RESEARCH IMPACT EVALUATION

Foot and Mouth Disease

October 2017

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1 Executive Summary

The challenge

A multi-state foot and mouth disease (FMD) outbreak in Australia could cost the Australian economy up to $50 billion over 10 years, primarily due to trade restrictions. The social impacts of the disease would also be significant, associated with animal culling and loss of income due to time to return to trade affecting producer psychological health.

Australia currently has a livestock product export market worth $22 Billion per annum. This is expected to increase by 12% by 2020-21 (ABARES 2017). Thankfully, Australia has been free of the disease since 1872 due to stringent pre- and post-border measures. However, FMD is endemic in many of our neighbours in Asia, resulting in high socio-economic impact for the whole region.

In many Asian countries, the livelihoods of the people are dependent on their livestock; and as FMD affects livestock productivity and trade, the disease can have a severe and relatively quick impact on many people.

Due to the risk posed by 'FMD endemic' countries and the impact of a FMD outbreak in Australia, we need to ensure that the country is prepared for a possible incursion and assist, where possible, to ensure tools are in place to help prevent an introduction of the disease.

Our response

CSIRO's scientists are helping several countries in the region improve their diagnostic capabilities and research into FMD, which in turn helps us better understand the FMD virus (FMDV) strains circulating in the region. In collaboration with the national laboratories and the World Organisation for Animal Health (OIE) Regional Reference Laboratory for FMD in South East Asia (SEA), CSIRO's continuing FMD project serves to improve preparedness in the event of an outbreak, through processing infected samples, and performing molecular, cell culture, and serological assays to detect and characterise FMD offshore.

The impact

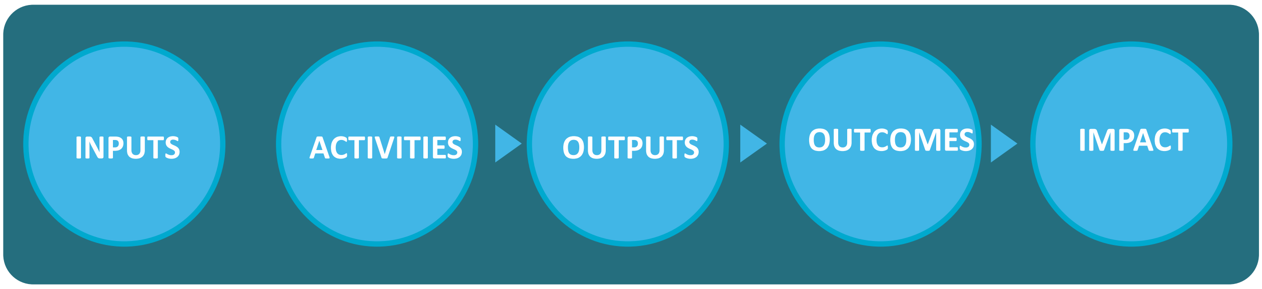
As vaccination is a key control measure that may be used in the face of an outbreak, CSIRO's research in FMD has achieved a number of outcomes. The key outcomes include:

- An improved understanding on the pathogenesis of various FMDV isolates in different species, and an understanding of the efficacy of the vaccine strains in the Australian Vaccine Bank (AVB) in three important livestock species.
- An enhancement of existing, and development of new, diagnostic and surveillance tools and approaches.
- Valuable capacity building, both at AAHL and in regional laboratories within SEA.

The impacts to date from CSIRO's FMD research lie primarily in costs avoided from potential outbreaks of animal diseases, or reduced costs due to earlier containment of outbreaks, should they occur. Looking at the midpoint of a range of impacts, our estimates suggest that the real research program expenditure of $10.95 million will lead to:

- Total benefits (measured as economic loss avoided, in real, present value terms) between $10.36 million and $73.60 million per year, depending on the assumptions made.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the FMD case study are summarised in Figure 1.



• CSIRO investment (FTE, in-kind contributions, equipment/facilities and background IP) • Investment from collaborators • Cost of adaptive development and extension by the industry	• Testing the vaccines in the Australian Vaccine Bank • Improve and validate early diagnostic tests locally • Building capabilities in South East Asia • Study the epidemiology of FMD in SEA • Stakeholder engagement	• Publications • Awards • Patents • New diagnostic tools and approaches • Information on potential threats to the Australian livestock industries	***Uptake and adoption*** • Adoption of better surveillance and response capacity by the livestock industries, the meat and dairy processing industries • Potential earlier detection and containment of outbreaks of FMD • Valuable capacity building in SEA	***Economic impact*** • Economic costs avoided from outbreaks of FMD • Sustained export market access ***Environmental impact*** • Reduced slaughter and disposal of infected animals ***Social impact*** • Social licence to operate • Rural community resilience • Resilient producer psychological health

Figure 1: Impact Pathway for Foot and Mouth Disease Project

2 Purpose and audience

This independent case study has been undertaken to assess the economic, social, and environmental impact of CSIRO's Health & Biosecurity Business Unit.

