranging from a low of $119,849 in FY2018 to a high of $923,270 in FY2015.

**FIGURE 3.2** ANNUAL R&D COSTS OF PHYSI-TRACE PROJECTS, FY2009 TO FY2018 ($)




*SOURCE: ACIL ALLEN CONSULTING CALCULATIONS BASED ON APL DATA*

For the cost-benefit analysis, a 14 per cent administrative/management cost multiplier was used to determine the total expenditure for APL for the projects that have been commissioned, conducted and reported on. This multiplier was applied on top of the annual R&D costs shown in **Figure 3.2**.

### 3.4.2 Costs of maintaining Physi-Trace database and trace backs

The costs of maintaining the Physi-Trace database to a sensitivity at which traceback can be accurately ascribed to the farm level, are estimated by APL at $330,000 per year in 2017 dollars. They include the cost of obtaining samples from producers and abattoirs on a regular basis to ensure the currency of the database and accurate matching during trace backs. Each trace back to a particular farm is assumed to cost $7,000 in 2017 dollars.

To maintain the premium branding of the offal exports to China, it is assumed that an offal trace back for country of origin is undertaken for every 500 kg of offal exports. Each offal trace back for country of origin is assumed to cost $100 in 2017 dollars.

## 3.5 CBA results

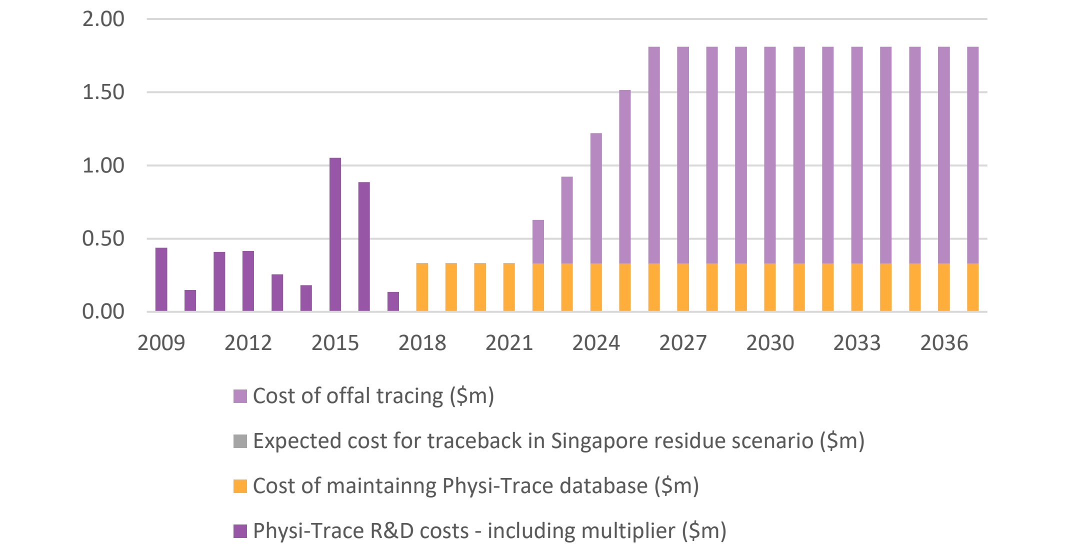
### 3.5.1 Present value of costs

The year-by-year costs associated with Physi-Trace to FY2037 are shown in **Figure 3.3**.

The present value of all costs associated with Physi-Trace to FY2022 is estimated at $6.35 million in 2017 dollars under a 5 per cent real discount rate.

The present value of all costs associated with Physi-Trace to FY2027, FY2037 and FY2047 is estimated at $11.22 million, $19.80 million and $25.07 million in 2017 dollars respectively under a 5 per cent real discount rate.

**FIGURE 3.3** YEAR-BY-YEAR COSTS OF PHYSI-TRACE TO FY2037 ($M)




*SOURCE: ACIL ALLEN CONSULTING CALCULATIONS BASED ON APL DATA*

### 3.5.2 Present value of benefits

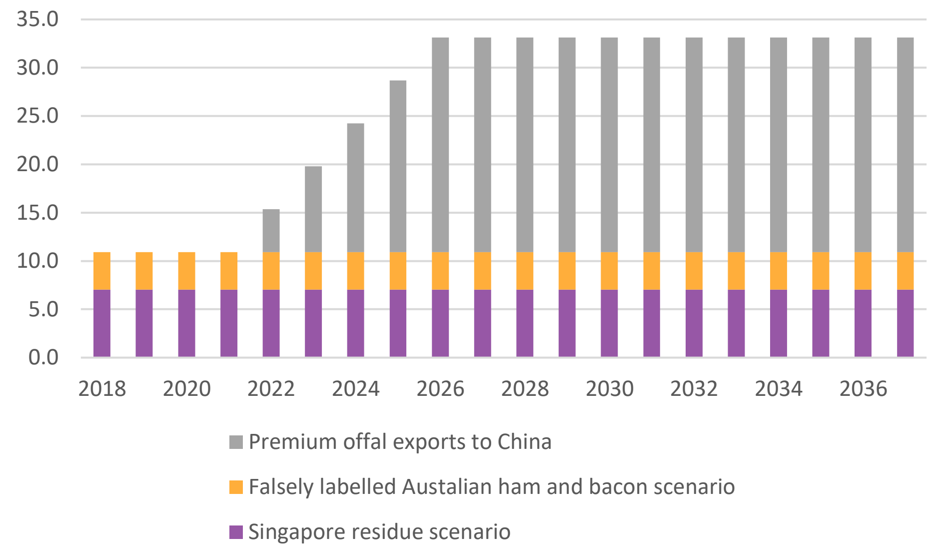
The projected annual benefits of Physi-Trace to FY2037, by benefit stream, are shown in **Figure 3.4**.

The present value of benefits of Physi-Trace to FY2022, across the three benefit streams described previously, is estimated at $50.8 million in 2017 dollars under a 5 per cent real discount rate.

The present value of benefits of Physi-Trace to FY2027, FY2037 and FY2047 is estimated at $143.9 million, $301.0 million and $397.4 million in 2017 dollars respectively under a 5 per cent real discount rate.

Excluding future offal exports to China, the present value of benefits of Physi-Trace to FY2022, FY2027, FY2037 and 2045 would be $47.3 million, $84.4 million, $136.2 million and $168.0 million in 2017 dollars under a 5 per cent real discount rate. These calculations are shown as there is some uncertainty as to whether offal exports to China will eventuate.

**FIGURE 3.4** PROJECTED ANNUAL BENEFITS OF PHYSI-TRACE, FY208 TO FY2037 ($M, 2017 DOLLARS)




*SOURCE: ACIL ALLEN CONSULTING*

### 3.5.3 Net present value

The net benefits or net present value (NPV) of Physi-Trace to FY2022, obtained by subtracting the present value of costs from the present value of benefits, is estimated at $44.4 million in 2017 dollars under a 5 per cent discount rate.

The NPV of Physi-Trace to FY2027, FY2037 and FY2047 is estimated at $132.7 million, $281.2 million and $372.3 million respectively in 2017 dollars under a 5 per cent real discount rate.

Excluding future offal exports to China, the NPV of Physi-Trace to FY2022, FY2027, FY2037 and 2045 would be $41.0 million, $73.2 million, $116.4 million and $142.9 million in 2017 dollars under a 5 per cent real discount rate.

### 3.5.4 Benefit-cost ratio

The benefit-cost ratio (BCR) of the Physi-Trace R&D program to FY2022, obtained by dividing the present value of benefits by the present value of costs, is estimated to be 7.99.

The BCR of Physi-Trace to FY2027, FY2037 and FY2047 is estimated at 12.83, 15.20 and 15.85 respectively.

Excluding future offal exports to China, the BCR of Physi-Trace to FY2022, FY2027, FY2037 and FY2047 would be 7.45, 7.52, 6.88 and 6.70 respectively.

### 3.5.5 Internal rate of return

The internal rate of return (IRR) of Physi-Trace to FY2022, FY2027, FY2037 and FY2047 is estimated to be 43.5 per cent, 48.2 per cent, 48.9 per cent and 48.9 per cent respectively.

Excluding future offal exports to China, the IRR of Physi-Trace to FY2022, FY2027, FY2037 and FY2047 is estimated to be 42.8 per cent, 45.2 per cent, 45.5 per cent and 45.5 per cent respectively.

### 3.5.6 Modified internal rate of return

The modified internal rate of return (MIRR) of Physi-Trace to FY2022, FY2027, FY2037 and FY2047 is estimated to be 25.8 per cent, 26.7 per cent, 21.6 per cent and 17.8 per cent respectively.

