NATIONAL
Fire Ant Eradication
PROGRAM

ABN 66 934 348 189 | 145–157 Wayne Goss Drive, Berrinba QLD 4117
PO Box 426, Browns Plains QLD 4118

12 December 2023

Mr Tas Larnach
Committee Secretary
Senate Standing Committees on Rural and Regional Affairs and Transport
PO Box 6100
Parliament House
Canberra ACT 2600

Email: rrat.sen@aph.gov.au

Dear Mr Larnach

I refer to your correspondence of the 25 October 2023, to the Director-General of the Department of Agriculture and Fisheries, Queensland, inviting submission to the Senate Rural and Regional Affairs and Transport References Committee (the committee) inquiry into red imported fire ants (RIFA).

The National Fire Ant Eradication Program (NFAEP) is a nationally cost shared program overseen by the NFAEP Steering Committee. The Steering Committee which provides guidance and support to the NFAEP, includes representatives from state, territory and the federal governments. I chair the committee as an independent chair.

The NFAEP have prepared a submission in accordance with the inquiry terms of reference, and I enclose it with this letter for the committee's consideration.

Yours sincerely

Dr John Robertson
Chair, Steering Committee
National Fire Ant Eradication Program

Enc

NATIONAL
Fire Ant Eradication
PROGRAM

ABN 66 934 348 189 | 145–157 Wayne Goss Drive, Berrinba QLD 4117
PO Box 426, Browns Plains QLD 4118

Submission to the National Red Imported Fire Ant Eradication Program Inquiry into Red Imported Fire Ants in Australia

a) The expected costs and impacts, if red imported fire ants are able to spread across Australia, on human health, social amenity, agriculture, the environment, infrastructure and regional workers.

Red Imported Fire Ants (fire ants) are considered a super-pest globally, causing costly long-term public health, agricultural, economic and environmental costs in countries they invade. Australia's climate is optimal for fire ants and if left untreated, they have the potential to inhabit most of Australia.

Public health impacts occur when fire ant nests are disturbed and when they are foraging for food. In the United States of America (USA), a 1988 survey of physicians resulted in reports of 83 deaths (32 confirmed) attributed to fatal anaphylactic reactions to fire ant stings[1]. Haifi et al[2] (2014) estimated that the total cost of medical attention for Australian households (based on 2011 population) due to stings could be as high as $114 million per annum (~$146 million CPI adjusted).

> Estimates of people in infested areas that are stung each year range from 30-89%. More than 1% of people stung are hypersensitive and may require medical attention[1]. The population of Australia as of December 2020 was 25.7 million. If fire ants infested Australia, at a conservative estimate of 30% of people within infested areas being stung, 8.3 million people could be stung and 83,100 could require medical attention for stings each year.

Social amenity impacts are difficult to determine on a national scale, but schools can provide an indicative example, with an estimated annual cost to Australian schools potentially exceeding $133 million (based on 9,404 schools in Australia in 2015[1]),

> Students are most likely to encounter fire ants in playgrounds or sports fields and thus are at greater risk of stings. In addition to the health and safety of students, fire ants can damage school electrical equipment and other infrastructure. In Texas in 2016, the average annual costs of treatment, repair and replacement of damaged equipment was estimated at US $4954/school/year (or A$14,176 values)[1]. Most ongoing costs would be associated with treatment of grounds and fields.

Environmental impacts would be significant if fire ants were to become established in Australia. Fire ants are listed as a key threatening process under the *Environment*

[1] Wylie F.R. and Janssen-May S. (2016) Red imported fire ant in Australia: what if we lose the war? Ecological Management and Restoration 18, 1–13 http://dx.doi.org/10.1111/emr.12238

[2] Hafi A., Spring D., Croft L., Kompas T. and Morey K. (2014) Cost-Effectiveness of Biosecurity Response Options to Red Imported Fire Ants in South East Queensland. Australian Bureau of Agricultural and Resource Economics and Sciences, Department of Agriculture, Canberra

Protection and Biodiversity Conservation Act 1999 (Cwlth) and directly endanger a high proportion of Australian fauna and flora.

> Fire ants have the potential to reduce the biodiversity of Australian native fauna and flora by endangering 45 per cent of birds, 38 per cent of mammals, 69 per cent of reptiles and 95 per cent of amphibians[3], including iconic species such as the platypus, echidna, spotted tail quoll, southern cassowary, night parrot, saltwater turtles and endangered frogs.
>
> Climate change is likely to increase risks of fire ant spread, into previously forested bushfire-affected land and by increased spread with flooding events. More severe weather events will also interfere with control efforts.

Agricultural impacts caused by fire ants across Australia would be substantial across with potential costs to the beef industry exceeding $300 million per annum and potential costs to the cropping industry exceeding $330 million per annum[1].

> In Texas, fire ants reduced cattle industry gross margins by about 10 per cent or A$11.24 per head of cattle, in 2016[1]. Meat and Livestock Australia estimate the cattle herd size in Australia is currently around 28.8 million and total losses to the industry from fire ants could total more than $300 million. This impact could also be applied to the Australian sheep industry.
>
> In relation to cropping, more than 50 commercial food crops are reported to be impacted by fire ants in the USA, including vegetable, melon, fruit, nut, vine and grain crops[1]. All these crops are grown in Australia. In Texas in 2016, increased annual crop production costs (based on six major crops) due to fire ants are estimated to be US$8.95/acre or US$22.12/ha (A$53.27 at 2016 values)[1]. With more than 6 million hectares sown in Australia[1], excluding cotton and sugar but including fruit and nuts, and vegetables that are known to be impacted[1]. Potential costs in relation to cropping are approximately $330 million.

Infrastructure impacts would be broad based on the impacts to telecommunications and electrical supply and equipment in the USA. Costs to the electrical and telecommunication companies in Australia could amount to $508 million per annum[1].

> Fire ants are attracted to electrical utilities, shorting out switching mechanisms and causing corrosion to housing of transformers and other equipment. Road and airport runway lights can also be affected[1]. Studies in the US estimate costs of US$8.90 (or A$21.43 in 2016 values) per capita per year for treatment and repair of electrical components by electrical and telecommunication companies[1]. Extrapolated to Australia with its current population of over 26.4 million (Australian Bureau of Statistics), costs to the electrical and telecommunication companies in Australia could amount to $508 million.

The economic, agricultural, social and environmental benefits of eradicating fire ants, globally, have been widely studied, analysed and publicised. There are four significant and detailed Cost Benefit Analyses (CBA) of the National Red Imported

[3] Lach L. and Barker G. (2013) Assessing the effectiveness of tramp ant projects to reduce impacts on biodiversity. A report prepared for the Australian Government Department of Sustainability, Environment, Water,

Fire Ant Eradication Program (the Program) with the earlier CBAs (2001, 2014) estimating the benefit cost ratio of implementation of a 20-year eradication program would be as high as 25:1.

