BUSHFIRE RISK MANAGEMENT CASE STUDY 1

BOX 1 EXECUTIVE SUMMARY

Key findings

CSIRO's Bushfire Risk Management (BRM) work is exemplified by two projects - the Tanker Burnover Project and the Queensland Bushfire Mapping Project – which have produced the following outcomes:

- improvements in the design and operation of tanker crew protection systems – while there have been multiple burnover events since fitting the systems, no firefighter lives have been lost
- better informed training programs for firefighter response in burnover situations based on the data collected during simulator and field trial burnover testing
- a new State-wide mapping methodology has been implemented to identify Bushfire Prone Areas in support of bushfire hazard provisions of Queensland's State Planning Policy
- the improved approach to developing bushfire prone area mapping allows Queensland local governments to more accurately identify areas exposed to potential hazard and inform planning and building decisions and associated mitigation strategies.

CSIRO's BRM work has delivered significant benefits which are essentially the same across both the Tanker Burnover Project and the Queensland Bushfire Mapping Project. Benefits include:

- reduction in loss of life/injury
- reduction in the economic impact: the total economic cost of bushfires in Australia is very high, and under current conditions, is estimated to average around $1.1 billion per year (2017 figures) comprising direct tangible costs, indirect tangible costs and intangible costs
- reduction in infrastructure losses/disruptions including: public infrastructure and services that are damaged or destroyed by bushfires; transport networks are disrupted; loss of electricity supply and communications equipment; impact to potable water supply catchments and private infrastructure losses (homes and other private rural infrastructure, iconic or important buildings (both public and private)) and fire fighting vehicles and equipment
- better fire management resource (human and equipment) deployment
- better/more informed planning decisions through adoption of a methodology that has a clear focus on bushfire hazard mapping aligned with national emergency risk assessment guidelines.