Excluding future offal exports to China, the MIRR of Physi-Trace to FY2022, FY2027, FY2037 and FY2047 is estimated to be 25.1 per cent, 22.7 per cent, 17.9 per cent and 15.0 per cent respectively.

## 3.6 Sensitivity analysis

To test the robustness of the CBA results, sensitivity analysis was undertaken by varying key parameters in the 3 analytical scenarios. The results are reported for the 20-year analytical timeframe (that is, to FY2037).

### 3.6.1 Singapore residue incident

**Likelihood of incident**

In the central case of the CBA, it is assumed that the annual probability of a Singapore residue incident is 20 per cent. If this probability is higher at 30 per cent, the BCR rises from 15.20 to 17.40. Conversely, if the probability is lower at 10 per cent, the BCR falls to 12.99.

**Duration for market recovery**

In the central case of the CBA, it is assumed that Physi-Trace enables the period of disruption of the Singapore market to decrease from 3 months to 2 weeks. If the recovery (with Physi-Trace) takes only a week, the BCR rises slightly from 15.20 to 15.32. Conversely, if the recovery takes 3 weeks, the BCR falls slightly to 15.07. If the recovery takes 2 months, the BCR falls to 14.45.

**Decrease in Australian domestic price of pork during incident**

In the central case of the CBA, it is assumed that the Australian domestic price of pork declines from $3.50 per kg to $3.10 per kg during the incident, due to the influx onto the domestic market of pork originally destined for the Singapore market. If the price declines to $2.90 instead, the BCR rises significantly from 15.20 to 17.54. Conversely, if the price declines to $3.30, the BCR falls significantly to 12.86.

### 3.6.2 Falsely labelled “Australian” ham and bacon

**Likelihood of incident**

In the central case of the CBA, it is assumed that the annual probability of a mislabelled “Australian” ham and bacon incident is 5 per cent. If this probability is 8 per cent, the BCR rises from 15.20 to 16.67. Conversely, if the probability is 2 per cent, the BCR falls to 13.73.

**Immediate loss in sales of ham and bacon produced from Australian pork**

In the central case of the CBA, it is assumed that Physi-Trace reduces the immediate loss in the sales of ham and bacon produced from Australian pork from 20 per cent to 10 per cent. If the reduction is from 20 per cent to 5 per cent instead, the BCR rises from 15.20 to 15.44. Conversely, if the reduction is from 20 per cent to 15 per cent, the BCR falls to 14.95.

**Duration for market recovery**

In the central case of the CBA, it is assumed that Physi-Trace reduces the market recovery period from 3 years to a year. If the recovery period is reduced to only 6 months, the BCR rises from 15.20 to 15.44. Conversely, if the recovery period is reduced by Physi-Trace from 3 years to 2 years, the BCR falls to 14.71.

### 3.6.3 Offal exports to China

**Price of premium branded Australian offal in China**

In the central case of the CBA, it is assumed that premium branded Australian offal (backed by Physi-Trace) can command $5.00 per kg in the Chinese market. If this price is $6.50 per kg instead, the

BCR rises considerably from 15.20 to 19.36. Conversely, if this price is only $3.50 per kg, the BCR falls to 11.04.

**Share of offal production that is exported to China**

In the central case of the CBA, it is assumed that by 2026 25 per cent of offal produced in Australia will be exported to the Chinese market, with this proportion remaining constant at 25 per cent thereafter. If this proportion flat lines at 35 per cent in 2028 instead, the NPV rises from $281.2 million to $323.0 million (both in 2017 dollars). If the proportion flat lines at only 15 per cent in 2024, the NPV falls to $228.6 million in 2017 dollars.

**Cost of an offal trace**

In the central case of the CBA, it is assumed that each offal trace costs $100. If this cost is decreased to $50, the BCR rises from 15.20 to 21.03. Conversely, if this cost is increased to $150, the BCR falls to 11.90.

**Average export volume per offal trace**

In the central case of the CBA, it is assumed that a trace back is undertaken for every 500 kg of offal exported to China. If this sampling intensity is decreased to a trace back for every 1,000 kg of offal exported, the BCR rises from 15.20 to 21.03. Conversely, if the sampling intensity is increased to a trace back for every 250 kg of exported offal, the BCR falls to 9.78.

## 3.7 References

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4

# NUTRITION

ACIL Allen conducted a cost-benefit analysis of key nutrition R&D projects that have been funded by APL.

## 4.1 Overview of APL-funded nutrition R&D

A key challenge that continues to be faced by the Australian pig industry is variable feed intake of pigs at different production stages, and the potential negative consequences that this may have on pig health and/or growth performance. Efficiency of feed utilisation is also a major and ongoing industry constraint that significantly affects margin over feed cost (MOFC), which is the major driver of industry profitability.

In response, APL commissioned and funded a series of research projects that examined the effect of different dietary additives on feed intake of grower and finisher pigs and explored some of the underlying physiological and neuro-endocrinological mechanisms that might be involved.

Another strand of research commissioned by APL examined the efficacy of nutritional interventions in enhancing the performance of light weight weaners in order to reduce overall variation at slaughter.

## 4.2 Research projects

Of the APL-funded nutrition R&D projects assessed by ACIL Allen, lauric acid (LA) was found to be the most promising dietary additive in pig production. While both LA and mineral salts (calcium chloride and sodium triphosphate) reduced average daily feed intake (ADFI), there was a reduction of 13.0 per cent and 10.3 per cent on average daily growth (ADG) in the pigs fed mineral salts and mineral salts plus LA respectively. On the other hand, pigs fed LA at 25g/kg maintained an ADG similar to that of pigs on the control diet. There was no dietary effect of any of the additives on P2 backfat depth nor on parameters of pork quality.

In addition, while the inclusion of albus lupins at 20 per cent reduced feed intake, the growth rate during the last 28 days of growth was adversely impacted by approximately 15 per cent. These or other APL projects also found epigallocatechin gallate (EGCG), n-oleoyethanolamide (OEA), boron, vitamin E, cinnamon and omega-3 fatty acids (n-3 FA) to be ineffective in suppressing feed intake.

The aims, methods and findings of the R&D projects are summarised below.

### APL Project 2015/051 – Non-starch polysaccharides (NSP) contents of common feed ingredients

*Organisation undertaking the research: University of New England*

**Project aims**

The aim of this project was to establish a non-starch polysaccharide (NSP) database for use in feed formulation by measuring the soluble and insoluble NSP contents of feed ingredients used in pig and poultry feeding.

The values presented in this project will enable the industry to make accurate predictions about the true fibre values in diets and allow new technologies to be developed and evaluated that determine and potentially improve the nutritional value of fibre and high fibre co-products.

Having the soluble, insoluble and total NSP levels included in nutrient databases will also enable nutritionists to use different ingredients judicially in terms of enzyme application and setting proper fibre levels.

**Project method**

The soluble, insoluble and oligosaccharide contents of 835 feed ingredient samples from Australia were collated into a database, based on values measured at UNE or presented in literature. The database comprises a minimum of 10 replicate samples for each ingredient and includes values for both conventional and unconventional ingredients used in the pig and poultry industry.

**Project findings**

The database presents the average, range and sugar composition of the soluble, insoluble and total NSP and oligosaccharide contents of the ingredients. These values can be added to nutrient databases used for feed formulation.

### APL Project 2014/445 – Management strategies to reduce feed intake and back fat in pigs receiving Improvac®

*Organisation undertaking the research: Department of Agriculture and Food Western Australia*

**Project aims**

This project included two experiments that were designed to investigate the use of in-feed ingredients such as *Lupinus albus* (albus lupins) and a combination of calcium chloride and sodium tri-phosphate (mineral salts) to suppress the voluntary feed intake of immunocastrated (IC) male pigs.

**Project method**

The first experiment was a 2×3 factorial comprising two sexes (entire males and IC males) and three dietary treatments (control, 3% calcium chloride + 1.6% sodium tripolyphosphate, or 200-300 g/kg albus lupins).

The second experiment was also a 2×3 factorial, comprising two sexes (entire males and IC males) and three dietary treatments (control, 200 g/kg albus lupins for the last 28 days prior to slaughter (Albus28) or only for the last 14 days (Albus14)).

**Project findings**

In the first experiment, IC male pigs fed the mineral salt diet ate less feed than those fed the control diet (2.92 vs. 3.16 kg/day) with no effect on growth rate. IC male pigs fed the albus lupin diet had both a reduced feed intake and growth rate compared to those fed the standard finisher diet (2.30 vs. 3.16 kg/d and 0.86 vs. 1.15 kg/d for feed intake and growth performance, respectively).