The case study has been prepared so it can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of CSIRO's activities.

This case study is proposed for accountability, reporting, communication, and continual improvement purposes. Audiences for this report may include the Business Unit Review Panel, Members of Parliament, Commonwealth Departments, CSIRO, and the general public.

3 Background

Australia currently has an export meat industry of 1.36 million tonnes (ABARES 2017). These export markets are supported by highly optimised commodity supply chains, poorly adapted for halts in demand without massive losses. The value of Australian livestock export markets are built on its FMD free status. These markets are currently worth $22 Billion; and are expected to increase by 12% by 2020-21. Australia is classified as 'free from FMD without the use of vaccination'; however, the disease is endemic in much of Asia. In many Asian countries, the livelihoods of the people are dependent on their livestock; and as FMD affects livestock productivity, the disease can have a severe and relatively quick impact on many people. The ease and rapidity of international travel by large numbers of people means that Australia remains at risk of an outbreak due to illegal importation of contaminated livestock products.

FMD is the most serious biosecurity threat facing Australian agriculture. A multi-state FMD outbreak could cost the Australian economy up to $50 billion over 10 years. Losses would result primarily from immediate shutdown of all livestock export markets, halting all production supply chains as livestock commodities immediately lose their market value with huge economic (livestock still need to be fed), and supply and demand, consequences. There would also be major control costs associated with eradicating a severe FMD outbreak, challenged by a long tail of new detections long after the peak of detection has passed before a return to trade is even possible (Buetre et al. 2013). The ABARES evaluation did not consider the heavy social costs on producers, overnight losing the value in their livestock assets for the entire control period, and the impact this and the massive culling of infected animals has on their psychological wellbeing.

Historically, stamping out (animal culling) has been used around the world to manage FMD outbreaks. This approach targets disease eradication and a swift return to disease-free status and access to international markets. However, it involves the rapid destruction and disposal of large numbers of livestock. This can be highly resource intensive and has been poorly managed (over-culling) in other outbreaks leading to criticism and backlash from the broader community.

More recently, several countries have combined vaccination with stamping out to achieve effective control of FMD. There have been significant changes to the emergency preparedness plans in several countries/region that are free of FMD, such as the European Union, the United States, New Zealand, and Australia. These countries now make allowances for the use of vaccines as part of the control measures as early vaccination may assist with or be essential for effective disease control. However, removal of vaccinated animals can delay the time to regain market access after eradication is achieved. There also remains an ongoing economic debate about vaccination, primarily about the ultimate fate of these animals and whether they will be allowed to live out their productive lives, or be removed from the population.

The Australian Animal Health Laboratory (AAHL) provides Australia with important disease mitigation and outbreak response mechanisms for animal and zoonotic (human pathogens of animal origin) diseases that could devastate industries and affect human health. AAHL was officially opened in 1985 (although research work began in 1984). Most of the research capacity of the facility can be attributed to the Health and Biosecurity (H&B) team within CSIRO. However, due to the perceived risk of the disease accidentally escaping from the facility, the import of live FMD virus is not allowed.

In 2010, the FMD Risk Management Project (FMD-RMP) was conceived to focus largely on testing vaccines in the Australian Vaccine Bank (AVB) against viruses currently circulating in South East Asia (SEA), investigate the pathogenesis of these viruses and assist with laboratory assays to detect and characterise them. The outputs of the project would be used in response strategies to mitigate the impact, and to ensure a faster return to trade, in the event of an outbreak. The project was funded in part by the livestock industries in Australia through Animal Health Australia (AHA) with matching funds through Meat and Livestock Australia (MLA) Donor Company by the Australian Government under MLA Project P.PSH 0652 (Phase 1) and P.PSH 0668 (Phase 2).

The previous director at AAHL, Dr Martyn Jeggo, engaged with the livestock industries (cattle, sheep, goats, and pigs) that would be impacted by FMD via Animal Health Australia, from 2007, to determine the research needs for Australia's preparedness for an FMD outbreak. The gaps in FMD preparedness were identified based on the Beale Review into Australia's biosecurity, and the Matthew's Report on Australia's preparedness for the threat of FMD. The FMD Risk Management project's objectives were based on all of these inputs. This was the first time CSIRO and AAHL engaged in a large-scale, coordinated project focussing specifically on FMD. Prior to this project, there had been small projects for PhD students and some vaccination studies performed with funding obtained directly from the livestock industries (cattle, sheep, and pigs).