The most recent CBA, completed in 2021 by the Central Queensland University[4], predicted that without the Program, by year 15 the natural spread would take fire ant infestation to far north Queensland including the Whitsunday Islands and as far south as the Blue Mountains in NSW, with more than $1.25 billion annual cost to the Australian economy. With human-assisted movement of fire ants representing one of the highest risks for spread, without the biosecurity zones in place the infestation would likely be far larger. This figure does not consider the potential non-market losses from fire ants such as the forgone value of outdoor activities and tourism, reduced biodiversity and associated ecosystem services and implications for Australian export and international trade, which could then cause significant negative multiplier effects in regional economies. Further, the study concluded that even with those incomplete potential benefits, the benefit cost ratio of implementation of a 15-year eradication program would likely still remain as high as 9:1 at a 5% discount rate.

The CBA only forecasts out to 15 years, with fire ant spread at that time of approximately 20% of the total potential spread across Australia. At 15 years, estimated costs avoided are already $1.2 billion per annum. At full spread, estimated in previous CBAs to take up to 80 years, annual costs avoided will be many times this conservative estimate.

The 2021 CBA estimated households will have the greatest economic impacts at more than half a billion dollars, followed by agriculture at almost 400 million. It should be noted household economic impacts were given a discount factor of 50%. This is estimated to account for only half of the households who detect fire ants self-managing and treating for fire ants.

The following table represents the impact of increasing spread based on natural flight and the cost on different areas at year 15, at a per annum basis.
The relevance of 5km reflects the current rate of the spread of RIFA, while the relevance of 48km is the average annual rate of spread in Texas over the period 1957 to 1977[1]. These then represent the expected and maximum infestation scenarios that could be expected to occur. Human assisted movement cannot be modelled, but spread would be accelerated and associated costs would likely rise quickly.

[4] Star, M., Rolfe, J. 2021. *Assessing the Impacts of the Red Imported Fire Ant Report* for Biosecurity Qld, Department of Agriculture and Fisheries.

Impact Area	Bears Costs	5km Spread Yr 15 @7%	48km Spread yr 15 @7%
Household	Households	$447,880,224.30	$536,869,066.43
Agriculture	Qld, NSW Business'	$256,163,315.51	$381,130,000.10
Water	Sunwater, NSW Water, NRM Groups, Coucil	$82,942,151.72	$133,813,803.31
Environment	Community	$39,642,845.27	$84,012,204.67
Education	Dept of Education, Private Schools	$34,674,661.61	$39,710,868.38
Parks and Rec Areas	Council's Local Sporting Committees	$11,705,235.69	$57,788,587.55
Industrial	Business' and Coucil	$6,491,657.71	$7,198,735.63
Tourism	Business'	$3,338,354.01	$3,502,646.29
Hospital	Dept of Health	$2,750,864.96	$3,295,295.60
Commerical	Businesses	$2,355,674.21	$2,714,780.59
Health	Dept of Health	$2,339,257.85	$2,404,846.30
Transport	Main Roads & Council	$102,121.69	$106,680.15
	Total	$890,386,364.52	$1,252,547,515.01

Table 1: Impacts at the expected (5 km) and maximum (48 km) different areas at year 15 applying 7% discount[4]

b) An assessment of the current and any proposed fire ant response plans for achieving the eradication of red imported fire ants.

In late July 2017, the national Agriculture Ministers' Forum approved funding of $411.4 million over 10 years, cost-shared between jurisdictions for implementation of the 10-year plan and to be overseen by a multi-jurisdictional Program Steering Committee[5].

Delays in gaining national funding approval meant that in 2017, the operational zone comprised an area of 500,470 which was significantly larger than the area delimited in 2015, on which the operational budget of $411 m over 10 years had been developed[6].

The Steering Committee commissioned an independent Strategic Review[6] of the Program in 2021 in response to activation of a risk management trigger in the Ten-Year Plan, namely "any event or circumstance that means the objectives and eradication targets of the 10-year plan are unlikely to be achieved within the agreed time frame or budget". The immediate trigger was the detection in late 2020-21 of multiple infestations outside the Operational Boundary. The aim of the review was to examine the Program's effectiveness, the feasibility of achieving fire ant eradication and alternative strategies for achieving the eradication objectives.

The key review finding was that fire ants can still be eradicated, provided substantial changes to the response strategy are implemented at National, State, and local levels. The review found that additional funding from the Australian, State and Territory Governments is required, as the benefits of eradication outweigh the ongoing costs of addressing the impact of fire ants.

The Strategic Review also recommended that a coordinated suppression program should be implemented in areas not receiving eradication treatment. The review panel recommended the Program focus solely on eradication and the Queensland Government mobilise government (Local, State and Federal), community and businesses to increase fire ant suppression activities.

On the 30 September 2021, the Program Steering Committee supported the option in the Strategic Review 2021, for continued eradication (Contain, Suppress, Eradicate, by 2032) recommended by the Review panel.

The response focused on two areas, stronger containment outside the known infested area by the Program and more aggressive suppression in the current residual area, managed and funded by Queensland.

Fire Ant Suppression in areas awaiting eradication

The Queensland Government subsequently approved funding of $37.1 million from 2021–26, to establish the Fire Ant Suppression Taskforce (FAST). The suppression area, which is managed by the Taskforce, covers more than 650,000 hectares in Biosecurity Zones 1 and 2 where suburbs are waiting for eradication treatment. The

---

[5] The Steering Committee provides guidance and support on all aspects of our program's delivery to ensure that we have the best chance of achieving our objectives.
The Steering Committee is led by an independent chair and includes expert representatives from state, territory and federal governments.

[6] NRIFAEP Strategic Review Report August 2021 by Helen Scott-Orr, Monica Gruber and Will Zacharin
https://www.agriculture.gov.au/sites/default/files/documents/Strategic%20Review%20of%20the%20National%20Red%20Imported%20Fire%20Ant%20Eradication%20Program%20August%202021.pdf

Taskforce is collaborating with local, State and Federal Government departments and agencies, industry and communities to suppress fire ant populations ahead of eradication. This collaboration includes a significant amount of expenditure and in-kind resources from other parties such as local government which is in addition to the Queensland Government investment.

Fire Ant Response Plan 2023 - 2027

A new eradication response plan was prepared by the Department of Agriculture and Fisheries (DAF) during 2022/23 which incorporates learnings from past efforts, uses the best available science, technology, and innovative approaches to address the recommendations from the independent review. The new plan employs proactive baiting beyond the outermost known infestation to deal with the problem of undetected spread and includes a large increase in compliance resources to address the risk of human-assisted movement.

Development of the Response Plan 2023 – 2027 has been overseen by both the Program Steering Committee and the National Biosecurity Committee (NBC). The Steering Committee endorsed the final Response Plan 2023-27 on 15 June 2023 and NBC endorsed the response plan to be presented to Agricultural Senior Officials Committee (AGSOC) on 29 June 2023.