Albus lupins thus show potential in reducing voluntary feed intake and thereby reducing the increase in backfat associated with IC males, although growth rate was adversely affected. Mineral salts may be useful in situations where a reduction in feed intake and improvement in feed conversion is desired and reducing back fat is not the objective.

In the second experiment, the inclusion of albus lupins at 20 per cent in the diets of IC male pigs was successful at reducing feed intake, body fat and backfat to similar levels of entire males. However, the growth rate of the IC male pigs during the last 28 days of growth was adversely impacted by approximately 15 per cent, which is more than would be desirable in commercial pork production.

### APL Project 2013/2411 – Reducing variation in finisher performance – early (<35 kg) intervention

*Organisation undertaking the research: CHM Alliance Pty Ltd*

#### Project aims

The primary objective of this project was to reduce the variation in slaughter stock by enhancing the performance of light weight weaners with nutritional interventions up to 35 kg live weight, which would be assessed by measuring the comparative growth performance of light weight weaners post-35 kg when they had an extended period of nutritional intervention pre-35 kg.

#### Project method

This experiment was a randomised block design with weaner weight as the blocking factor. Three groups of weaner weights were investigated - a Control group, a Low group and a High group, with eight replicates per treatment.

The standard feeding program consisted of six diets. The Creep diet was fed for the first four weeks and then subsequent diets were fed to match the average weight of the treatment such that diet transitions occurred at different stages for the Control and High treatments. The modified feeding program saw the Low pigs receive the Creep diet until they reached 35 kg live weight, whereupon they transitioned directly to the Grower diet, with this and subsequent diets being fed to match the average weight as per the program the Control and High treatment received.

#### Project findings

This project shows that a compromised weaner will remain a compromised grower and finisher pig. Despite an intervention that increased feed costs per kg of gain by 15 per cent, there was no boost in the performance of Low weight weaners to the mean level of the population, let alone to the performance of High weight weaners.

The main recommendation from this study to researchers and funding bodies is that it is hard to influence the performance of the pig post-weaning, and that return on expenditure is likely to be better from projects or interventions that result in a larger weaner being produced than from projects or interventions trying to remediate the compromised weaner.

### APL Project 2013/2406 – Development of nutritional strategies to attenuate the impact of poor environments through down-regulation of eicosanoid mediators

*Organisations undertaking the research: Department of Agriculture and Food Western Australia, Murdoch University, Rivalea Australia Pty Ltd*

#### Project aims

The hypotheses tested in this project were:

1. Dietary supplementation of boron will improve intestinal barrier function through down-regulation of eicosanoid mediators.
2. Supplementation of vitamin E and omega-3 fatty acid with boron will synergistically down-regulate eicosanoid mediators.

#### Project method

Two experiments were conducted. Experiment 1 used a total of 35 individually-housed male weaner pigs weighing 6.2 ± 0.05 kg (mean ± SEM) in a completely randomised block experiment with five dietary treatments (n=7 pigs per treatment).

1. Control diet (commercially formulated diet).
2. Control diet + 7.5 mg/kg boron.
3. Control diet + 7.5 mg/kg boron + vitamin E (200 IU)
4. Control diet + 7.5 mg/kg boron + 20 g/kg omega-3 fatty acids.

5. Control diet + 7.5 mg/kg boron + vitamin E + 20 g/kg omega-3 fatty acids

Pigs were orally challenged with enterotoxigenic E. coli on day 7, 8 and 9 after weaning and euthanised for blood and tissue sample collection on day 10 after weaning. Tissue and blood samples were used for measurements of intestinal health and immunity markers.

Experiment 2 used a total of 770 finisher pigs weighing 52.2 ± 1.17 kg (mean ± SEM). A completely randomised block experiment with five dietary treatments (14 pigs per pen x 11 replicate pens per treatment x 5 treatments) was conducted in a commercial finisher facility. Pigs were fed for 48 days and performance parameters were recorded.

**Project results**

Although correlation analysis showed a number of positive relationships between intakes of boron, vitamin E and *n*-3 FA on intestinal structure, tight junction protein expression and empty body weight, the experimental hypotheses were not supported. Therefore, it is concluded that dietary inclusion of boron, vitamin E and *n*-3 FA in diets for weaner and finisher pigs had limited impact on the intestinal health and performance of pigs.

### APL Project 2012/1034.494 – Dietary mechanisms to suppress voluntary feed intake in pigs

*Organisation undertaking the research: Murdoch University*

**Project aims**

The objective of this research project was to examine the effect of different dietary additives on pig feed intake in growing and finishing pigs, and to explore some of the underlying physiological and neuro-endocrinological mechanisms possibly involved.

**Project method**

Three experiments were undertaken. In Experiment I, a total of 28 individually-housed finishing pigs with a starting body weight (BW) of 66.9 ± 0.19 kg (mean ± SD) was used in a randomised complete block design to examine the effects of diet on performance indices in the finisher period (n = 7 pigs per treatment). Pigs were fed *ad libitum* for three weeks and Average Daily Growth (ADG) and Average Daily Feed Intake (ADFI) were measured weekly.

Dietary treatments consisted of: (i) Control diet (commercially formulated diet); (ii) Control diet + 4% Ca-Chloride ($CaCl_2$) + 2.2% Na-triphosphate ($Na_5P_3O_{10}$) (S); (iii) Control diet with CDCA (chenodeoxycholic acid) included at 120 mg/kg BW (CDCA); and (iv) Control diet + 50 g/kg lauric acid (LA).

Experiment II was conducted to determine whether the use of various pharmacological agents, some of which are used in human medicine and health to modulate feed intake, might have similar effects in pigs. A total of 30 individually-housed finisher pigs with a starting BW of 66.1 kg was used in a randomised complete block design of treatments to examine the effects of several dietary additives on performance in the finisher period.

Pigs were fed *ad libitum* during the three-week study, and ADFI and ADG were measured weekly. Dietary treatments comprised the following: (i) Control diet (C) (n=9); (ii) Control diet + (-)-epigallocatechin gallate [EGCG; a black tea extract and FAS (fatty acid synthase) inhibitor at 8,000 mg/pig/day] (EGCG) (n=7); (iii) Control diet + n-oleoyethanolamide added at 1,000 mg/pig/day (OEA) (n=7); and (iv) Control diet + sitagliptin added at 200 mg/pig/day (sitagliptin) (n=7).

In Experiment III, the effect of including $CaCl_2$+$Na_5P_3O_{10}$ and LA in the diet was measured on pig performance, carcass fatness and meat quality under commercial conditions. The possible mechanisms of action of the compounds were also explored.

A total of 420 pigs housed in pens of seven pigs each, with a starting BW of 83.9 ± 0.21 kg LW (mean ± SD), was used in a randomised complete block design study to examine the effects of the inclusion of $CaCl_2$+$Na_5P_3O_{10}$ and LA at two different levels, and the combination of both the salts and LA at low levels (n=10 pens of seven pigs per pen).

The study started in two equal batches (210 pigs; five pens per treatment in each batch) two weeks apart. Pigs were fed *ad libitum* different diets (as follows) during the four week-finisher period, following one week of acclimation where they were fed the Control diet. The diets were: (i) Control (C); (ii) Control + 25 g/kg (2.5%) LA (Low LA); (iii) Control + 50 g/kg (5.0 %) LA (High LA); (iv) Control + 1% $CaCl_2$ + 0.55% $Na_5P_3O_{10}$ (Low S); (v) Control + 2% $CaCl_2$ + 1.1% $Na_5P_3O_{10}$ (High S); and (vi) Control + 1% $CaCl_2$ + 0.55% $Na_5P_3O_{10}$ + 25 g/kg (2.5%) LA (LA+S).

**Project findings**

The results of the three experiments collectively indicated that a reduction of feed intake in finisher pigs can be achieved by the inclusion of $CaCl_2$+$Na_5P_3O_{10}$ in the diet. Feed intake can also be reduced by the use of LA in the diet of pigs.

Results showed a significant reduction of 10.8 per cent on average in ADFI in pigs fed LA, a mix of Ca-chloride and Na-triphosphate (at low and high levels), or the mix of LA and Ca-chloride + Na-triphosphate over the 28-day period.

However, there was a significant consequent reduction of 13 and 10.3 per cent on ADG in the pigs fed Low S and High S and the mix LA + S, respectively, compared to the Control pigs. Pigs fed LA at 25 g/kg (Low LA) maintained an ADG similar to that of pigs on the Control diet.

Performance results were reflected on the carcass measurements, and there was no dietary effect on the P2 backfat depth nor on parameters of pork quality.