From July 2016 a larger MLA Project P.PSH.0779 has been funded through the Rural Research and Development for Profit Program (RRDfP) until 2020 adding three new research areas to vaccine testing. This project has four components:

1. *Rapid diagnostics and vaccination strategy preparedness* : assurance that Australia continues to have a fit-for-purpose FMD vaccine bank effective against the highest risk FMD viral strains for Australia and quality-assured rapid diagnostic tests suitable for testing strains pre-emptively and during an outbreak. This will be achieved by applying novel genome sequencing, data management and bioinformatic approaches;

2. *Supporting Farmer-led surveillance systems*: multi-stakeholder developed and led national emergency animal disease surveillance systems for early detection of incursions leading to fewer, less impactful and more readily controlled, outbreaks. CSIRO will not undertake, but rather support surveillance by ensuring we have diagnostic assays that could be used on samples. This will be a new, producer-led system built on diverse producer/stakeholder values and needs, to replace the current centralised system with documented critical weaknesses;
3. *Decision support tools for decision makers during outbreaks*: technology-driven support systems for industry and decision makers ensuring cost-effective emergency response to high impact animal diseases and pests. This will integrate the existing Department of Agriculture and Water Resources spatial epidemiological AADIS model with new economic impact modules to allow response scenarios to be rapidly tested and costed before and during outbreaks and;
4. *Analytical tools to reduce time to eradication by understanding farm-to-farm disease transmission*: "Big data" driven animal disease movement and trace-back tools aimed at shortening post-outbreak emergency animal disease impact duration during both emergency response and proof-of-freedom phases. This will reduce the human stresses and costs associated with the costly "long tail" of an incursion by minimising the time to recovery.

4 Impact Pathway

Project Inputs

The FMD research is a collaboration between the industries that could be affected by FMD via AHA, government (e.g. federal and state departments) and CSIRO. Given the scope and data constraints of this evaluation, we focus on inputs that the project has received since 2010. According to Table 4.1, the FMD project has been the recipient of investment to the value of more than $10 million since 2010/11 from CSIRO and external collaborators. The project was funded in part by the livestock industries in Australia through Animal Health Australia (AHA) with matching funds through Meat and Livestock Australia (MLA) Donor Company by the Australian Government under MLA Project P.PSH 0652 (Phase 1) and P.PSH 0668 (Phase 2). Key industry contributors include:

- Cattle Council of Australia
- Australian Dairy Farmers
- Australian Lot Feeders' Association
- Sheep meat Council of Australia
- Wool Producers Australia
- Australian Pork Limited
- Goat Industry Council of Australia

According to Table 4.1, external collaborators contributed $4.06 million in cash and CSIRO's contribution totalled $6.54 million in terms of in-kind.

Table 4.1: Cash and In-kind support for project ($ nominal terms)

CONTRIBUTOR / TYPE OF SUPPORT	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	TOTAL
Cash								
Collaborators Contributions	75,000	625,715	1,148,644	151,650	131,116	910,486	1,021,603	4,064,214
In-kind								
CSIRO	75,000	625,715	1,148,644	151,650	131,116	910,486	1,021,603	6,537,868
Total	598,993	625,715	1,358,471	1,807,344	2,674,960	2,019,296	1,517,303	10,602,082

Note: a) External contribution equals Invoiced Revenue; b) estimated WIP value at June 2016 $562,000 not included in above table and c) CSIRO contribution is calculated as Total Expenditure less External Revenue.

Activities

The AAHL facility has both the infrastructure and scientific capability to manage testing and research requirements during an FMD outbreak. However, all 'peace time' research on the infectious virus is performed in partner laboratories overseas.

As vaccination is one of the key control measures that may be used in the face of an outbreak, CSIRO is working with these partner laboratories to study the effectiveness of FMD vaccines in target animal species to verify that the currently available vaccine strains in the AVB will protect against newly emerging strains of the virus.

The work of the Health and Biosecurity team at CSIRO is largely centred on generating valuable data on the vaccines and the emerging viruses, enabling the capability of AAHL to respond to an outbreak of FMD, thereby mitigating potential impacts to the country. Some of the key activities which are undertaken include:

- Testing the efficacy of the vaccines in the AVB. This showed the efficacy of vaccines in cattle and sheep but less so in pigs. However, even where vaccines provided only partial protection, the research identified reduced virus excretion and therefore a slower potential spread of disease during an outbreak.
- Pathogenesis studies of FMD virus variants in pigs and sheep. The research helped improve an understanding of key events associated with infection, primary site of replication and virus dissemination during generalisation of the disease.
- Vaccination and persistent infection in cattle and sheep. The research explored the effects of vaccination on persistent infections (presence of virus/virus genome in the oro-pharyngeal region).
- Laboratory assays to test the match between vaccines in the AVB and field viruses from SEA, and genetic comparisons to look for viral changes. This research better informs researchers on the FMD situation in SEA and trends/changes to virus. It also adds to confirm that relevant vaccine strains are included in the AVB.

- Diagnostic test validation activities, which have resulted in improved diagnostic capabilities and confidence in assays at AAHL.
- Testing swabs as diagnostic tools during and after outbreaks. These nasal/oral swabs may be positive for FMD prior to onset of clinical signs, serving as a method for early detection.
- Capacity building in Australia and SEA. In working with FMD laboratories in SEA, CSIRO scientists have had the opportunity to work with live FMD and ensure continued expertise can be applied.