The Steering Committee and the Program are advised by the National Exotic Invasive Ant Scientific Advisory Group[7] (SAG) which provides consistent, high-quality specialist scientific and technical advice relating to the eradication of fire ants in Australia. The SAG has international representation and incorporates leanings and advice from the USA.

Following endorsement by the Program Steering Committee, the NBC and AGSOC, the new Response Plan was endorsed by all Agriculture Ministers in July 2023.

Ministers committed to work within their jurisdictions to bring forward previously agreed future year budget allocations to further support eradication, noting that many jurisdictions have already done so, while future funding arrangements are secured.

---

[7] The SAG membership includes Australian and international specialists with expertise and knowledge relevant to eradication programs. They have scientific expertise in the following areas:

- exotic species/ant management/eradication
- surveillance techniques
- modelling
- working on novel technologies
- treatment efficacy.

c) An evaluation of funding provided for the current or any proposed fire ant response plans.

The strategic review panel highlighted eradication success was only possible with considerable changes to strategy and the size of the Program. The panel noted that funding delays regarding the 10-year eradication plan 2017-27, contributed to fire ants spreading beyond the scope of the approved plan.

The strategic review panel recommended an approach to fire ant eradication that they estimated could cost between $200 million and $300 million per year. The Strategic Review report stated that the "these figures should be viewed as estimates rather than minimum or maximum" and noted that "the budget is based on Program experience and focuses on quality rather than cost-cutting to meet a constrained budget."

The 2023-24 financial year detailed budget build for the National Fire Ant Eradication Programs Response Plan 2023-27 (Response Plan) has been completed in accordance with the DAF's Financial Management Practice Manual using the Adaptive Insights budget tool.

The Response Plans forecast costings 2023-25 (Tranche one) and 2025-27 (Tranche two) were calculated through an activities-based forecast model (linear) which was then validated against the Programs 2021-22 actuals data. Activities considered in the model included: treatment, surveillance, compliance, business services, strategy and policy, logistics and supply chain, scientific services, information services and innovation investment.

The forecast costings have been calculated to apply the Consumer Price Index after the first year.

The Response Plan outlines that a gate review will be completed during the 2024-25 financial year. This review will measure whether the Program's outcomes have been successful in meeting the defined objectives and if so, result in the release of the next two years, 2025-26 and 2026-27 financial years funding. Tranche two funding is committed for the remaining two years of this eradication strategy 2025-26 and 2026-27 financial years. A Program review will take place during the 2026-27 financial year to define the continuing national response plan beyond the 2026-27 financial year to achieve eradication by 2032. Funding approval for the full 2023–27 Program Response Plan was delayed, and alternate funding arrangements were initially required for 2023–24.

The Response Plan budget is calculated based on the planned activities; however, it is important to note that in every biosecurity response, there are often requirements for the governance committee to consider unexpected costs requiring additional budget. Gate Review 1, being completed during the FY24/25, is important in reassessing if the budget is still appropriate for the remainder of the plan.

d) The effectiveness of eradication efforts and the spread of fire ants.

The Queensland Government has led the eradication of fire ants under the National response since 2001. It is important to note that this approach is considered a National Environmental Biosecurity Response Agreement (NEBRA)-like response. This program predates the national deeds that facilitate national cost sharing of major biosecurity responses. Between 2001 and 2017 the Australian and state and territory governments have collectively spent $366.9 million to eradicate fire ants and managed to contain the pest within a small part of South East Queensland (SEQ).

In the absence of the Program's eradication and suppression activities, forecasting indicates that fire ants would have spread to more than 20 per cent of the Australian mainland by now, as illustrated below. Left untreated, fire ants would likely have reached Canberra and have spread to most capital cities in Australia by long distance movement in carrier materials.

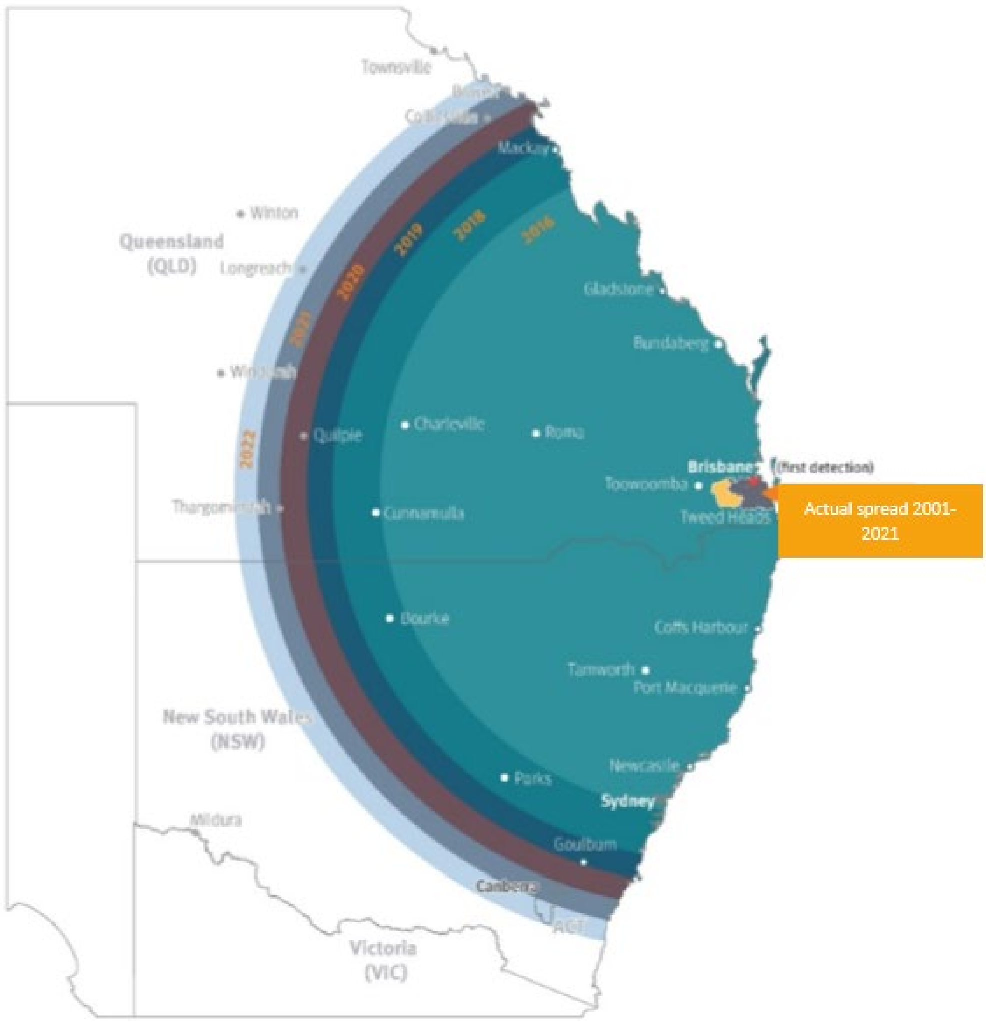

Figure 1: Forecast spread of fire ants if no response was mounted since 2001, and actual spread of fire ants 2001- 2021.