**APL Project 2012/1027 – Effect of dietary cinnamon on growth performance and adiposity in pigs**

*Organisation undertaking the research: The University of Melbourne*

**Project aims**

A previous study on a single dose of 1.25% cinnamon in the diet of finisher pigs found improved feed conversion ratio (FCR), daily gain and glucose clearance after an intravenous glucose tolerance test. Dietary cinnamon also increased ($P<0.05$) the expression of some of the insulin-signaling and other genes in skeletal muscle. This study was conducted to determine the optimum dose of cinnamon and whether it varied with the sex of the pig.

**Project method**

Sixty Large White and Landrace cross-bred finisher boars (n=30) and gilts (n=30) with an initial average live weight of 61.5 kg were weighed and stratified on live weight into five blocks within each sex. Within each block, pigs were randomly allocated to an individual pen and then randomly allocated into one of six diets containing either 0, 0.33, 0.67, 1.0, 1.33 and 1.66% cinnamon offered ad libitum.

The control diet was a wheat-based diet containing 14.0 MJ digestible energy/kg, and 0.69 g available lysine/MJ DE and 3.0% fat. The diets were formulated to meet requirements. Feed intake and live weight were recorded weekly.

**Project findings**

The major finding from this study was that dietary cinnamon may increase growth rate and feed efficiency in finisher pigs but that the responses seem to be limited to gilts and may be only transient in nature. Also, there was no clear plateau in response with the response being maximised at the highest dose investigated.

Since there was no clear dose response, the inclusion rate appears to be at least 1.25 per cent or even higher, which may preclude its use commercially.

## 4.3 Assessment of costs

The budgets of the nutrition R&D projects commissioned and funded by APL are shown in **Table 4.1**. They include the cash contribution by APL and the cash and in-kind contributions by organisations undertaking the R&D. The total budget of the projects is $1.785 million.

**TABLE 4.1** APL-FUNDED NUTRITION R&D PROJECTS – PROJECT BUDGETS INCLUDING CASH AND IN-KIND CONTRIBUTIONS BY R&D ORGANISATIONS

| Project number | Project title | Project budget |
|---|---|---|
| | **Completed projects** | |
| 2013/2406 | Development of nutritional strategies to attenuate the impact of poor environments through down-regulation of eicosanoid mediators | $163,850 |
| 2015/051 | Establishment of a soluble and insoluble NSP database by University of New England for all feed ingredients commonly fed in the pig and poultry industry to replace crude fibre values in feed formulation. | $421,500 |
| 2014/445 | Management strategies to improve feed efficiency and reduce the increase in backfat in pigs receiving Improvac® | $99,764 |
| 2012/1034.494 | Dietary Mechanisms to Suppress Voluntary Feed Intake | $101,300 |
| 2012/1027 | Effect of dietary cinnamon on growth performance and adiposity in pigs | $87,000 |
| 2013/2411 | Reducing variation in finisher performance - early (<35 kg) intervention. | $200,000 |
| | **Projects not yet completed** | |
| 2015/019 | Development of nutritional strategies to reduce initiation of the stress response by suppression of relevant neurotransmitters | $290,150 |
| 2015/015 | The role of the n-6:n-3 polyunsaturated fatty acid ratio on the health and performance of grower finisher pigs | $129,913 |
| 2015/014 | The supplementation of pig diets with mineral strontium | $65,408 |
| 2012/1034.495 | Dietary manipulation of feed intake in pigs by bitter compounds | $226,350 |

*SOURCE: APL*

Extension costs have not been estimated by APL and are not included in the cost-benefit analysis.

The annual cost of the nutritional supplements that may be potentially adopted by the Australian pig industry is discussed in the next section.

## 4.4 Assessment of benefits

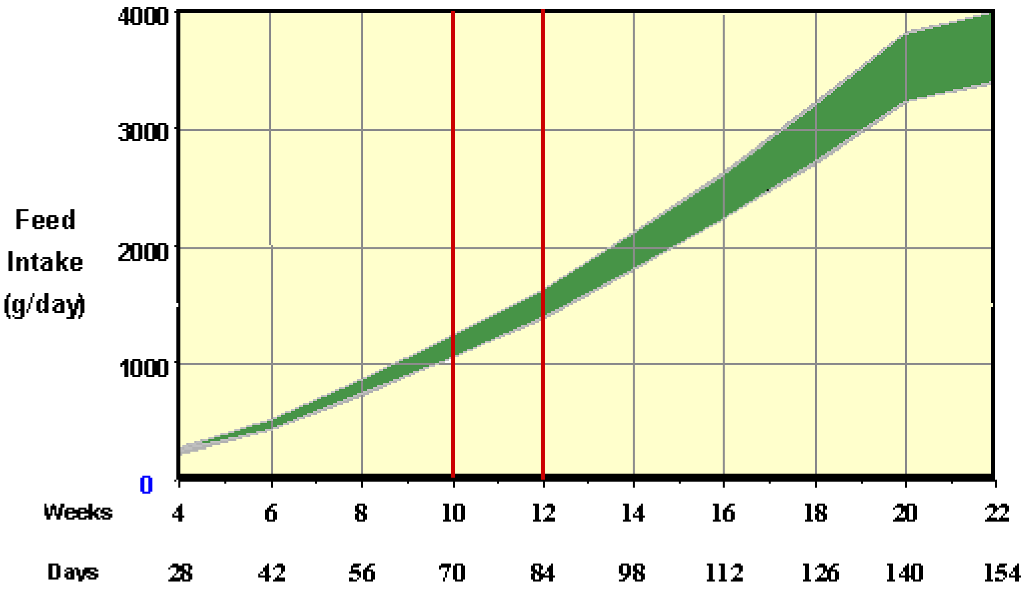
As discussed previously in Section 4.2, the APL-funded nutrition R&D projects assessed by ACIL Allen indicate that LA is the most promising dietary additive in pig production.

According to APL Project 2012/1034.494, pigs fed LA at 25g/kg as a supplement had a 10.8 per cent reduction in ADFI during the 28-day finishing period prior to slaughter with no change in ADG.

At a LA price of $3.50 per kg and assuming a daily feed intake of 3.0 kg (see **Figure 4.1**), the daily cost of the LA supplement (at 25g/kg) is $0.2625 per pig. The cost per pig over the 28-day finishing period is $7.35.

On the benefits side, the reduction in ADFI is worth $0.1233 per pig, assuming daily feed intake of 3.0 kg per pig and feed cost at $380.60 per tonne (being a weighted average of the feed cost in Queensland at $460 per tonne and the feed cost in the rest of Australia at $360 per tonne, with the weights based on March 2018 production figures). The benefit per pig over the 28-day finishing period is $3.45. The net benefit per pig is thus -$3.90. That is, at the current price of LA, the cost of the supplement exceeds its benefit in reduced feed cost.

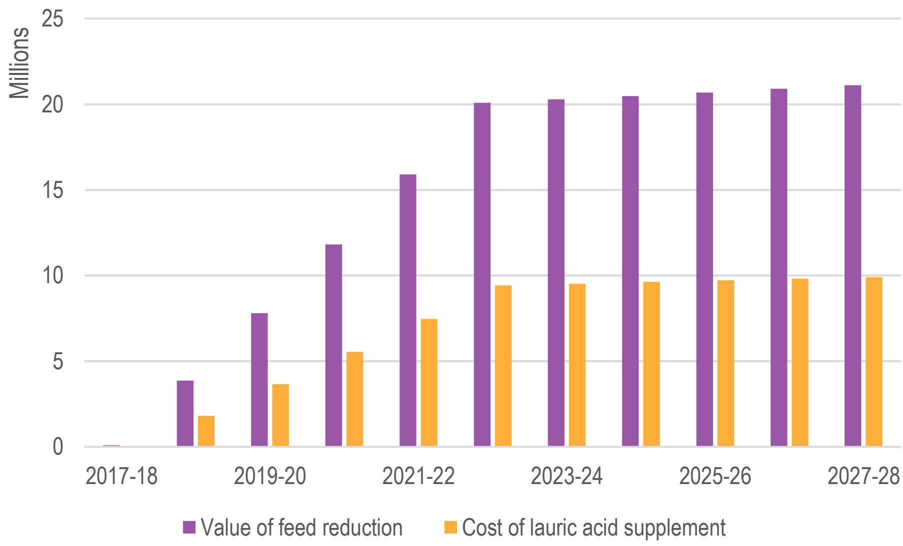
**FIGURE 4.1** PIG AVERAGE DAILY FEED INTAKE




*SOURCE: WWW.THEPIGSITE.COM/STOCKSTDS/18/DAILY-FEED-INTAKE/*

Assuming that annual pig production increases at 1 per cent each year from the current level of approximately 520,000 tonnes a year, the annual costs and benefits of LA as a feed supplement to 2027-28 is shown in **Figure 4.2**. A linear adoption profile (rising from zero per cent in 2017-18 to 50 per cent of the Australian pig industry in 2022-23 in increments of 10 per cent a year) is assumed. The analysis period ends in 2027-28 as it is assumed the APL-funded nutrition research brings forward the findings on the efficacy of LA as a nutritional supplement in pork production by 10 years.