Outputs

The CSIRO FMD scientists are helping several countries in the region to improve their diagnostic capabilities and research into FMD, which in turn helps AAHL better understand the FMDV strains circulating in the region. Some of the key outputs of the FMD - RMP project include:

- Confirmation that the AVB contains suitable vaccine strains and an understanding of their utility in different species.
- Understanding of the behaviour of different FMDV isolates/serotypes in different livestock species, shedding light on transmission risks and best samples to collect at different times post infection.
- Establishment of fit-for-purpose diagnostic assays and a store of samples of known origin to serve as controls in these assays.
- Improved understanding of FMD in SEA, with established networks to ensure continued monitoring of the evolution of FMDV strains and the relevance of AVB vaccines.
- Increased staff in Australia with direct experience identifying lesions in FMDV infected animals, processing infected samples and performing assays to detect and characterise FMDV.

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Awards

Foot & Mouth Disease Risk Management Project Team has been awarded with the CSIRO Health and Biosecurity - Inclusive & Diverse Team award, 2016 for "*Building on the diversity of their team and an inclusive approach to engagement to achieve outstanding collaborative outcomes with multiple overseas laboratories, as well as within CSIRO".*

Outcomes

There are a variety of existing and potential beneficiaries from the work of the H&B FMD team. The beneficiaries (and potential beneficiaries) of FMD-RMP include:

- The livestock industries (cattle, sheep and pigs);
- The meat and dairy processing industries and supply chains;
- Animal and animal product customers in countries that import from Australia; and
- The Australian community in general including consumers and governments.

Many of the outcomes from the FMD team's research will have global reach. The benefits of that research will also accrue to our international partners and neighbours both across the region and globally.

Some of the key outcomes arising from the uptake and adoption of the research outputs include:

- Dependable FMD vaccine bank: Confidence that the AVB contains suitable vaccine strains and an understanding of their utility in different species. Knowledge on best application of the vaccine and what species to include in a control program will enhance Australia's response to an outbreak with faster return to trade and lesser economic impact.
- Improved animal wellbeing: Access to FMD vaccine means a reduction in the number of infected livestock and less need to dispose of diseased animals.
- Improved animal health outcomes: Early warning of emerging health threats will help to develop intervention strategies and reduce the severity of any disease outbreak.
- Protection of livestock trade: An outbreak of an animal disease such as FMD would be extremely damaging to Australia's international livestock trade. Outbreaks of FMD could lead to the loss of billions of dollars of live animal and meat exports.
- Capacity building in Australia and SEA that impacts on response activities both locally and overseas; the latter addressing the risk at source.

In the event of a FMD outbreak, the adoption rate of the results generated by the H&B FMD team is likely to be high. For example, the seriousness of such an event would ensure that the expected adoption rate of AAHL's work would be 100 per cent.

Impacts

CSIRO's FMD research has contributed to a range of delivered and potential impacts, including reduced economic costs due to earlier containment of outbreaks and faster return to trade, improved health outcomes to various livestock species and improved security for rural communities.

The direct beneficiaries of this work are livestock producers and the indirect benefits flow to suppliers of goods and services to the agricultural sector and to the consumers i.e. the general public and trading partners through animal diseases impacting availability or price of agricultural products.

The Department of Agriculture and Water Resources and all the other state governments are also benefiting from the research, as the research outcomes will inform the design of government policies and programs on the risk management of FMD.

Experience from FMD outbreaks in other countries provide an indication of the scale of the risks that Australia faces:

- In Taiwan, following the 1997 FMD outbreak, pork exports valued at $US 1.6 billion, fell by over US$1.3 billion to $US 234 million with the loss of the Japanese market (Chang et al., 2006). Other countries stepped in to take over Taiwan's market share. With the loss of export markets, 27 million tons of pork was diverted to the domestic market with disastrous consequences for producers.
- An outbreak of FMD in the Republic of Korea in 2000 had similar consequences, however long lasting effects were seen with a repeat of outbreaks. This was highlighted by the destruction of 3.4 million livestock and costs of $US 2.78 billion (Knight-Jones et al., 2005).
- In 2000-2001, the FMD outbreaks in South America had a significant effect on the beef industry. Argentina's beef exports fell by 52 per cent (Rich, 2004) and the outbreaks in Uruguay and Brazil resulted in loss of export markets, prices falling below the cost of production and serious damage to the livestock industries of these countries (FAO 2006).
- The UK suffered outbreaks in both 2001 and 2007. The 2001 outbreak had a significant effect with the estimated losses of £5.8 to £6.3 billion (Thompson et al., 2002). This was across both agriculture, food chains and tourism. It took more than 18 months to regain the normalization of trade following the eradication of the disease.

Given that the value of Australia's cattle, sheep, and pig, the meat market in 2012-13 was worth over $10 billion (including slaughter of dairy cattle and skin value for sheep and lambs), the potential losses from a FMD outbreak are large (ABARES, 2013a).