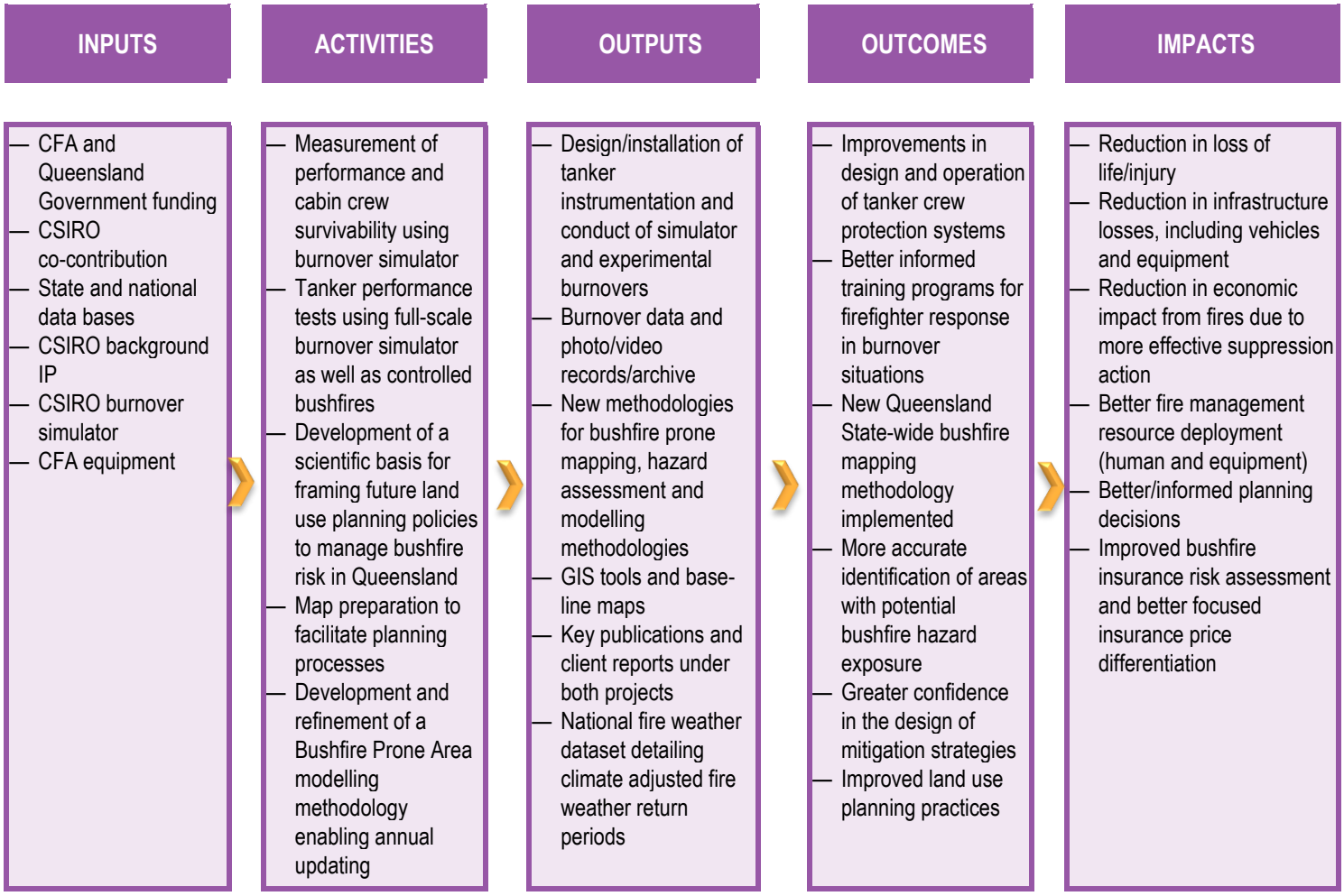
Innovation impact

CSIRO is a global leader in the field of tanker burnover testing. The simulator is internationally unique and affords CSIRO a significant opportunity to develop a niche export market for products and/or services that can be delivered using the simulator (as a provider of burnover testing of tankers and a wide range of infrastructure).

Through the Queensland Bushfire Mapping Project, CSIRO has initiated interaction with insurance industry. The weather datasets and national climate adjusted regression curves are already used by insurance agencies to better assess bushfire risks and more accurately differentiate is insurance premium charges via a direct correlation between risk and premium. A reduction in the economic impact arising from bushfires achieved through better planning and more effective suppression (thus less private and public infrastructure loss) should ultimately be manifest in lower insurance premiums.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework in the case study into CSIRO's engagement in Bushfire Risk Management (BRM) work are summarised in **Figure 1.1**. Two projects have been identified which exemplify CSIRO's work in managing fire risk – the Tanker Burnover Project and the Queensland Bushfire Mapping Project - they are used as the basis of the BRM Case Study.

FIGURE 1.1 BUSHFIRE RISK MANAGEMENT CASE STUDY – IMPACT FRAMEWORK DIAGRAM



SOURCE: ACIL ALLEN

1.1 Purpose and audience for case study

This case study describes the economic, environmental and social benefits arising from CSIRO's involvement in BRM.

This evaluation is being undertaken to assess the positive impacts arising from the BRM work undertaken by CSIRO. However, it can also be used to inform a range of other stakeholders. The case study can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of the Land & Water (L&W) Business Unit's activities as a whole relative to the funds invested in these activities.

This information in this case study is provided for accountability, communication and continual improvement purposes. This case study is primarily intended to be an input into the independent review of the L&W Business Unit. Other audiences for this report may include Members of Parliament, Government Departments, CSIRO and the general public.

1.2 Background

CSIRO engagement with work on fire management has been a long-term activity. Its origins can be traced back to the 1940s when CSIRO published a report which detailed the way in which houses were lost in the Beaumaris bushfire on 12 January 1944.[1] The work, which focuses on the interactions between the natural and the built environments, can be grouped around two broad themes:

[1] Barrow G. J.; 1945: *A Survey of Houses Affected in the Beaumaris Fire, January 14, 1944*; Division of Forest Products – Reprint No. 88; Preprint from the Journal of the CSIRO Vol.18, No.1, February 1945

1. **Fire as a land management tool** (not looking at the protection of lives/infrastructure). This research is primarily centred on the north of Australia and focused on both agriculture and environmental issues. The work also has a strong emphasis on GHG emissions and carbon farming methodologies.
2. **Managing fire risk to life and infrastructure.** The primary emphasis here is on identifying and managing the risks associated with fires and developing better tools to prepare for and respond to wild fires. This includes:

— impact analysis
— risk quantification
— risk mitigation strategies
— fire management – both controlled burning and suppression of wild fires
— predictive modelling (of fire spread and likely impact of fires)
— fire danger rating systems – recent introduction of the 'catastrophic' category
— hazard reduction systems.
— infrastructure design
— providing the scientific basis for fire safety education and policy development.