In the USA, annual fire ant spread has averaged 48 km and is as high as 80 km in China. The Program's efforts have kept the fire ant spread rate in SEQ to about 5 km per year and have greatly reduced fire ant densities within the eradication areas, thus limiting local impacts and potential for spread from those areas.

Eradication feasibility

The assessment of fire ants against the National Environmental Biosecurity Response Agreement (NEBRA) technical feasibility criteria has been provided in Appendix 1.

Eradication is technically feasible because fire ants are distinguishable on physical characteristics and genetic analysis, effective chemical treatments and surveillance options are available, and there is a high level of confidence that the organism is detectable at very low densities.

Program staff have had direct involvement with all fire ant and other exotic ant incursions since 2001 and contributed to their successful eradications or containment. The program has achieved the largest eradication of any ant species in the world to date (the 2001 Port of Brisbane population of 8,300 hectares[8]). Considering the difficulty of eradicating or even containing ants, this repeated success demonstrates the capability that has been developed within the Program.

Previous successful eradications

The program has successfully eradicated five fire ant incursions:

Location	**Detected**	**Source**	**Eradication**
Port of Brisbane	2001	new incursion from U.S.	eradicated 2012
Yarwun (Gladstone)	2006	new incursion from Argentina	eradicated 2010
Port of Gladstone	2013	new incursion from U.S.	eradicated 2016
Port Botany NSW	2014	new incursion from Argentina	eradicated 2016
Brisbane Airport	2015	new incursion from U.S.	eradicated 2019

In addition, a fire ant incursion from China found at Fremantle, Western Australia in 2019 is nearing the ‘declaration of freedom’ stage. The Program assisted the West Australian Government with treatment and surveillance expertise. In 2022, the Program's odour detection dog teams assisted the West Australian Government with clearance surveillance. A new incursion from the USA detected at the Port of Brisbane in 2021 is currently receiving eradication treatment.
Since its inception, the Program has eradicated four post quarantine detections where fire ants were destroyed prior to establishment. These include Melbourne in 2001, Port of Brisbane in 2004, Lytton Qld in 2009 and Roma Qld in 2011. The

Roma detection was intercepted on a shipment of goods enroute to Western Australia.

Nationally, a further eight fire ant quarantine interceptions have been eradicated at the point of entry. There were in Darwin in 2007, Melbourne in 2006 and 2015, South Australia in 2009 and 2017, the Port of Brisbane in 2009 and 2014, and in Western Australia in 2011.

Appendix 1: Technical feasibility of eradication

This appendix assesses the technical feasibility of the proposed response for eradication of fire ants in SEQ against the following criteria:

- capability to accurately diagnose or identify fire ants
- effectiveness of the control techniques
- level of confidence that all individual fire ants present can be destroyed by the recommended control techniques
- level of confidence that it is possible to remove fire ants at a faster rate than they can propagate until the population is reduced to a non-viable density
- confirmation that the recommended control techniques are publicly acceptable
- endemic pest or disease controls that may limit or prevent establishment
- legislative impediments to undertaking the eradication
- the known area of infestation
- the likely distribution of the pest or disease and dispersal ability of the organism
- identification of the pathways for the entry into, and spread within, Australia of the pest or disease and level of confidence that further introductions are sufficiently low
- the level of confidence that the organism is detectable at very low densities (to help determine if eradication has been achieved), and that all sites affected by the outbreak have or can be found
- surveillance activities that are in place or could be put in place to confirm proof-of-freedom for sites possibly infested by the pest or disease.

4.1 Capability to accurately diagnose or identify fire ants

In comparison with Australian native *Solenopsis* species, *Solenopsis invicta* is easily distinguishable by its generally larger size, polymorphic workers, darker colour and the presence of a middle clypeal tooth.

Diagnosticians use microscopic laboratory diagnosis to positively identify fire ants. Field staff provide preliminary identification, and geneticists undertake genetic analysis to determine social form, population structure and intra-population analysis. A fire ant identification kit is also available which may be used by non-experts to positively identify fire ants in the field.

4.1.1 Field identification

Field officers make preliminary identifications in the field using the following characteristics:

- worker caste is polymorphic
- head and body are a coppery-brown colour, with a darker abdomen
- if visible, nests vary in shape and size, but can be up to 40 cm high dome-shaped mounds without any obvious entrance and exit holes. Foraging holes generally occur every 1–5 m along the underground tunnels.

Samples are then taken of ants with features consistent with the above characteristics and submitted for diagnostic testing.

4.1.2 Laboratory diagnosis

National Program scientific staff diagnose samples using visual examination of morphological diagnostic characteristics as outlined by specialised scientific web databases such as AntWeb and PaDIL.

The diagnostic characteristics of *Solenopsis invicta* are:

- worker caste is polymorphic and ranges in size from 2–6 mm
- head and body are a coppery-brown colour, with a darker abdomen
- propodeal spines are absent
- antennal scrobes are absent
- waist has two segments (petiole and post-petiole)
- antennae have 10 segments, with a two-segment club
- petiolar process is either reduced or absent
- mandibles have four teeth
- a single central seta visible on the lower edge of the clypeus
- anterior clypeal margin has a middle tooth between two lateral teeth.

National Program scientists then send confirmed positive samples for genetic analysis if required. The National Program has made a large investment in progressing genetic analysis of fire ant populations in Queensland. There are two components to the current analysis: determination of social form (monogyne or polygyne) and fragment analysis using microsatellites to determine relatedness.

4.1.3 Determination of social form

Within the National Program, the social forms of fire ant samples are determined using genetic analysis of the Gp-9 alleles. Fire ant workers and queens from monogyne (single queen) colonies always have the genotype BB, whereas fire ant queens from polygyne (multiple queen) colonies have the genotype Bb, and polygyne workers can be either BB, Bb, or bb.

Since December 2007, genetics staff conduct this analysis using a High Resolution Melt (HRM) polymerase chain reaction (PCR) technique developed by Oakey (2009) (from the National Program). During 2007, the National Program validated this method against the standard restriction endonuclease analysis (REA) PCR described by Krieger & Ross (2002). It was necessary to develop this test as the DNA extracted from field samples was of inadequate quality to perform reliable analysis.

The National Program performs a 'bulk' DNA extraction using a pool of 5–10 fire ant workers from a colony. Pooling multiple ants, rather than single ants, from a colony eliminates falsely assigning the monogyne genotype to a polygyne colony (as the BB genotype exists in workers from both types of nests). The National Program performs DNA extraction using a commercial kit (QIAgen DNeasy Blood and Tissue kit) according to the manufacturer's instructions.