As international trade and travel increase, so does the risk of animal diseases reaching Australia from overseas sources. The benefits of AAHL's work in relation to FMD preparedness can be directly determined from the estimated loss that would be incurred in case of an outbreak.

Using CSIRO's triple bottom line impact classification approach, Table 4.2 summarises the nature of the existing and potential impacts.

Table 4.2: Summary of FMD project impacts

TYPE	CATEGORY	INDICATOR	DESCRIPTION
Economic	Trade and competitiveness	Economic costs avoided	Costs of lost livestock product exports avoided from FMD outbreaks, or reduced costs due to earlier containment of outbreaks and faster return to trade.
	Securing and protecting existing markets	Economic costs avoided	Costs of lost livestock product value and management costs associated with supply chain collapse avoided from FMD outbreaks, or reduced costs due to earlier containment of outbreaks and faster return to trade.
Environmental	Ecosystem health	FMD Incidence and impact of slaughter and disposal	An outbreak of FMD, beyond direct trade implications, would propose a severe health threat to the various livestock species with significant negative impact on production. Access to FMD vaccine will result in a reduction in infected animals, and those needing to be disposed of.
Social	Improved health outcomes	Frequency and severity of outbreaks	Early warning of emerging animal health threats will help to develop intervention strategies and reduce the severity of any disease outbreak.
	Community resilience	Income and employment	CSIRO's FMD team work underpins the security of rural employment for farmers and for other businesses in the supply chain avoiding welfare and psychological health issues associated with extended periods of farm losses and business insolvency.
	Community resilience	Social licence to operate	The reduction in disease incidence and the need to cull infected animals provide a higher level of confidence in the sector among the general population.

5 Clarifying the Impacts

Counterfactual

The counterfactual scenario describes what happens if CSIRO's FMD research is not implemented and the status quo or extension of current trends prevails. As identified in the outcome section, the counterfactual scenario has been simplified into two broad elements:

- Given the unique nature of the AAHL with its high level containment facility, the work described in this case study could not have been undertaken by any other institution or group in Australia. The delays in accessing these facilities during an emergency would add significantly to the cost of managing an outbreak of FMD.
- The following disease control strategies were adopted : a) for the small and large outbreaks: stamping out, which involves destruction and disposal of all animals in infected and dangerous contact premises; and b) for the large multi-state outbreak (in addition to the above): stamping out with extensive disease surveillance activities, which requires testing of all FMD-susceptible animals within a designated ring surrounding infected and dangerous contact premises; and removal of all animals once the disease is contained.

Conversely, the CSIRO intervention scenario includes the following three broad key elements. CSIRO's activities in relation to FMD are expected to assist in the early detection of the index case and control of a FMD outbreak in Australia in three ways:

- CSIRO's testing activities, in conjunction with those of other relevant State/Territory and Commonwealth government agencies, ensures 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). Subsequently, the testing capabilities will be essential after the outbreak to provide serological evidence that the disease is successfully eradicated and now free and ready to trade again.
- Australia maintains a vaccine bank with a private company in Europe and the H&B FMD team is involved in testing these vaccines and developing knowledge on how effectively these work for the strains of FMD that are currently circulating in SEA and internationally.
- CSIRO's FMD team works closely with the World Organisation for Animal Health (OIE) and the UN Food and Agriculture Organisation (FAO) to improve FMD surveillance and response capacity across SEA to decrease the potential likelihood of FMD spreading from Asia into Australia.

Contribution

The evaluation has been undertaken by the CSIRO to both understand the payoff from the technology, as identified above, and to identify specifically the potential net benefit (and success) of the CSIRO. It is therefore necessary to tease out the CSIRO's costs and benefits - requiring a disaggregation of the positive externalities back to either the CSIRO or other collaborators such as governments and industries. In practice, this require that we make a judgement about the value of CSIRO's contribution to the project.

This evaluation has assigned 50 per cent of the benefits of FMD to CSIRO's H&B research team. There are of course other participants in the FMD preparedness strategy who undoubtedly add substantial value to the strategy. The reason for the 50 per cent attribution is that CSIRO's FMD research is a critical contributor to the source of the impacts generated by the FMD preparedness strategy.

6 Evaluating the Impacts

Modelling approach

Literature on economic impact of FMD outbreaks

A FMD outbreak would have large direct and indirect economic impacts. Producers of FMD-susceptible livestock would bear most of the revenue losses as a result of countries placing restrictions on imports from Australia. Loss of exports and plunging domestic prices would significantly reduce the revenues of producers. It is also likely that consumers will decrease intake of affected animal products due to perceived risks, which could lead to collapse of local markets as well.

In 2013 ABARES modelled FMD disease control strategies for the following three scenarios:

- 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):

- 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 the vaccination of all cattle and sheep on mixed cattle and sheep farms within a designated ring surrounding

infected and dangerous contact premises. In outbreak areas outside the high-risk ring, stamping out (without vaccination) is undertaken.