A key product arising from CSIRO's work on managing fire risk is a joint publication with the Australasian Fire and Emergency Service Authorities Council Limited (AFAC) –*A guide to rate of fire spread models for Australian vegetation*[2]. The Guide consolidates, for the first time, all available published Australian models into one resource guide, together with a comprehensive analysis of their potential applications, benefits and limitations. It evaluates applications in different vegetation types and burning conditions and provides detailed performance appraisals. It provides a level of assurance as to the robustness of fire spread modelling and the resultant predictions and greater confidence that decisions are being taken based on best practice approaches.

The use of fire as a land management tool is being addressed as part of the separate GHG case study. Accordingly, this case study focuses on CSIRO's work in relation to bushfire risk management. For the purposes of examining this work, the Black Saturday fires in 2009 are considered a watershed and reasonable start point[3]. The case study focuses on post 2013 work, but recognises earlier contributory efforts – it uses expenditure from 2011 onwards (see **Table 1.1**)

Two projects have been identified which exemplify CSIRO's work in managing fire risk to urban and peri-urban areas, namely the Tanker Burnover project and the Queensland Bushfire Mapping project.

Tanker Burnover Project

Given frontline firefighters are most at risk in the event of a bushfire burnover, existing practices relating to bushfire safety are under continual review. CSIRO was commissioned to identify the parameters of importance in protecting firefighters and their vehicles and assess opportunities to improve the protection afforded by firefighting vehicles. CSIRO conducted a series of experimental burnover tests (using a bush fire simulator). They also conducted field experiments to assess the effectiveness of modifications made to the tankers including shielding and water sprays. CSIRO provided the theory and measurement relating to the bushfire flame front and conducted the onboard measurement of fire tanker performance during testing.

Queensland Bushfire Mapping Project

CSIRO developed a new State-wide mapping methodology to identify Bushfire Prone Areas in support of bushfire hazard provisions of Queensland's State Planning Policy (which came into effect on 2 December 2013). The methodology scales bushfire hazard based on the Potential Fire-line Intensity of a severe bushfire and can be used to predict the radiation profile of areas adjacent to potentially hazardous vegetation and an associated Potential Impact Buffer. Potential Fire-line Intensity is also a useful indicator of the level of safety afforded for resident egress and firefighter access. The scientific platform and fire risk mapping system underpins State-wide planning.

1.3 Impact Pathway

1.3.1 Project Inputs

The total funding of the BRM work elements considered was $1,159,807 in cash and in-kind contributions (see **Table 1.1**). The Country Fire Authority (CFA) provided $290,106 towards the Tanker Burnover Project while the Queensland Government (through

[2] Cruz M.G., Gould J.S., Alexander M.E., Sullivan A.L., McCaw W.L., Matthews S. (2015) A Guide to Rate of Fire Spread Models for Australian Vegetation. CSIRO Land and Water Flagship, Canberra, ACT, and AFAC, Melbourne, Vic, 123pp.
[3] The Black Saturday bushfires were a series of bushfires that ignited or were burning across Victoria on and around Saturday 7 February 2009. They were considered to be Australia's all-time worst bushfire disaster.

Queensland Fire and Emergency Services {QFES} and its predecessors) provided $414,041 towards the Queensland Bushfire Mapping Project. CSIRO made co-contributions to both projects totalling $455,660 (around 39 per cent of the total cost of the combined project elements).

TABLE 1.1 SUPPORT FOR BUSHFIRE RISK MANAGEMENT

Contributor/type of support	2011	2012	2013	2014	2015	2016	2017	TOTAL
Tanker Burnover Project								
Cash*								
CFA to CSIRO	$62,819	-	$69,000	$58,874**	-	$41,413	$58,000	$290,106
In-kind/Co-contribution								
CSIRO internal resources	$41,879	-	$46,000	$47,667	-	$27,609	$24,500	$187,655
Total	$104,698	-	$115,000	$106,541	-	$69,022	$82,500	**$477,761**
Queensland Bushfire Mapping Project								
Cash*								
Queensland Government	-	-	$174,091	$180,000	-	$59,950	-	$414,041
In-kind/Co-contribution								
CSIRO internal resources	-	-	$116,060	$121,000	-	$30,945	-	$268,005
Total	-	-	$290,151	$301,000	-	$90,895	-	**$682,046**
GRAND TOTAL	$104,698	-	$405,151	$407,541	-	$159,917	$82,500	**$1,159,807**