Knowledge of social form is useful to the National Program, as both forms have different dispersal characteristics and associated risk of spread, meaning that the operational response to the detection of a polygyne colony can be different to that for a monogyne colony. For instance, the detection of a polygyne colony may require more thorough tracing (and possibly require more intensive treatment methods to reduce the initial high density of colonies) but may not require the same extent of surveillance compared to the discovery of a monogyne colony, as the polygyne social form rarely develop from nuptial flights.

4.1.4 Determination of colony relatedness

Microsatellites are short tandem repeats found within the genes of eukaryotic organisms. These repeats are prone to higher levels of mutation and can be used in genetic analysis to determine kinship and levels of relatedness between individuals. The variable number of repeats can be detected using PCR. An individual's pattern of microsatellite lengths (alleles) at multiple microsatellite sites (loci) in nuclear DNA provides a microsatellite genotype for that individual. The National Program conducts fragment analysis to determine the following:

- population structure - which aids in the determination of:
  - how many populations are present and how many separate incursions have occurred
  - the presence/absence of sub-structure within a population
  - whether a population is demonstrating genetic equilibria (population stability)
- intra-population analysis – which aids in the determination of:
  - estimating the number of founding queens – the relatedness between colonies
  - estimating the dispersal distances of newly detected colonies
  - whether newly identified colonies survived treatment or are a new infestation
  - estimating the number of undetected colonies.

Colony relatedness and population analysis are useful to the National Program as they provide crucial information about the number of times fire ants have established (number of separate incursions), and whether new detections are the result of treatment survival, or the result of colony spread.

4.2 Effectiveness of the control techniques

The incidence of fire ant infestation is reduced through:

- the early detection of fire ant colonies
- the destruction of those colonies and the treatment of all areas around the colonies (based on the limit of natural dispersal of the pest)
- the prevention of new colonies forming in areas outside of the limit of natural dispersal of the pest (as a result of human-assisted spread).

Since 2001, Australia has had measures in place to detect, control and contain fire ants in areas of Queensland where they are known to occur, and measures to eradicate fire ants from known infested areas.

Detection strategies used depend largely on abiotic and resource-related factors (e.g. targeting surveillance to suitable fire ant habitat in proximity to known infestations and conducting detection surveys at times when treatment will be ineffective due to ant foraging behaviour). Control and containment measures include addressing the risk of human-assisted spread, and eradication measures include the use of chemical products to destroy infestations.

Experience gained in dealing with fire ants in the USA initially provided the basis for developing a course of action for control and eradication of fire ants in Australia. Subsequently, national oversight groups,

4.2.1 Detection methods

The National Program employs a number of surveillance strategies for the detection of fire ants, dependent on abiotic factors that influence fire ant behaviour, infestations levels and available resources.

4.2.2 Containment measures

The key control measures for containment of fire ants is the implementation of movement controls on infested areas and high-risk materials, as well as treatment around the perimeter of the infestation.

Queensland's *Biosecurity Act 2014* (the Act) provides the legislative framework for biosecurity measures designed to safeguard our economy from pests including fire ants. The Biosecurity Regulation 2016 (the Regulation) sets out how the Act is implemented and applied.

4.2.3 Eradication measures

The National Program uses a number of chemical products that have been approved for use under the conditions of the relevant product label or permit. The following section details chemicals currently used in the National Program, as well as their destruction effect on the pest. These chemicals have been employed in the eradication of the Brisbane Airport (2015), Yarwun (2013), Yarwun (2006) and Port of Brisbane (2001) incursions. It is proposed that the same chemicals will continue to be used to treat fire ants in SEQ.

a) *Fipronil treatment and effect*

The National Program currently uses fipronil in a liquid form to conduct direct nest injection (DNI), in a once only application. Fipronil is a slow-acting poison which is non-repellent and undetectable. It kills insects by both contact and ingestion as it disrupts normal nerve function and works by blocking the GABA-gated chloride channels of neurons in the central nervous system. The GABA-receptor system is responsible for inhibition of normal neural activity (i.e. prevents excessive stimulation of the nerves). When the system's regular functions are blocked by fipronil, the result is neural excitation and the death of the insects.

b) Insect growth regulator treatment and effect

Currently, broadcast treatment baits are crushed corn impregnated with soybean oil and an insect growth regulator (IGR), either S-methoprene or pyriproxyfen.

The use of an IGR interferes with the growth and development of ants, thereby breaking the reproductive life cycle, causing starvation of the colony. Ant workers pick up the bait granules and take them back to the colony, where workers extract the toxic oil and feed the bait to both the queen and immature ants, preventing worker replacement through the degeneration of the queen's reproductive organs. The lack of worker replacement results in colony death as the existing worker ants age and die.

In field trials conducted in the USA on methoprene (0.5% active ingredient), with one application, efficacy rates ranged between 66% and 98% (average 83% over several studies). The time taken to reach maximum efficacy ranged from 4–8 months (the 98% efficacy was achieved over eight months) (National Program unpublished data 2011).

In field trials with one application of pyriproxyfen, efficacy rates ranged between 86.9% and 100% (average 95% over five studies). The time taken to reach maximum efficacy ranged from 2–9 months, but in a few studies, efficacy rates of 95–100% were achieved in 2–6 months. Pyriproxyfen is relatively stable in sunlight with a half-life of 3–16 days (National Program unpublished data 2011).

S-methoprene is permitted for use up to the edge of waterways, whereas pyriproxyfen cannot be applied within 8 m of water when using ground-based equipment. S-methoprene is used for the aerial baiting regime.

c) Indoxacarb treatment and effect

The National Program has implemented the use of a fast-acting bait alternative to aid in the treatment of polygyne infestation and in areas that are awaiting the roll out of eradication treatment. Like the IGR baits, this product is made of a corn grit carrier that is impregnated with soybean oil and indoxacarb. Indoxacarb is a slow acting poison that disrupts the insect central nervous system by blocking sodium channels. When the sodium channels are blocked by indoxacarb, the insect stops feeding, becomes paralysed, and dies.

Similar to the IGR baits, indoxacarb bait is collected by foragers and returned to the colony where the toxic oil is extracted and passed through the colony via communal feeding behaviours (trophallaxis). Indoxacarb has the most profound impact on workers and does not cause sterility in colony queens or immature reproductive ants. As such, indoxacarb baits are utilized where the goal is to rapidly reduce the number of worker ants. This product may be used in combination with insect growth regulator baits as part of a broader treatment strategy.

The National Program will continue to investigate existing and new treatment products as they become available and liaise with the Australian Pesticides and Veterinary Medicines Authority (APVMA) in regard to approvals for these products.