**FIGURE 4.2** COSTS AND BENEFITS OF LA AS A FEED SUPPLEMENT (2017-18 DOLLARS)




*SOURCE: ACIL ALLEN CONSULTING*

While the use of LA as a dietary supplement is uneconomic at the current LA price, the benefits of LA will exceed its cost when the price of LA falls below $1.65 per kg.

In addition, APL's nutrition R&D program has generated valuable knowledge about the efficacies of different potential dietary supplements that will help guide researchers as to which are the most promising areas they should focus their future research on. This knowledge is particularly valuable given the significant impact of feed costs on the profitability and financial viability of the pig industry in Australia.

## 4.5 CBA results

The present value of total costs (encompassing the cost of the APL nutrition research program between 2011-12 and 2017-18 and the industry cost of the LA supplement between 2017-18 and 2027-28) is $116.6 million in 2017-18 dollars under a 5 per cent real discount rate.

At the current prices of nutritional supplements, the present value of quantified and monetised benefits in reduced feed cost for the pig industry in Australia is projected to be $53.6 million in 2017-18 dollars under a 5 per cent real discount rate.

The net present value (NPV) of APL's nutrition research program, obtained by subtracting the present value of costs from the present value of monetised benefits, is thus projected to be -$62.9 million in 2017-18 dollars under a 5 per cent real discount rate. The benefit-cost ratio (BCR), obtained by dividing the present value of benefits by the present value of costs, is 0.46.

(In the shorter time horizon to 2022-23, that is 5 years from the base year of 2017-18, the present values of costs and benefits are $49.8 million and $22.3 million respectively in 2017-18 dollars under a 5 per cent discount rate, while the NPV is -$27.5 million and the BCR is 0.45.) The internal rate of return (IRR) cannot be calculated because the returns to the R&D investment are negative.

## 4.6 Sensitivity analysis

ACIL Allen has undertaken sensitivity analysis to test the robustness of the cost-benefit analysis results to changes in key assumptions and parameter values.

In the central case of the cost-benefit analysis, the average cost of feed is assumed to be $380.60. If the average cost of feed is higher by 25 per cent at $452.10, the BCR increases from 0.46 to 0.55. Conversely, if the average cost of feed is lower by 25 per cent at $309.10, the BCR decreases to 0.37.

In the central case of the cost-benefit analysis, the cost of LA is assumed to be $3.50 per kg. If the cost of LA is 50 per cent higher at $5.25 per kg, the BCR decreases from 0.46 to 0.31. Conversely, if the cost of LA is 50 per cent lower at $1.75 per kg, the BCR increases to 0.90. In the central case of the cost-benefit analysis, the daily feed intake is assumed to be 3 kg per pig. If the daily feed intake is 4 kg per pig, the BCR increases marginally from 0.460 to 0.463. Conversely, if the daily feed intake is 2 kg per pig, the BCR decreases very slightly to 0.455.

In addition, the choice of the real discount rate has virtually no impact on the BCR.

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5

# BIOSECURITY / EXOTIC DISEASES

ACIL Allen conducted a cost-benefit analysis of R&D projects on biosecurity and exotic diseases that have been funded by APL.

## 5.1 Overview of APL-funded R&D in biosecurity and exotic diseases

Australian agriculture benefits enormously from its freedom from the more devastating epidemic diseases that plague livestock industries in other parts of the world. The introduction of exotic diseases could cause serious production losses to Australia's livestock industries, jeopardise export markets for livestock products and/or have serious public health implications.

It is therefore essential that effective contingency plans and trained personnel are available to counter any diseases that penetrate Australia's quarantine barriers. The Australian Veterinary Emergency Plan (AUSVETPLAN) is a coordinated national response plan for the control and eradication of high impact animal diseases.

APL is party to the Emergency Animal Disease Response Agreement (EADRA). This deed splits financial responsibilities in the event of a disease outbreak between impacted industries and the government.

The main emergency animal diseases (EADs) that could affect the pig industry are: Foot and Mouth Disease (FMD), Classical swine fever, African swine fever, Aujeszky's disease, Porcine reproductive and respiratory syndrome (PRRS), Postweaning multisystemic wasting syndrome (PMWS) and Porcine Epidemic Diarrhoea virus (PEDv).

Farm biosecurity focuses on practices that producers can implement on farm to keep diseases out. Keeping diseases out is important to pig producers because diseases can reduce the productivity of livestock, affect farm incomes, affect animal welfare, reduce the value of farming land, close export markets and/or reduce the prices Australian producers can get for their exports – with a flow-on effect to domestic prices.

Recognising the serious economic impact that lapses in biosecurity and presence of exotic diseases would have on the Australian pork industry, APL commissioned and funded a series of R&D projects that focused on biosecurity and exotic diseases. These projects are described in the next section.

## 5.2 Research projects

### APL Project 2013/2416 – Detection of *Clostridium difficile* in piggery effluent treated in on-site ponds and prevalence in biosolid by-products including land application, compost, and root vegetables

*Organisations undertaking the research: University of Western Australia School of Pathology and Laboratory Medicine; PathWest Laboratory Medicine, Microbiology Research and Development, Queen Elizabeth II Medical Centre*

The objectives of the research project were to:

1. Detect and quantify viable *C. difficile* spores in piggery effluent before and after treatment in onsite pond systems.
2. Determine the prevalence and molecular type of viable *C. difficile* spores in biosolid-enriched soils, either through irrigation or direct land application of sludge.
3. Determine the prevalence and type of viable *C. difficile* spores in compost that contains organic material of porcine origin.
4. Determine the prevalence and molecular type of *C. difficile* spores in Australian-grown root vegetables.

In the study, *C. difficile* was isolated from raw effluent in 100 per cent (7/7) of farms investigated, with the same strain isolated from treated effluent in 71 per cent (5/7) of farms. This indicates that *C. difficile* was able to survive effluent treatment. It was also detected in 92 per cent (11/12) of effluent-applied soil samples.

On average, *C. difficile* was isolated from 20 per cent (14/71) organic Australian-grown vegetable samples from 11 retailers in Western Australia, comprising 5 per cent (1/19) carrots, 6 per cent (1/18) onions, 22 per cent (4/18) beetroot and 50 per cent (8/16) potatoes.

Thirteen different PCR ribotypes were identified in the study, 11 of which matched human or animal ribotypes in the database including UK 237 (A-B+CDT+), a strain unique to a single Australian piggery, and QX 158 (A+B+CDT-), the same strain responsible for a recent outbreak in humans in WA. This data was sufficient to suggest that current effluent management practices within the Australian pork industry pose a risk in relation to dispersal of toxigenic strains of *C. difficile*, and that a broader risk-management assessment is required.

### APL Project 2013/2419 – National animal biosecurity RD&E strategy implementation project

*Organisation undertaking the research: Animal Health Australia*

The objectives of the research project were to:

1. Develop, implement and evaluate Australia's long-term strategic RD&E needs and priorities
2. Promote and facilitate collaboration amongst stakeholders
3. Monitor Australia's RD&E capability
4. Evaluate, review and report on the implementation of the strategy.

### APL Project 2013/2422 – Swill feeding compliance and awareness project

*Organisation undertaking the research: Animal Health Australia*

The objectives of the research project were:

1. FMD prevention – to ensure through legislative compliance that, in the unlikely event of FMD entering/occurring in Australia, it will not be spread through stock feeds and the feeding of swill.
2. Market confidence - to maintain a nationally integrated inspection system to ensure and demonstrate compliance with legislation that bans the feeding of swill to pigs.
3. Communications – to raise awareness of swill feeding issues along the pig production chain and suppliers (e.g. feed).
4. To review the needs and priorities relevant to compliance with the SFCAP and advise SAFEMEAT and AHC.

### APL Project 2014/505 – Foot and Mouth Disease real-time training program

The purpose of the program was to train Australian pig industry health professionals in the recognition of FMD.

The key messages disseminated in the program were:

— FMD continues to be one of the greatest threats to the economy and viability of the livestock industries in Australia.
— A widespread outbreak of FMD could cost the economy in excess of $12 billion.
— Governments and industry have taken the initiative to invest in a hands-on training program that allows livestock health professionals to recognise and detect FMD in a country where the disease is endemic.
— Vets and livestock officers will gain a comprehensive knowledge about FMD virus strains that pose a geographic high risk to Australia.
— Greater knowledge of the disease and on-farm Biosecurity will greatly assist in reducing the spread of FMD in the event of an outbreak.