*NOTE: *CASH PAYMENTS ARE EXCLUSIVE OF GST*

*NOTE: **$12,626 OF THE TOTAL ORIGIONALLY PROVIDED BY THE CFA FOR 2014 WAS ROLLOVER TO 2016 WORK – FIGURES ADJUSTED ACCORDINGLY*

SOURCE: ACIL ALLEN BASED ON CSIRO ADVICE

The CFA provided the vehicles used in both the simulator burnovers and the field experiments as part of the Tanker Burnover Project.

1.3.2 Project activities

Tanker Burnover Project

CSIRO has conducted a series of bushfire assessments to evaluate the performance of the tankers under bushfire conditions using the fire front simulator at the NSW Rural Fire Service Hot Fire Training Facility at Mogo, NSW and also under (experimental) grass and bushfire conditions. Tests have been conducted on a variety of tanker configurations including purpose built medium size tankers and ultra-light fire tankers (which are more challenging to protect within the weight constraints of the vehicle).

The following tests have been conducted:

- **2011** - measurement of the performance and cabin crew survivability of a CFA tanker fitted with various protection system options during a full-scale bushfire burnover using the fire front simulator. The tanker was equipped with instrumentation to measure air temperatures, surface temperatures, radiant heat and toxic gases.
- **2013** - measurement of the performance and cabin crew survivability of a CFA ultra-light fire tanker fitted with a gel protection system during a full-scale bushfire burnover using the fire front simulator. The tanker was equipped with instrumentation to measure temperature, radiant heat and toxic gases.
- **2014** - tanker performance tests were conducted using controlled grassfires at a property outside Wangaratta, Victoria. Three tests were conducted, one on the ultra-light tanker and two on a mid-sized tanker. The ultra-light tanker had been tested under flame over conditions in 2011 and 2013 using CSIRO's fire front simulator (see above), while a similar mid-sized fire tanker had also been tested at the CSIRO facility in 2009.
- **2016** - tanker performance tests were conducted using controlled bush fire conditions near Brucknell, Victoria. Three tests were conducted; on a gel spray protected ultra-light tanker; on a foam spray protected ultra-light tanker; and on a mid-sized tanker using a water mist protective system. The ultra-light tanker had been tested under flame over conditions in 2011 and 2013 using CSIRO's fire front simulator (see above), while a similar mid-sized fire tanker had also been tested at the CSIRO facility in 2009. Both the gel protected tanker and the mid-sized tanker had been tested under grassfire conditions in 2014.

— **2017** - measurement of the performance and cabin crew survivability of two CFA tankers (four tests in total) fitted with various protection system options during a full-scale bushfire burnover using the fire front simulator. The tankers were equipped with instrumentation to measure temperature, radiant heat and toxic gases.

Queensland Bushfire Mapping Project

As the first stage of the Queensland Bushfire Mapping Project (2013 funding), CSIRO prepared a report on the scientific basis for framing future land use planning policies to manage bushfire risk in Queensland addressing:

— the most effective strategies for managing bushfire risk through land use planning for Queensland under different bushfire hazard scenarios and different elements at risk

— the primary areas of intersection between land use planning and the complementary functions of building code regulations to manage bushfire risk

— a scientific framework for informing optional land use planning risk management practices, broadly suitable for adoption in different bushfire weather zones of Queensland (taking into account fundamental difference in the bushfire weather of Queensland compared to Victoria and New South Wales)

— the development of a series of maps to facilitate State-wide bushfire management planning including a:

- Fire Weather Severity Map - based on an agreed return period internal of 1 in 20 year using climate adjusted estimate for the year 2050
- Slope Map - a State-wide DEM (digital elevation model (DEM) cell) and slope rasters with a 25m resolution ready for use as a hazard map input
- Fuels Map (Vegetation Hazard Classes and associated fuel load estimates) - for integration into the Hazard Mapping product along with a summary of the process used to deriving the map for inclusion in the hazard map description
- Hazard Map - a State-wide bushfire hazard map (raster at 25m resolution) based on fire line intensity potential and including a description to estimate appropriate zones of ember attack and estimation of worst case radiation exposure as a function of distance from the vegetation boundary
- State Bushfire Planning Map – the official map designating (through state planning policy) what is bushfire prone. This map is based on the above bushfire hazard map and is a smoothed high-resolution vector based derivative of the 25m Hazard Map Raster. Its dimensional accuracy makes it suitable to direct designation of local bushfire severity.