4.2.4 Bait distribution methods

Bait in SEQ will be distributed either aerially, on foot, or using an utility terrain vehicle (UTV) or blower truck, with aerial baiting being the most efficient method of application. Manual application of bait on foot is the most labour intensive and expensive method of treatment, but it is the only option available for use in heavily built-up areas or other areas where it is not possible or practical to treat using mechanical methods. This method involves program staff carrying handheld and operated bait dispersal devices and systematically walking over the area surrounding the fire ant infestation. In heavily vegetated areas and steep terrain, a backpack blower unit may be substituted for, or work in combination with, hand-operated bait spreaders to ensure a more effective coverage of the area.

4.3 Level of confidence that all individual fire ants present can be removed/ destroyed by the recommended control techniques

Australian efficacy data proves that DNI is almost 100% effective in destroying a fire ant colony and is not subject to foraging activity and associated temperature considerations (National Program unpublished data 2009, 2019).

Published data from the USA indicates that broadcast IGR baiting has proven to be effective against fire ants (Drees *et al*. 1996), with reports indicating 80–95% control within 1–6 months (Barr 2000). A higher level of confidence in achieving eradication of a known infestation is achieved through the conduct of multiple rounds of treatment and combining the confidence obtained from each treatment.

This is represented by the formula:
C=1–(1–C1) x (1–C2) x (1–C3) ... (1–Cn)

Where C is the confidence provided after n treatments, and Cn is the confidence provided by each round of treatment.

Assuming the confidence provided by each round of treatment is constant, the confidence of success over multiple rounds of treatment may be represented by the following formula:

C=1–(1–tE)n

Where tE is the treatment efficacy, and n is the number of treatments conducted in the treatment area.

Assuming a treatment efficacy of 80% for each round of bait treatment, **Table 4** demonstrates that a confidence of success in destroying fire ant infestation in the treatment area after six rounds of treatment is 99.994%.

Efficacy per round of treatment (%)	Confidence for treatment success (%)					
	1 round	2 rounds	3 rounds	4 rounds	5 rounds	6 rounds
10	10.000	19.000	27.100	34.390	40.951	46.856
20	20.000	36.000	48.800	59.040	67.232	73.786
30	30.000	51.000	65.700	75.990	83.193	88.235
40	40.000	64.000	78.400	87.040	92.224	95.334
50	50.000	75.000	87.500	93.750	96.875	98.438
55	55.000	79.750	90.888	95.899	98.155	99.170
60	60.000	84.000	93.600	97.440	98.976	99.590
70	70.000	91.000	97.300	99.190	99.757	99.927
75	75.000	93.750	98.438	99.609	99.902	99.976
80	**80.000**	**96.000**	**99.200**	**99.840**	**99.968**	**99.994**
90	90.000	99.000	99.900	99.990	99.999	100.000
100	100.000	100.000	100.000	100.000	100.000	100.000

Table 4: Confidence of treatment success over multiple rounds of treatment

However, additional unquantifiable factors such as temperature, terrain and the effectiveness of delivery systems can impact on the confidence of eradication of a colony provided by an individual or series of treatments. The theory also assumes that each treatment is a 'perfect' treatment and is applied without error and as specified over the treatment area.

National Program experience has shown that polygyne infestations take longer to kill and more rounds of bait. A National Program trial (concluded April 2016) with Distance® bait at Ebenezer required five rounds of treatment before all colonies were destroyed. Analysis of early National Program data on 60 study sites showed that, using baits alone, all monogyne infestations (n=22) were eradicated in 15–18 months, but polygyne infestations (n=38) were not eradicated until 24–30 months (McNaught *et al*. 2014).

Polygyne colonies have multiple queens (up to several hundred have been recorded in the USA) and higher density of mounds. For IGRs to work effectively, the active chemical must be maintained within the colony at levels high enough to cause brood production to cease and for long enough to allow the colony to age and die. At high initial populations of fire ants, competition between colonies for available bait may result in insufficient quantities of chemical circulating within some colonies, allowing them to persist for longer than populations with lower densities. As well, there is a hierarchy of feeding of queens in polygyne colonies; dominant (alpha) queens are fed first and the other queens get the crumbs from the table. This means that not all queens receive the required dosage of the chemical at each round of treatment.

In order to destroy polygyne infestations faster, the National Program may use a combination of IGR baits and a toxicant or DNI to reduce the initial high density of colonies. However, the National Program will only apply this treatment regime to known polygyne infestations and is unable to implement this for incipient or undiscovered infestations.

Assuming a gross overestimate of the efficacy or accounting for imperfect treatment during each round of treatment, Table 4 also demonstrates that to achieve an acceptable 99% confidence that fire ants have been destroyed in the area after six rounds of treatment, the efficacy provided by each round of treatment may be as low as 53.6%.

This is represented by the formula:
tE=1–(1–C)1/ n

Where tE is the treatment efficacy, n is the number of treatments conducted in the treatment area, and C is the desired confidence to be provided after n treatments.

Therefore:

tE=1–(1–0.99)1/ 6 tE= 53.58%

The National Program will continue to undertake treatment efficacy testing throughout the life of the eradication to maintain confidence that treatment methods used are effective.

4.4 Level of confidence that it is possible to remove fire ants at a faster rate than they can propagate until the population is reduced to a non-viable density

DNI of known fire ant colonies is almost 100% effective in destroying the colony and broadcast baiting has proven to be effective against fire ants (refer to Section 3.2.3).

A treatment program using a combination of DNI and broadcast baiting was used to eradicate fire ants at Yarwun (2006 and 2013), the Port of Brisbane (2001) and Brisbane Airport (2015), with these areas subsequently being declared free of fire ants.

The same strategy is being implemented for eradication of the South East Queensland fire ant incursions. To remove fire ant populations at a faster rate than they can reproduce requires the application of the full treatment regime across all infested areas.

4.5 Confirmation that the recommended control techniques are acceptable

The National Program has operated since 2001, and with some limited exceptions, operates with community support, as evidenced by the continual submission of ant samples by the public. The National Program has applied for and been granted approval for a number of chemical products to be used under the conditions of the relevant product label or permit. All chemicals are used in accordance with label specifications and permits as issued by the APVMA. The National Program will continue to monitor the availability of new chemicals for possible use in the enhanced program.

4.6 Endemic pest or disease controls that may limit or prevent establishment

No endemic pest or disease controls have been identified that may limit or prevent establishment.

4.7 Legislative impediments to implementing eradication

There are no legislative impediments to the implementation ofthe Response Plan. Fire ants are restricted biosecurity matter under the Queensland *Biosecurity Act 2014*.

4.8 Known area of infestation

The current 'footprint' of this infestation, the area in which controls are applied on the movement of materials likely to harbour fire ants, is approximately 800 000 hectares, but the actual area infested is only a small fraction of that, and is very dispersed and generally low density.

4.9 Likely distribution of fire ants and dispersal ability of fire ants

CLIMEX and Climatch modelling of the potential distribution of fire ants indicates that there are few places in Australia where fire ants could not establish (refer to section 5.2 'Cost-sharing apportionments'). In arid regions, fire ants can colonise anywhere there is a source of water (e.g. surface, accessible groundwater or irrigation). Potential spread modelling was initially based on US climatic limitations such as a low cold tolerance (Buren *et al*. 1974), but fire ants have been seen to survive in areas with winter snow such as the east and west coasts of the USA, and could well reach Canada (Bennett 2016).