ABARES' estimates of the present value of direct costs of an FMD outbreak over 10 years in each scenario and under each disease control strategy is shown in Table 6.1. 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. The control costs are estimated to be $0.32-0.37 billion (depending on the control strategy) for the large multi-state outbreak, $0.09-0.10 billion for the small outbreak in Victoria and $0.06 billion for the small outbreak in North Queensland.

Table 6.1 Present value of total direct costs of an FMD outbreak over 10 years by type of outbreak and control strategy ($billion)

Type of outbreak and control strategy	Total direct costs ($billion)
Large multi-state outbreak	
Stamping out	$52.21
Stamping out with extensive vaccination	$49.89
Stamping out with targeted vaccination	$49.62
Small outbreak in Victoria	
Stamping out	$6.00
Stamping out with extensive vaccination	$6.26
Small outbreak in Queensland	
Stamping out	$5.64
Stamping out with extensive vaccination	$5.96

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

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).

Based on ABARES' modelling results, ACIL Allen 2014 summarised the total direct costs of an FMD outbreak over 10 years with and without the vaccination option (see Table 6.2). The composite small outbreak is a combination of the small Victorian outbreak and the small Queensland outbreak (with equal weighting for both).

Table 6.2 Present value of total direct costs of an FMD outbreak over 10 years by type of outbreak and availability of vaccination option ($billion)

Type of outbreak and control strategy	Total direct cost ($billion)
Large multi-state outbreak	
With vaccination option	$49.62
Without vaccination option	$52.21
Small outbreak in Victoria	
With vaccination option	$6.00
Without vaccination option	$6.00
Small outbreak in Queensland	
With vaccination option	$5.64
Without vaccination option	$5.64
Composite small outbreak	
With vaccination option	$5.82
Without vaccination option	$5.82

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

In order to measure the benefits of CSIRO's FMD research, we employed a Markov chain to quantify the likelihood of economic loss from FMD outbreaks over a period of 10 years (Figure 6.1).

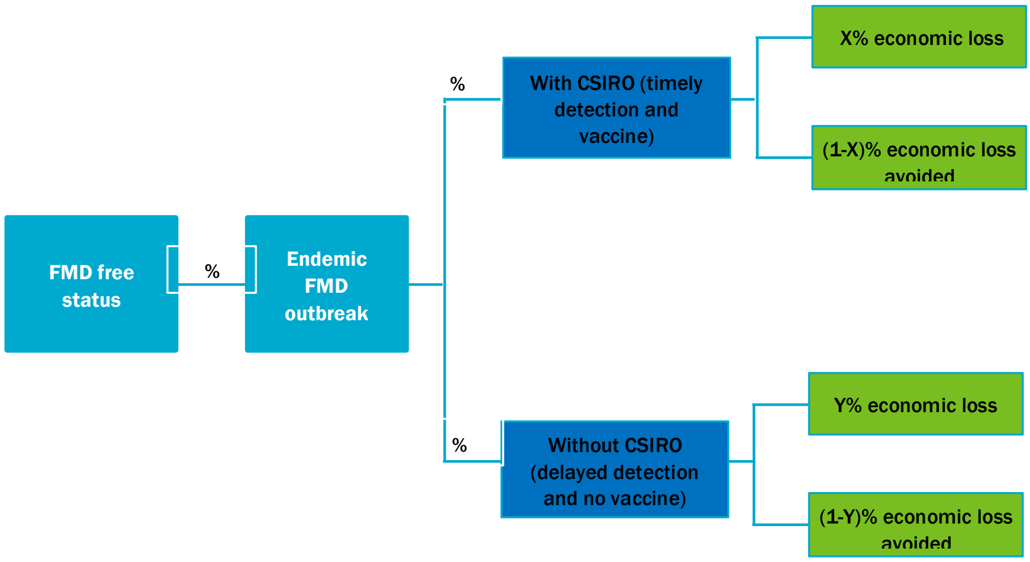

Figure 6.1. Model structure

Modelling relative probability of FMD outbreaks by severity

In the ARARES 2005 study, 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.

Based on new evidence provided in recent FMD research, including two led by ABARES researchers (Garner et al. 2009, Buetre et al. 2013), a series of simulations have been undertaken for this evaluation to investigate the final size of the epidemic, or the percentage of livestock that is slaughtered towards the end of FMD epidemics under a wide range of hypothetical scenarios (refer to appendix for a detailed discussion of the model). These include:

Scenario 1: No proactive intervention

- detection of disease on day 21; and
- stamping out of infected and possibly exposed population from day 22.

Scenario 2: Intervention with surveillance-related activities

- detection of disease on day 7;
- a reduction of 80% exposure from infectious population to susceptible from day 8; and
- stamping out from day 8.

Scenario 3: Intervention with surveillance-related activities accompanied by sufficient vaccines

- detection of disease on day 7;
- a reduction of 80% exposure from infectious population to susceptible from day 8;
- vaccination of susceptible population from day 8; and
- stamping out from day 8.