Utilising 2014 funding, CSIRO developed GIS maps, tools and a report describing the 2014 update of the September 2013 State-wide Bushfire Prone Area maps (using the most recent data sets), and a repeatable methodology (a Bushfire Prone Area modelling methodology) for regular updating. A second component of this involved the development of GIS maps, tools and a report describing a methodology for annual bushfire hazard assessments including current Bushfire Fuel Load, Fire-line Intensity, and Bushfire Hazard. The annual bushfire hazard assessment methodology was adapted from the above Bushfire Prone Area modelling methodology.

Experiences with using the mapping following its release in 2013 highlighted the opportunity for improvements to the approach to better reflect recent research knowledge about bushfire attack mechanisms and to also take advantage of improvements in vegetation mapping prepared by the QFES. While the disruptive effects of non-flammable surfaces on fire spread were well documented and adequately reflected in the methodology developed for State-wide mapping of Bushfire Prone Areas in 2014, greater account of the contextual effect of grassland or other continuous vegetation types was considered warranted in order to give greater certainty to land use planning decisions in the bushfire interface.

Subsequently, CSIRO continued work to refine a number of the key inputs to the mapping products (i.e. topographical slope has a quantifiable impact on modelled bushfire characteristics and improving the accuracy of the digital topographical slope produces more accurate State-Wide Bushfire Prone Area Mapping). In 2017, CSIRO was funded to update Bushfire Prone Area Mapping Code and prepare a report describing improvements to the mapping rules that were integrated into the spatial modelling process in order to better reflect the spatial complexities of bushfire behaviour for small and narrow patches of hazardous vegetation.

1.3.3 Project outputs

Tanker Burnover Project

The objective of the assessments was to understand the survivability of the cabin interiors (across different vehicle types) which are protected by a combination of different mechanisms including external foam protection, external spray gel protection, interior heat shields, vehicle mounted spray units and various other vehicle modifications. Similar tests had been conducted over the period using the same vehicle types to enable comparisons. Outputs from the Tanker Burnover Project include:

— design/installation of truck instrumentation - CSIRO undertook the layout design and installation of the instrumentation for all tanker burnover tests including:

air toxics and radiation instrumentation for tankers
cabins were instrumented for temperature and air toxics
the tray area was instrumented for temperature and radiation
the radiometers on the tray were also used to provide a feedback for controlling the radiation load applied by the simulator gas grid.

— performance of burnovers - the simulator grid was instrumented for temperature and radiation.

temperatures were measured using thermocouples mounted on towers
external radiation measured by radiometers were placed on a pole - the radiometers on the grid were used to provide a feedback for controlling the radiation load applied by the gas grid
a wireless weather station was installed on site to monitor the wind direction and speed.

— data and photo/video records/archive - both still and audio-visual records of the tests were made. Video cameras from a number of positions were used to record each test. Photos before, during and after each test were also taken.

— experiment reports were provided to the client - detailing methods used and observations concerning thermal conditions, radiant heat and toxic gases. These reports provided useful data on vehicle performance/survivability. A range of publications have also been released (see Publications below).

Queensland Bushfire Mapping Project

Outputs for the Queensland Bushfire Mapping Project included:

— a detailed report on the scientific basis for framing future land use planning policies to manage bushfire risk in Queensland

— a full series of mapping products for the State at 25 metre resolution including: maximum landscape slope; vegetation hazard classes used to estimate potential fuel load; fire weather severity; potential fire-line intensity (derived by combining the previous three variables).

The project identifies bushfire prone areas including: potential bushfire intensity classes derived from the classification of potential fire-line intensity mapping; and a potential impact buffer for land adjacent to the identified bushfire prone area. It also identifies grassfire prone areas and Low Hazard area slope and DEM detail for use in the hazard mapping methodology, patch-filtered fuels map and vegetation hazard class maps and digital hazard maps in 25 metre raster format for the final hazard map.