Scanlan *et al*. (2006) also modelled the spread of fire ant based on dispersion through the formation of new locations of infestations and spread within each location. The estimations of new locations were based mainly on natural spread, with some allowances for human-mediated spread. This modelling indicated that fire ants could spread to an area of 6 million km2 across Australia. While natural spread may take some time, it may occur sooner as a result of human-assisted spread.

If spread were to occur at the same rate as recorded in Texas in the USA (i.e. 48 km each year between 1957 and 1977 (Hung & Vinson 1978)), fire ants would now extend west to Longreach, north to Bowen and south to Canberra (National Program unpublished data 2017). In China, spread has occurred at an estimated rate of 80 km per year (Lu *et al*. 2008).

4.10 Level of confidence that fire ants are detectable at very low densities and that all sites affected by the outbreak have or can be found

The National Program employs a number of surveillance techniques for the detection of fire ants. The most appropriate method depends on infestation and treatment status, terrain type, infrastructure, available resources and cost efficiency. Most commonly, surveillance is undertaken on foot by a field team, but post-treatment validation processes may use odour detection dogs, in-ground lures and visual surveillance. Community engagement (passive surveillance) is also a very effective surveillance tool, generating valuable positive and negative sample data.

The National Program will consider remote sensing surveillance technologies (RSS) Previously, RSS was used to undertake delimitation activities, but in the future, it may be used as a tool to undertake broadscale surveillance and support a clearance methodology.

On-ground visual surveillance, odour detection dogs, and passive surveillance will be employed in SEQ to determine that all infested sites have been found and that fire ants have been eradicated.

Visual surveillance

Members of the field team form a line with pre-set spacing, determined by difficulty of detection as a result of terrain or vegetation type, and move forward to conduct a survey sweep across the land parcel to be surveyed. The method will be repeated until all areas of the land parcel have been inspected.

It is estimated that visual surveillance has an 80% efficacy of detection. The ground/visual search detection rate of 80% is derived from trials conducted in Taiwan by staff of the Biosecurity Queensland Control Centre.

Odour detection dogs

National Program testing indicates that there is an 80–100% confidence level for odour detection dogs in detecting fire ant infestation if present.

Passive surveillance

Passive surveillance by the community is a useful tool to detect infestation within and outside known infested areas. The invasive and aggressive nature of fire ants support their detection through passive surveillance techniques in areas where there is human activity and fire ant awareness material or activity is provided.

Remote sensing surveillance

The need for accurate and reliable RSS has been highlighted in several of the NFAEP reviews to-date and was recommended by the Strategic Review Panel. Investments in this capability have yet to be fully realised, however it is anticipated that this capability will improve as the technology matures and its use becomes more widespread in other contexts. Effective improvement in this form of surveillance will greatly assist the NFAEP to meet its eradication objective.

4.11 Surveillance activities that are in place or could be put in place to confirm proof of freedom for sites possibly infested by fire ants

A pest-free area is defined as 'an area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained' (FAO 1996).

In Australia, principles for the establishment of pest-free areas have been set to provide guidance to Commonwealth and state agencies in making formal decisions about the pest-free status of Australia, or parts of it, and to provide evidence to that effect. These guidelines are provided as a report commissioned by the Department of Agriculture, Fisheries and Forestry and Plant Health Australia, *Guidelines for the Establishment of Pest Free Areas for Australian Quarantine* (Jorgensen et al. 2003).

In cases where the spread of the pest has been clearly delineated and the infested area clearly has some form of natural or artificial boundaries that would in some way limit the spread of a pest (e.g. host availability, climate characteristics or regulated control and containment measures that would limit the spread of the pest out of the area), national principles for the establishment of pest free-areas may be applied as the risk of reinfestation from outside the defined area has been addressed.

a) Estimating a minimum predicted apparent pest prevalence

As part of the survey validation process, estimation must be made on the minimum predicted apparent prevalence of the pest within the survey area at the time of survey. In this instance, a determination of minimum predicted prevalence at the time of each survey is based on a conservative but realistic consideration of the likely multiplication, spread and survival of the pest since the 'pest prevalence start date', which is the date after which the last treatment was applied. A conservative approach was taken by assuming that the minimum number of colonies survived treatment (i.e. one colony). Modelling work by Schmidt et al. (2010) provides a quantitative estimate of the increase in fire ant nests over time. The estimates are based on colony point data in SEQ provided by the National Program. A minimum apparent pest prevalence (in nests) may be estimated at the time of each survey round.

b) **Estimating sensitivity of surveillance and overall test sensitivity**

Collaborative survey sensitivity trials conducted in Taiwan by the National Program provide some guidance for estimating surveillance sensitivity. The trials consisted of multiple passes of surveillance of plots with low to high densities of fire ant mounds. The trials found that, for a fire ant colony where a nest structure is visible, and the area is inspected by National Program staff on foot undertaking an 'emu parade' inspection, an average of 82% survey sensitivity was achieved using the specified inspection method. For large mounds (>30 cm) 100% were detected.

Based on these trials, the National Program assumes a conservative 80% sensitivity of surveillance for detecting a fire ant nest using the specified method. Suspicious samples collected during surveys are considered as 'presumptive positives' and are sent for laboratory diagnosis. The final assessment of the presumptive positive sample taken as part of the field inspection is undertaken through the conduct of two independent diagnostic tests. The initial diagnostic identification is followed by an additional confirmatory analysis by a second diagnostician.

This process also provides for independence by allowing the independent diagnostician to confirm the result by performing the same test. This provides for an extremely high diagnostic test specificity (the probability of a negative test result given that the sample is not fire ant). However, multi-layer diagnostic tests can provide a potential for reduction in diagnostic test sensitivity (the probability of diagnosing a positive test result given that the pest is present) by providing more opportunities for test failure where a final determination is made based on the result at the final level diagnostic test (the test layer where the result comes up negative and the result is considered as negative and no further action is taken). In this case, and in many cases where multiple independent tests are performed, the testing protocol incorporates a number of controls and the provision for the diagnostician to repeat the test where the test result is ambiguous or unexpected based on the results of previous tests.

Further, samples generally include between one and 10 ants. The diagnostic process requires that each ant in the sample is diagnosed, further reducing the likelihood of a sample being fire ant and being dismissed as a negative sample. The test sensitivity is the probability of detection of a red imported fire ant nest, taking account of the survey sensitivity and that provided by the diagnostic test. In this instance, the probability of detection through two statistically independent tests equals the product of the individual probabilities of detection of both tests. It is represented by the following equation:

$$Set = Ses \times Sed$$

Where Set is the test sensitivity, Ses is the survey sensitivity, and Sed is the diagnostic test sensitivity.