### APL Project 2014/483 – The epidemiology of African swine fever virus and its potential for introduction into Australia

*Organisation undertaking the research: Epi-Insight Limited*

A systematic review of the scientific literature on African swine fever was conducted. The worldwide English-language literature was surveyed using PubMed and supplemented by other sources of peer-reviewed papers. The non-peer-reviewed literature on African swine fever was included infrequently when important or unusual data could not be identified elsewhere. The review included published papers from 1921 through October 2014.

The literature review uncovered detailed information on the epidemiology of the African swine fever virus and its potential for introduction into Australia.

### APL Project 2014/484 – The significance of feral pigs as a transmission vector or reservoir species for PRRS virus Australia

*Organisation undertaking the research: Epi-Insight Limited*

The objectives of the project were:

1. To understand the role of feral pigs in initiating an outbreak of porcine reproductive and respiratory syndrome (PRRS) in Australia.
2. To determine the likelihood of feral pigs to act as a persistent reservoir for PRRS virus in the event Australia experienced an incursion of PRRS virus.

Three outbreak scenarios were developed to evaluate the effect of single- versus multi-centric incursions of PRRS from feral pigs into backyard pigs (BYPs) and in the case of multi-centric incursions, the effects of various combinations of temporal and spatial proximity amongst the incursion events were determined.

Outbreaks were simulated in semi-rural areas of north QLD (Townsville area), south QLD (Darling Downs region), NSW (Central West region), VIC (Murray River region), and WA (South West region). Each outbreak model was simulated through 99 iterations, each lasting 365 days. The outbreaks were allowed to develop in the absence of any control measures.

The study found that Scenario 1 outbreaks that were initiated in a single BYP farm tended to remain localized, usually involving fewer than 100 herds. Infrequently the outbreak extended into the commercial sector.

Scenario 2 outbreaks initiated in five BYP herds at intervals of up seven days were much larger in scale than Scenario 1 outbreaks and were in fact much larger than the ‘5-times’ multiplier that might be expected. There was no statistical difference in the resulting outbreaks if the primary herds were infected at 3, 5, or 7-day intervals. Median size outbreaks generally involved 350 to 500 herds; small BYP herds represented most of the infected population.

Scenario 3 outbreaks were very similar in scale to Scenario 2 outbreaks. However, the Scenario 3 outbreaks developed more slowly, as might be expected as a result of the 30-day interval between primary farm infections.

The study found that no features unique to the Australian feral pig population could be identified that suggested epidemiological features of the disease, different than those present in other parts of the world, would predominate in Australia.

**APL Project 2014/486 – Assessing the risk of feral pigs interacting with domestic pig herds in southeastern Australia**

*Organisation undertaking the research: CSIRO Biosecurity*

The study aimed to:

1. Develop a habitat suitability model for feral pigs that applies to areas of south-eastern Australia where most domestic pig herds occur
2. Develop a metric to spatially represent the relative risk of feral pigs coinciding with domestic pig herds
3. Generate risk maps for domestic herds encountering feral pigs
4. Provide management recommendations relating to biosecurity implications of this work, and for future research and development

A habitat suitability model was developed for feral pig habitat in south-eastern Australia. The model was built on expert knowledge from participants with experience in feral pig research and management across states. Habitat suitability for feral pigs was a function of food availability, water availability, thermal refuge and cover from disturbance. Four model scenarios were run to account for seasonal (summer or winter) and climatic (wet and dry conditions) conditions.

Relative risk zones were identified where highly suitable feral pig habitat (probability > 0.5) occurred within the vicinity of commercial piggeries. An identified area of suitable habitat within 100 m of a piggery was considered high risk. An identified area of suitable habitat between 100-500 m was considered moderate risk.

The study found that suitable feral pig habitat was mainly driven by water and food availability and was greatly influenced by seasonal growing conditions and climate. Suitable habitat was much more extensive in wet years in winter compared with summer in dry years, with a concomitant increase in risks to commercial piggeries. Year-round irrigated cropping areas removed the seasonality effect, creating a wet year each year.

The results of the study highlighted the potential threat that feral pigs pose to the commercial pig industry, and how an improved spatial representation of that threat can help the industry better prepare for future disease incursions.

**APL Project 2015/030 – Reverse zoonoses affecting pigs, and the risk to Australian pig production. A critical review to direct risk assessment and management recommendations**

*Organisation undertaking the research: Murdoch University School of Veterinary and Life Sciences*

The objectives of the research were to:

1. Perform a comprehensive and critical review of the scientific literature addressing zooanthroponoses affecting swine.
2. Perform a qualitative risk analysis/assessment of zooanthroponotic organisms concentrating on likelihood and potential modes of entry into Australian pig production systems.
3. Provide a management document utilising the background information in objective 1 and the risk analysis in objective 2 to provide recommendations on management practices aimed at preventing zooanthroponotic infection in Australian pig herds.
4. Outline knowledge gaps both in Australia and internationally.

In order to ensure a balance between industry and academia, a multi-tiered approach was taken to the review and ranking process. Firstly, an extensive literature review was undertaken by the authors of this report, to determine those agents which had some basis in the scientific literature for consideration as zooanthroponotic agents. Secondly, the authors included a small number of organisms which, while not appearing in the literature as confirmed zooanthroponotic agents, none the less were considered as agents which should be assessed for risk. Finally, to determine the ranking of these agents, a semi-quantitative risk prioritization system was developed which relied upon evidence-based expert opinions combined with stakeholder input from the Australian pork industry.

The review identified 22 agents with reverse zoonotic potential which could present some risk to the Australian pig production industry. Following development and dissemination of a detailed questionnaire, 22 responses from industry representatives were used to finalise a scoring matrix, and this was then used to rank the pathogens according to their score.

### APL Project 2015/070 – Evaluation of diagnostic assays for porcine epidemic diarrhoea coronavirus (PEDV)

*Organisation undertaking the research: NSW Department of Primary Industries*

The objectives of the research project were:

1. Assemble a collection of samples from animals across the Australian pig herd
2. Secure suitable kits and PEDV reference samples
3. Evaluate commercially available diagnostic qRT-PCR kits by testing the reference and Australian samples. Compare the performance of the best kit(s) with an 'in house' assay used in a large US diagnostic laboratory
4. Identify the performance characteristics of the preferred diagnostic kit(s) and provide recommendations on their use.

This study evaluated four commercially available qRT-PCR assays and two 'in-house' assays provided by US diagnostic laboratories by the testing of a reference collection (n=141) and samples from Australian origin (n=484).

Through the completion of a national survey, this study provided evidence for the freedom from PEDV and PDCoV in Australian pig populations. A total of 484 samples including rectal swabs (n=385) and environmental swabs (n=99) from 28 herds across the Australian pig producing population demonstrated negative results in six PEDV qRT-PCR assays and five PDCoV qRT-PCR assays.

This study identified several viable options involving the use of commercially available assays but concluded that consideration should be given to the PEDV and PDCoV qRT-PCR capabilities of the 'in-house' assays as these are considerably less expensive and present an alternative where delays in international transport may prevent the rapid delivery of commercial assays.

### APL Project 2015/079 – Housing and managing pigs for healthy efficient pork production – a risk assessment approach

The output of this project was a best-practice manual for the production of clean healthy pork. The manual was designed to provide a series of validated "best practices" for pork production that have been shown to improve management systems, improve production efficiency and at the same time reduce the use and reliance on antibiotics.

Section I of the manual provided a summary of the pig's defence mechanisms for resisting disease and infection and information on the range of environmental, physical, biological, social and nutritional stressors identified, and how they impact on the pig.

Section II was written by experienced practicing veterinarians with a range of skills and a sound understanding of animal production, nutrition, immunology, microbiology, appropriate use of antibiotics and vaccines, as well as biosecurity, hygiene and housing.

Section III contained a series of appendices with some real-life stories of how these management changes were put into practice on both large corporate farms and smaller family farms with positive results.

## 5.3 Benefits from reducing economic costs of a FMD outbreak

ACIL Allen has estimated the potential benefits of the APL R&D on biosecurity and exotic diseases in attenuating the adverse economic impacts of a potential FMD outbreak in Australia, drawing on the findings of a 2005 ABARE report and a 2013 ABARES report. FMD was chosen as the focus of the cost-benefit analysis because of its very large potential economic costs and because credible modelling of the disease's potential spread in Australia has previously been undertaken.