The results suggest that the possibility of a large (severe) FMD outbreak, which is defined in this evaluation as more than 80 percent of the livestock being slaughtered towards the end of the epidemic, is 0.95 without surveillance-related activities accompanied by sufficient vaccines. The possibility drops to 0.14 with surveillance-related activities only and further to 0 should the surveillance-related activities and sufficient vaccination be provided in time by CSIRO's FMD research. Similarly, the possibility of a small FMD outbreak, defined as less than 80 percent of the entire population being slaughtered, is 0.05, 0.857 and 1, respectively. CSIRO's research intervention, as highlighted in Table 6.3, will not remove the probability of outbreaks, however will reduce the severity of outbreaks.

In the reference case of the 2005 ABARES study, the probability of a severe FMD outbreak under a stamping out disease control strategy was only 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.

Table 6.3 Change in relative probability of FMD outbreaks by severity (%)

	No intervention of CSIRO		Intervention with CSIRO's surveillance-related activities		Intervention with CSIRO's surveillance-related activities accompanied by sufficient vaccines	
	Severe outbreak	Small outbreak	Severe outbreak	Small outbreak	Severe outbreak	Small outbreak
Probability	0.95	0.05	0.14	0.86	0	1

Source: CSIRO based on ACIL Allen 2014.

Estimation of the benefits of CSIRO's FMD Research

The impact of CSIRO's activities to date on the economic impact of a FMD outbreak is summarised in Table 6.4. The expected direct economic costs for each type of outbreak is equal to the product of its relative probability and its direct economic costs. CSIRO's surveillance-related activities mainly are associated improvements in diagnostic assays. Given that these activities only support the Diagnostic Surveillance and Response (DSR) section of AAHL, who undertake the testing of samples, CSIRO's contribution in the event of an outbreak lies dominantly in vaccine-related activities. These vaccine related activities refer to testing of vaccines to ensure the AVB is prepared, as well as monitoring the viruses in SEA to have advanced knowledge of any significant changes in the epidemiology of the virus.

Our analysis suggests that CSIRO activities to date have helped reduce the expected total direct economic costs of a FMD outbreak in Australia by $1.78 billion in present value terms over 10 years, from $7.6 billion without CSIRO (surveillance only) to $5.82 billion with CSIRO (vaccine and surveillance). It does so by preventing a small outbreak from becoming a severe one.

Table 6.4 Expected cost of a FMD outbreak in Australia with and without CSIRO (in present value terms over 10 years)

Type of outbreak	Relative probability A	Direct economic costs B	Expected direct economic costs C= A*B
With CSIRO (vaccine and surveillance)			
Severe outbreak	0.00	$49.62	$0.00 billion
Composite small outbreak	1.00	$5.82	$5.82 billion
Aggregate			**$5.82 billion**
Without CSIRO (surveillance only)			
Severe outbreak	0.14	$52.21	$7.31 billion
Composite small outbreak	0.05	$5.82	$0.29 billion
Aggregate			**$7.60 billion**
Impact	World with CSIRO research – without CSIRO		**$1.78 billion**

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. CSIRO estimates that likelihood of an outbreak in any given year is currently in the order of 1 in 50 years (that is, a probability of 2 per cent), due to an increase in international travel, reduced percentage of luggage testing (only high risk luggage is tested) at custom checkpoints, illegal imports and the threat of bioterrorism.

While AAHL is an important link in the Australia-wide FMD surveillance system, it also plays a critical role in ensuring an effective national response once an outbreak has occurred. Assuming a 2 per cent annual probability of a FMD outbreak and that AAHL contributes 50 per cent to the effectiveness of the FMD surveillance system once an outbreak has occurred, we estimate that AAHL's benefits (its "insurance value") in relation to FMD is approximately $17.8 million a year. This impact analysis is only based on historic work, not the large new multi-facetted RRDfP project currently underway.

Sensitivity analysis

As there is considerable uncertainty about the probability of a FMD outbreak in Australia in any given year and about the magnitude of CSIRO's contribution to help reduce the economic losses, sensitivity analysis has been undertaken to assess the impact of these uncertainties on the estimate of AAHL's benefits in relation to FMD. The results of this analysis are shown in

Table 6.5.

Table 6.5 Estimate **of CSIRO's annual benefits in relation to FMD under alternative assumptions**

Contribution of CSIRO ("insurance value")	**FMD outbreak probability (small) = 0.2**	**FMD Outbreak probability (severe) = 0.1**
CSIRO contribution = 25%	$24.57 million	$10.36 million
CSIRO contribution = 50%	$49.13 million	$20.71 million
CSIRO contribution = 75%	$73.60 million	$31.07 million

SOURCE: ACIL ALLEN CONSULTING

If the probability of a small FMD outbreak in any given year is again assumed to be 0.2 and that CSIRO contributes 75 per cent to the effectiveness of the Australia-wide FMD response system in the event of an outbreak, then CSIRO's benefits (its "insurance value") in relation to FMD due to its role in effective animal vaccines accompanied by disease surveillance alone is estimated to be approximately $73.60 million per year.