No studies have been undertaken on the diagnostic test sensitivity. However, the National Program suggests a 99% diagnostic test sensitivity as a conservative estimate. The estimation of test sensitivity is provided in **Table 5**, which provides likely test sensitivities over a range of diagnostic test sensitivities and a range of survey sensitivities. Assuming a survey sensitivity of 80% and a diagnostic test sensitivity of 99%, an overall test sensitivity of 79.20% is achieved.

Sensitivity of survey	Sensitivity of diagnostic test						
	95.00%	96.00%	97.00%	98.00%	99.00%	99.50%	99.90%
65%	61.75%	62.40%	63.05%	63.70%	64.35%	64.68%	64.94%
70%	66.50%	67.20%	67.90%	68.60%	69.30%	69.65%	69.93%
75%	71.25%	72.00%	72.75%	73.50%	74.25%	74.63%	74.93%
80%	76.00%	76.80%	77.60%	78.40%	79.20%	79.60%	79.92%
85%	80.75%	81.60%	82.45%	83.30%	84.15%	84.58%	84.92%
90%	85.50%	86.40%	87.30%	88.20%	89.10%	89.55%	89.91%
95%	90.25%	91.20%	92.15%	93.10%	94.05%	94.53%	94.91%
99%	94.05%	95.04%	96.03%	97.02%	98.01%	98.51%	98.90%

Table 5: Estimation of test sensitivity for diagnosing fire ant in an area

c) Validation surveillance strategy and determining the likelihood of success

Table 6 provides estimations for the likelihood of detecting pest infestation of some size in an area should every individual colony be encountered by the surveillance activity.

Likelihood of detecting infestation (%) in the survey area should infestation be present											
Test sensitivity (Se^{tt})	Number of visible mounds present within the survey area at the time of inspection										
	1	2	3	4	5	6	7	8A	9	10	20
10.000%	10.000	19.000	27.100	34.390	40.951	46.856	52.170	56.953	61.258	65.132	87.842
20.000%	20.000	36.000	48.800	59.040	67.232	73.786	79.028	83.223	86.578	89.263	98.847
30.000%	30.000	51.000	65.700	75.990	83.193	88.235	91.765	94.235	95.965	97.175	99.920
40.000%	40.000	64.000	78.400	87.040	92.224	95.334	97.201	98.320	98.992	99.395	99.996
43.780%	43.780	68.393	82.231	90.010	94.384	96.842	98.225	99.002	99.439	99.685	99.999
50.000%	50.000	75.000	87.500	93.750	96.875	98.438	99.219	99.609	99.805	99.902	100
60.000%	60.000	84.000	93.600	97.440	98.976	99.590	99.836	99.934	99.974	99.990	100
65.000%	65.000	87.750	95.713	98.499	99.475	99.816	99.936	99.977	99.992	99.997	100
70.000%	70.000	91.000	97.300	99.190	99.757	99.927	99.978	99.993	99.998	99.999	100
75.000%	75.000	93.750	98.438	99.609	99.902	99.976	99.994	99.998	100	100	100
79.200%	79.200	95.674	99.100	99.813	99.961	99.992	99.998	99.999	100	100	100
80.000%	80.000	96.000	99.200	99.840	99.968	99.994	99.999	100	100	100	100
90.000%	90.000	99.000	99.900	99.990	99.999	100	100	100	100	100	100
100.000%	100	100	100	100	100	100	100	100	100	100	100

A – Predicated minimum apparent pest prevalence after treatment assuming a 12 months period of dispersal and development.

Table 6: Estimation of confidence of pest freedom where the pest was not diagnosed and likelihood of detecting infestation (%) in the survey area should infestation be present.

The actual probability of detection is therefore scaled with the number of colonies expected to be encountered, which scales with the proportion of the area of interest to be surveyed.

A Bayesian approach is then used to estimate the probabilities of local eradications, within many small (2 500 hectare) “clearance zones,” based on the likelihood of observing zero colonies for a given surveillance effort, the hypothesis that a small infestation will grow through time, and baseline expectations of eradication, conventionally termed “prior” probabilities of eradication.

The overall probability of eradication is then calculated by pooling—via the exponentiation method—the individual within-clearance zone probabilities.

The National Steering Committee has set an overall target probability of freedom to exceed 95%. Program modelling has indicated that a > 17% coverage surveillance effort, annually for 6 consecutive years without a positive detection, in every clearance zone, will result in the target level Proof of Freedom > 95%.

References

Barr, C.L. (2000) B*roadcast baits for fire ant control. Texas Agricultural Extension Service Bulletin* B-6099, p. 14.

Bennett, C. (2016) When will fire ant march end? *Farm Journal*.

Buren W.F., Allen G.E., Whitcomb, W.H., Lennartz, F.E. and Williams R.N. (1974) Zoogeography of the imported fire ants. *Journal of the New York Entomological Society* 82: 113–124.

Drees, B.M., Barr, C.L., Vinson, S.B., Gold, R.E., Merchant, M.E., Riggs, N., Lennon, L., Russell, S. and Nester, P. (1996) Managing imported fire ants in urban areas. *Texas Agricultural Extension Service Bulletin* B-6043, p. 18.

FAO (1996) *Requirements for the establishment of pest free areas*, Food and Agriculture Organisation of the United Nations, Publication No. 4, Rome.

Hung, A.C.F., Barlin, M.R. and Vinson, S.B. (1977) Identification, distribution, and biology of fire ants in Texas. *Texas Agricultural Experimental Station Bulletin* 1185: 1–24.

Jorgensen, K., Cannon, R. and Muirhead, I. (2003) *Guidelines for the establishment of pest free areas for Australian quarantine*. Report prepared for Plant Health Australia Ltd and Agriculture, Fisheries and Forestry Australia.

Lu, Y.Y., Liang, G.W. and Zeng L. (2008) Study on expansion pattern of red imported fire ant Solenopsis invicta Buren, in South China. *Scientia Agricultura Sinica* 41:1053–1063.

McNaught, M.K., Wylie, R.F., Harris, E.J., Alston, C.L., Burwell, C.J. and Jennings, C. (2014) Effect of broadcast baiting on abundance patterns of red imported fire ants and key local ant genera at long-term monitoring sites in Brisbane, Australia. *Journal of Economic Entomology* 107(4): 1307–1315.

Scanlan, J.C. and Vanderwoude, C. (2006) Modelling the potential spread of Solenopsis invicta Buren (Hymenoptera: Formicidae) (red imported fire ant) in Australia. *Australian Journal of Entomology* 45:1–9.

Schmidt, D., Spring D., Mac Nally, R., Thomson J.R., Brook B.W., Cacho O. and McKenzie M. (2010) Finding needles (or ants) in haystacks: predicting locations of invasive organisms to inform eradication and containment. *Ecological Applications* 20: 1217–1227.