Australia is currently free of FMD, a highly contagious viral infection of cloven-hoofed mammals, including cattle, sheep, goats, pigs, deer, buffalo and camelids. In livestock, FMD has high rates of morbidity but mortality rates, particularly in adult animals, are low. Animals can spread the FMD virus for several days before showing clinical signs of the disease, and the virus can remain for long periods after clinical recovery

FMD outbreaks in the United Kingdom, Japan and the Republic of Korea show the disease can enter and spread in FMD-free countries with sophisticated biosecurity systems, and it can impose very significant economic and social costs.

Most of the economic costs from a FMD outbreak would arise from revenue losses caused by immediate and prolonged export bans by Australia's FMD-sensitive markets. An FMD outbreak results in trade restrictions on an exporter's livestock products as importing countries try to minimise the risk of introducing the virus.

For Australia, a large exporter of FMD-susceptible products, the loss of export markets is likely to increase the supply of livestock products onto the domestic market. This would significantly reduce domestic prices and result in large losses in producers' revenue. An outbreak can also lead to significant social disruption in the surrounding communities.

### 5.3.1 Economic impact of FMD outbreaks

In 2013 ABARES modelled FMD disease control strategies for three scenarios[6]:

- a *small outbreak in North Queensland*, where most cattle are raised on extensive rangelands
- a *small outbreak in Victoria's Goulburn Valley*, which has a high density of livestock and intensive dairy farms
- a *large multi-state outbreak* that, by the time of detection, has spread from Victoria to all eastern states (New South Wales, Queensland, South Australia, Victoria and Tasmania).

The following disease control strategies were examined:

- for the small and large outbreaks
  - **stamping out**, which involves destruction and disposal of animals in infected and dangerous contact premises
  - **stamping out with extensive vaccination**, which requires vaccination of all FMD-susceptible animals within a designated ring surrounding infected and dangerous contact premises; and removal of vaccinated animals once the disease is contained
- for the large multi-state outbreak (in addition to the above)
  - **stamping out with targeted vaccination**, which includes vaccination within a designated ring surrounding infected and dangerous contact premises. In outbreak areas outside the high-risk ring, stamping out (without vaccination) is undertaken.

Disease outbreak scenarios were developed and simulated using the AusSpread epidemiological disease spread model.

All strategies would be preceded by a national livestock standstill which would have a significant economic impact on day 1, before the implementation of any of the above strategies.

Historically, stamping out has been used to manage FMD outbreaks. It ensures disease eradication and a swift return to disease-free status and access to international markets. However, it involves the

[6] ABARES 2013, Potential socio-economic impacts of an outbreak of foot-and-mouth disease in Australia, Research report 13.11, October

rapid destruction and disposal of large numbers of stock. This can be highly resource intensive and can also lead to criticism within the community.

More recently, several countries have combined vaccination with stamping out to achieve effective control of FMD. Removal of vaccinated animals can delay the time to regain market access after eradication is achieved. However, early vaccination may assist with or be essential for effective disease control.

ABARES also examined targeted vaccination to explore the effectiveness of control in a situation where resources to undertake widespread extensive vaccination might not be available.

A FMD outbreak would have large direct and indirect economic impacts. Producers of FMD-susceptible livestock (including pigs) would bear most of the revenue losses as a result of countries placing restrictions on imports from Australia. Loss of exports and depressed domestic prices would significantly reduce the revenues of producers.

To estimate the economic impacts of an FMD outbreak, ABARES used results from the spread modelling as input into two separate models, AgEmissions and AusRegion. AgEmissions estimated direct revenue losses for affected producers, while AusRegion estimated economy-wide impacts of an FMD outbreak.

ABARES' estimates of the present value of direct costs of an FMD outbreak on the pork industry over 10 years in each scenario and under each disease control strategy is shown in **Table 5.1**. (The original ABARE cost estimates are shown, as well as cost estimates adjusted for inflation since the publication of the study.) The direct cost of an outbreak is calculated by adding the estimated revenue losses to livestock producers to the costs associated with the chosen control strategy.

ABARES' modelling showed that the lowest cost disease eradication strategy depends on the initial conditions of the outbreak and the type of production system in the outbreak area. In the smaller outbreaks, the additional time required to remove vaccinated animals from the population (and the consequent increase in delay in regaining FMD-free status and market access) was greater than the reduction in eradication time due to vaccination (at least in the case of the small Victorian outbreak – vaccination actually had no effect on the eradication time in the small North Queensland outbreak).

**TABLE 5.1** PRESENT VALUE OF TOTAL DIRECT COSTS OF AN FMD OUTBREAK ON THE AUSTRALIAN PORK INDUSTRY OVER 10 YEARS BY TYPE OF OUTBREAK AND CONTROL STRATEGY ($BILLION)

| Type of outbreak and control strategy | Total direct costs ($billion, 2013 dollars) | Total direct costs ($billion, 2018 dollars) |
|---|---|---|
| **Large multi-state outbreak** | | |
| Stamping out | $1.11 | $1.21 |
| Stamping out with extensive vaccination | $1.05 | $1.14 |
| Stamping out with targeted vaccination | $1.05 | $1.14 |
| **Small outbreak in Victoria** | | |
| Stamping out | $0.16 | $0.17 |
| Stamping out with extensive vaccination | $0.18 | $0.20 |
| **Small outbreak in Queensland** | | |
| Stamping out | $0.14 | $0.15 |
| Stamping out with extensive vaccination | $0.16 | $0.17 |

*SOURCE: ABARES (2013), POTENTIAL SOCIO-ECONOMIC IMPACTS OF AN OUTBREAK OF FOOT-AND-MOUTH DISEASE IN AUSTRALIA*

Based on ABARES' modelling results, ACIL Allen has summarised the total direct costs of an FMD outbreak on the pork industry over 10 years with and without the vaccination option (see **Table 5.2**). The composite small outbreak is a combination of the small Victorian outbreak and the small Queensland outbreak (with equal weighting for both).

**TABLE 5.2** PRESENT VALUE OF TOTAL DIRECT COSTS OF AN FMD OUTBREAK ON THE AUSTRALIAN PORK INDUSTRY OVER 10 YEARS BY TYPE OF OUTBREAK AND AVAILABILITY OF VACCINATION OPTION ($BILLION)

| Type of outbreak and control strategy | Total direct costs ($billion, 2013 dollars) | Total direct costs ($billion, 2018 dollars) |
|---|---|---|
| **Large multi-state outbreak** | | |
| With vaccination option | $1.05 | $1.14 |
| Without vaccination option | $1.11 | $1.21 |
| **Small outbreak in Victoria** | | |
| With vaccination option | $0.16 | $0.17 |
| Without vaccination option | $0.16 | $0.17 |
| **Small outbreak in Queensland** | | |
| With vaccination option | $0.14 | $0.15 |
| Without vaccination option | $0.14 | $0.15 |
| **Composite small outbreak** | | |
| With vaccination option | $0.15 | $0.16 |
| Without vaccination option | $0.15 | $0.16 |

*SOURCE: ACIL ALLEN ANALYSIS BASED ON ABARES (2013)*

### 5.3.2 Relative probability of FMD outbreaks by severity

In a 2005 study by ABARE[7], early detection of FMD was found to be highly significant in influencing the probability of containing the spread of the disease when vaccination is not available.

In the reference case of the 2005 ABARE study, the probability of a severe FMD outbreak under a stamping out disease control strategy was 0.19 while the probability of a small outbreak was 0.81. Under a stamping out with vaccination strategy, the probability of a large outbreak was zero while the probability of a small outbreak was one.

However, should detection be delayed by two weeks, the probability of a severe outbreak under a stamping out only strategy rises to 0.93 (with a concomitant reduction in the probability of a small outbreak from 0.81 to 0.07).

In the ABARE study, a large outbreak results in over 90 per cent of the livestock in the affected region being slaughtered, compared with fewer than six per cent if the outbreak were small.

### 5.3.3 Estimation of APL biosecurity / exotic diseases R&D benefits

The biosecurity/exotic diseases R&D commissioned by APL are expected to assist in the control of a FMD outbreak in Australia by ensuring that the possibility of delayed detection of a FMD outbreak is reduced and that the response to an outbreak is optimised (thereby preventing a small outbreak from becoming a severe one). It is assumed that the vaccination option is available regardless of APL's R&D in biosecurity / exotic diseases.

The impact of the APL R&D on the economic impact of a FMD outbreak is summarised in **Table 5.3**. The expected direct economic costs for each type of outbreak is equal to the product of its relative probability and its direct economic costs.

ACIL Allen's analysis suggests that the APL R&D in biosecurity / exotic diseases can help reduce the expected total direct economic costs of a FMD outbreak in Australia by $0.92 billion in present value terms over 10 years, from $1.08 billion without APL R&D to $0.16 billion with APL. It does so by preventing a small outbreak from becoming a severe one.