7 Limitations and Future Directions

This evaluation uses a mixed methodology to evaluate the research impact arising from CSIRO's FMD research. It combines quantitative and qualitative methods to illustrate the nature of the research's economic, environmental, and social impacts. In cases where the impacts can be assessed in monetary terms, a cost-benefit analysis (CBA) is used as a primary tool for evaluation.

As a methodology for impact assessment, CBA relies on the use of assumptions and judgments made by the authors. This relates primarily to the economic indicators for impact contribution, attribution, and the counterfactual. These limitations should be considered when interpreting the results presented in this case study.

Given the scope and budget for the analysis, we acknowledge that there are some limitations with regard to the evidence base of impacts. For example, the relative probability of FMD outbreak was based on estimates only as limited information was available about the actual occurrence. In addition, social benefit was not quantified, but were treated as potential impacts, owing to a lack of reliable data.

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9 Appendix

Methodology

1. SEIR MODEL

This report follows a SEIR model where the population is divided into 4 groups:

Susceptible (S): individuals that are not yet exposed or infected to the disease but is deemed vulnerable to the virus; Exposed (E): individuals that are exposed to the virus but are not yet infectious to others; Infected (I): individuals that carries the virus and pass the virus to susceptible population; Removed (R): individuals that are removed from the population and no longer infectious due to recovery or slaughtered (as in the case for FMD)

Their equations capturing the dynamics of such epidemics are:

$$\frac{dS}{dt} = -\beta(t) * \frac{SI}{N} - vS$$

$$\frac{dE}{dt} = \beta(t) * \frac{SI}{N} - \alpha E$$

$$\frac{dI}{dt} = \alpha E - \gamma I$$

$$\frac{dR}{dt} = \gamma I + vS$$

$$S + E + I + R = N$$

$\beta(t) =$ contact rate which may be time variant

$\alpha =$ latency rate (from exposed to infectious)

$\gamma =$ rate of removal (from infectiousness)

$v =$ vaccination rate

$R =$ basic reproductive ratio and;

The necessary condition for an outbreak of epidemics is for R to be greater than 1.

2. Simulations of FMD outbreak

At day 0:

$$E_0 = \bar{E}, S_0 = N - E_0, I_0 = 0, R_0 = 0$$

$$\frac{dS_0}{dt} = -\beta(t=0) * \frac{S_0 I_0}{N} - v(t=0)S_0$$

$$\frac{dE_0}{dt} = \beta(t=0) * \frac{S_0 I_0}{N} - \alpha(t=0)E_0$$

$$\frac{dI_0}{dt} = \alpha(t=0)E_0 - \gamma(t=0)I_0$$

$$\frac{dR_0}{dt} = \gamma(t=0)I_0 + v(t=0)S_0$$

At day t,

$$Y_t = Y_{t-1} + \frac{dY_{t-1}}{dt} * \Delta t$$

$$where\ Y_t\ is\ S_t, E_t, I_t\ or\ R_t$$

3. Stochastic element in FMD outbreak simulation

$$X \sim Norm\ (\bar{X}, \frac{1}{2} * (X_{upper} - X_{lower})$$

Where X represents variables and parameters that are randomized to test for the distribution of the final size of the epidemics ($E_0, \alpha, \gamma, R, v$)

The mean, upper bond and lower bond of the above variables are based on expert opinions of herd-specific cases extracted from Simulation of foot-and-mouth disease spread within an integrated livestock system in Texas, USA (Garner et al 2009) and Potential socio-economic impacts of an outbreak of foot-and-mouth disease in Australia (Beutre et al. 2013), which is summarized in the spreadsheet for 2017 update.

4. Hypothetical scenarios:

Scenario 1: no intervention of CSIRO

- detection of disease on day 21; and
- stamping out of infected and possibly exposed population from day 22.

Scenario 2: Intervention with surveillance-related activities

- detection of disease on day 7;
- a reduction of 80% exposure from infectious population to susceptible from day 8; and
- stamping out from day 8.

Scenario 3: Intervention with surveillance-related activities accompanied by sufficient vaccines

- detection of disease on day 7;
- a reduction of 80% exposure from infectious population to susceptible from day 8;
- vaccination of susceptible population from day 8; and
- stamping out from day 8.

The simulations are run under these scenarios separately against herd-specific parameters including initial exposure, direct contact rate, indirect contact rate, latency and duration of infectiousness.

It is assumed that the final size of the FMD outbreak is measured by the total number of livestock slaughtered towards the end of epidemic or its ratio against the whole population. For the purpose of distinguishing between a moderate outbreak and a severe one, it is assumed a severe outbreak is where more than 80 percent of any herd and its surrounding livestock are stamped out and vice versa. In the original 2005 ABARES paper, a severe outbreak is defined as more than 90 percent of livestock is depopulated and a small outbreak is where less than 60 percent slaughtered towards the end.

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