7 Abdalla, A. et al. (2005), *Foot and Mouth Disease: Evaluating alternatives for controlling a possible outbreak in Australia*, ABARE eReport 05.6, April.

It is difficult to estimate the probability of an FMD outbreak occurring in Australia – minor outbreaks are believed to have occurred in 1801, 1804, 1871 and 1872. ACIL Allen estimates that the likelihood of an outbreak in any given year is currently in the order of 1 in 100 years (that is, a probability of 1 per cent), taking into account the increase in international travel, selective (rather than 100 per cent) testing of luggage at custom checkpoints and the threat of bioterrorism.

**TABLE 5.3** EXPECTED COST OF A FMD OUTBREAK IN AUSTRALIA ON THE PORK INDUSTRY WITH AND WITHOUT APL R&D (IN PRESENT VALUE TERMS OVER 10 YEARS)

| Type of outbreak | Relative probability | Direct economic costs (2018 dollars) | Expected direct economic costs (2018 dollars) |
|---|---|---|---|
| ***With APL biosecurity/exotic diseases R&D*** | | | |
| Severe outbreak | 0.00 | $1.14 billion | $0.00 billion |
| Composite small outbreak | 1.00 | $0.16 billion | $0.16 billion |
| **Aggregate** | | | **$0.16 billion** |
| ***Without APL R&D*** | | | |
| Severe outbreak | 0.93 | $1.14 billion | $1.13 billion |
| Composite small outbreak | 0.07 | $0.16 billion | $0.01 billion |
| **Aggregate** | | | **$1.08 billion** |

*SOURCE: ACIL ALLEN CONSULTING*

Assuming a 1 per cent annual probability of a FMD outbreak and that APL's R&D contributes 5 per cent to the effectiveness of FMD surveillance and the FMD response once an outbreak has occurred, ACIL Allen estimates that APL's R&D benefits in relation to FMD is approximately $0.46 million a year.

## 5.4 Benefits of maintaining domestic and export revenues

APL R&D in biosecurity / exotic diseases also helps to maintain the disease-free status and reputation of Australian pork, thereby ensuring a price premium in export markets with high income consumers.

In April 2018, Australia exported 1,177 tonnes of pork to Singapore (worth $5.14 million) and 474 tonnes of pork to New Zealand (worth $1.49 million). In that month, it also exported 300 tonnes of pork to Hong Kong (worth $1.08 million). A 5 per cent price premium in pork exports to these three markets is thus worth approximately $4.63 million annually. If 10 per cent of this price premium can be attributed to the APL-funded R&D projects in biosecurity and exotic diseases, then this benefit is valued at approximately $0.46 million (that is, of the same magnitude as the FMD benefit).

In addition, by preventing an outbreak of diseases as such ASF, PRRS and PEDV, the APL R&D contributes to the justification of the ongoing ban against raw pork imports. However, from the perspective of the cost-benefit analysis, at least some of this is a likely to be a "transfer" as the benefits to domestic producers is potentially offset by a loss in consumer welfare.

## 5.5 Social and environmental benefits

### 5.5.1 Social impacts of an FMD outbreak

ABARES (2013) showed that in the event of an FMD outbreak, social impacts will occur at the personal, household and community levels. The severity of these impacts will be influenced not only by the size of the outbreak, but also the existing context, which influences the vulnerability of a community and its ability to recover.

Personal impacts include those on the mental health of community members, as well as those on their physical health and well-being. Household impacts include the social impacts of reduced income and the greater demands placed on family members. The community and regional impacts of an FMD outbreak encompass those on community cohesion, community services, the impacts on other industries as well as in-migration and out-migration.

The APL-funded R&D decreases the magnitude of social impacts by reducing the likely scale and severity of an FMD outbreak.

#### 5.5.2 Environmental impacts of an FMD outbreak

According to PC (2002), eradication and control of FMD potentially has a number of adverse impacts on the environment, primarily associated with the disposal of animal carcasses.

During an outbreak of FMD, there is a potential conflict between the need to dispose of infected animals urgently and doing so in a way that does not raise undue animal welfare issues or create long lasting environmental problems. The AUSTVETPLAN endorses burial as the preferred method, but also allows for burning or rendering.

On a smaller scale, the disposal of other animal products could, in some instances, cause environmental concerns. An example is the problem of disposing of milk during the standstill period when an outbreak first occurs.

There might also be some impacts on the environment or on emergency workers from the large-scale use of disinfectants to decontaminate properties.

Finally, large reductions in farm incomes owing to the loss of export markets may indirectly have an impact on the environment. On-farm expenditure on soil conservation, salinity reduction or general environmental preservation may be reduced as farmers face increased financial pressure and seek to reduce shorter term ‘discretionary’ expenditures.

All these potential environmental issues are ameliorated by the APL-funded R&D, which reduces the likely scale and severity of an FMD outbreak.

### 5.6 R&D costs

The cost of APL’s R&D program in biosecurity / exotic diseases is shown in **Table 5.4**. The cost of the 14 R&D projects, including the cash and in-kind contributions of organisations undertaking the R&D, total $984,033. The average annual cost of the R&D between 2013 and 2018 is thus $196,807.

For the cost-benefit analysis, a 14 per cent administrative/management cost multiplier was used to determine the total expenditure for APL for the projects that have been commissioned, conducted and reported on. This multiplier was applied on top of the annual R&D costs shown in **Table 5.4**.

**TABLE 5.4** APL BIOSECURITY/EXOTIC DISEASES R&D COSTS

| Project number | Title of project | Project budget |
|---|---|---|
| 2013/2422 | Swill feeding compliance and awareness | $95,580 |
| 2013/2419 | National Animal Biosecurity RDE Strategy Implementation | $33,333 |
| 2013/2416 | Quantitative detection of *C. difficile* in piggery effluent treated in covered and uncovered anaerobic ponds and presence in biosolid by-products including land application and compost | $105,053 |
| 2014/505 | Foot and Mouth Disease real-time training program | $20,000 |
| 2014/483 | The epidemiology of ASF virus and its potential for its introduction into Australia | $40,000 |
| 2014/484 | The significance of feral pigs as a transmission vector or reservoir species for PRRS virus Australia | $53,000 |
| 2014/486 | Assessing the risk of feral pigs interacting with domestic pig herds in south-eastern Australia | $44,845 |
| 2015/030 | Reverse zoonoses affecting pigs, and the risk to Australian pig production. A critical review to direct risk assessment and management recommendations | $31,276 |
| 2015/079 | Housing and managing pigs for healthy efficient pork production – a risk assessment approach | $80,000 |

| Project number | Title of project | Project budget |
|---|---|---|
| 2015/070 | Evaluation of diagnostic assays for porcine epidemic diarrhoea coronavirus | $99,629 |
| 2015/013 | Pilot prevalence of community-acquired MRSA in the Australian pig herd and MRSA in pig production in Australia | $187,620 |
| 2016/096 | Exotic Disease Preparedness, Evidence of Absence | $72,500 |
| 2016/084 | Biosecurity engagement of small-scale pig production | $75,197 |
| 2016/2242 | Standardisation of antibiotic sensitivity testing methodologies | $46,000 |
| **All** | | **$984,033** |

*SOURCE: APL*

Extension costs have not been estimated by APL and are not included in the cost-benefit analysis.

## 5.7 Assessment of benefits against costs

Comparing the projected FMD benefit of $0.46 million per year against the average R&D cost of $224,360 (inclusive of administrative/management costs) suggests a benefit-cost ratio (BCR) of approximately 2.0. That is, the benefits of the R&D in terms of FMD alone is projected to be twice the cost of APL's R&D program in biosecurity/exotic diseases.

The internal rate of return (IRR) cannot be calculated as we are comparing the annual investment in biosecurity R&D with the annual expected benefits in terms of a reduction in the economic costs of a potential FMD outbreak (rather than comparing a stream of benefits with a stream of costs).

## 5.8 Sensitivity analysis

In the central case of the cost-benefit analysis, it is assumed that there is a 1 per cent probability of an FMD outbreak in Australia in any given year. If the annual probability of an FMD outbreak is 2 per cent, the BCR increases from 2.0 to 4.0. Conversely, if the annual probability of an FMD outbreak is 0.5 per cent, the BCR decreases to 1.0.

In the central case of the cost-benefit analysis, it is assumed that APL's R&D in biosecurity / exotic diseases contributes 5 per cent to the effectiveness of FMD surveillance and the FMD response once an outbreak has occurred. If APL's contribution is 8 per cent, the BCR increases from 2.0 to 3.2. Conversely, if APL's contribution is only 2 per cent, the BCR decreases to 0.8.

The central case of the cost-benefit analysis focused only on the FMD benefit. Including the export premium benefit would double the BCR from 2.0 to 4.0.

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