Other outputs include:

— a report detailing the methodology used to develop the hazard mapping products and its potential for use to describe ember and radiation exposure beyond the forest edge

— GIS tools and support to allow Queensland to produce updated maps using more recent data sets (as they become available) and reports describing the update process and the methods used to derive these maps

— GIS tools and base-line maps of State-wide Bushfire Fuel Load, Fireline Intensity and Bushfire Hazard for annual bushfire risk assessment and supporting documentation describing a repeatable methodology to enable Queensland to implement annual updating of these maps

— updated Bushfire Prone Area Mapping Code and rules so as to enable better alignment between the fire-line intensity of smaller hazardous vegetation patches with the likely intensity of running fires that would occur under conditions assumed Queensland state-wide mapping of Bushfire Prone Areas.

Publications

A range of publications have been delivered under the Tanker Burnover Project that better inform decisions on tanker protection systems. However, most of reports prepared are commercial in confidence and prepared for the client (CFA). The only report in the public domain relates to the Brucknell field tests:

— Cruz MG, Hurley R, Bessell R, Nichols D (2016) *Brucknell vehicle burn trial - report on fuels, weather and fire behaviour*. CSIRO Land and Water, Client Report No EP163796, Canberra, Australia.

Key publications from the Queensland Bushfire Mapping Project include:

— Newnham, Glenn; Opie, Kimberley; Leonard, Justin; *Mapping current fire hazard across the state of Queensland*: CSIRO 2015, csiro: EP155066

— Leonard, J., Opie, K, Newnham, G. (2016) State-Wide Bushfire Prone Area Mapping Methodology – Patch and Corridor Filters. CSIRO, Australia.

— Leonard, J., Opie, K. (2017) Estimating the potential bushfire hazard of vegetation patches and corridors. CSIRO, Australia.

— Newnham, Glenn; Opie, Kimberley; Leonard, Justin; A methodology for State-wide mapping annual fuel load and bushfire hazard in Queensland: CSIRO 2017, csiro: EP175130

Innovation/commercialisation

Tanker Burnover Project - CSIRO is the only organisation with the background intellectual property (IP), models and simulation capacity to undertake tanker burnover work. Recent work (October/November 2017) has been far more innovative in its focus on:

— protection mechanisms fitted to ultra-light fire tankers utilising small slip-on units (these vehicles, while allowing greater manoeuvrability and flexibility in use, are far more challenging to protect within their weight constraints compared to the large tankers)

— understanding the performance of heavy tankers under more extreme fire burnover condition.

Queensland Bushfire Mapping Project - The mapping outcomes reflect heavily applied science utilising CSIRO background IP. While the project has integrated fundamental datasets put together/managed by others (i.e. Queensland Herbarium, European Centre for Medium-Range Weather Forecasts (ECMWF)) which are in the public domain, CSIRO has value added to these datasets by:

— converting the weather datasets into national climate adjusted regression curves (these have been published into the public domain and are used by insurance, agencies etc)

— creating improved digital elevation models for Queensland

— creating an improved approach to statewide bushfire fuel availability linked to the statewide vegetation mapping

— creating a risk and evidence based statewide bushfire prone area and hazard level maps to defining bushfire risk potential across the state

— creating house loss potential prediction for each existing house location across the state, for the prioritisation of risk mitigation effort and awareness.

1.3.4 Project Outcomes

Tanker Burnover Project

As a result of the truck burnover simulations the CFA now has a significant database with regard to the performance of crew protection systems installed on a variety of tanker types. Datasets encompass:

— radiation - on the side of fire tankers and inside the tankers

— temperature - inside cabin air temperature; outside air temperature and temperature measured on passenger doors (inside), windscreen (inside), driver door (inside), under body, roof, floor, pump and engine

— cabin air exchange rates

— air toxics - cabin air leakage; air toxics in tanker cabins.

These simulator-based datasets are enhanced and validated by the data collected in the experimental burnovers. This data plays a central role in the CFA's work to improve both the design and operation of tanker crew protection systems and in training fire crews on how to respond if caught in a burnover event. CSIRO has drawn on the data and project outputs to produce a series of reports and publications detailing the results of the truck burnover project that better inform decisions on tanker protection systems.

Queensland Bushfire Mapping Project

A new State-wide mapping methodology has been implemented to identify Bushfire Prone Areas in support of bushfire hazard provisions of Queensland's State Planning Policy (which came into effect on 2 December 2013). This new methodology overcomes a number of known limitations with the previous approaches including the failure to account for regional variation of bushfire weather severity and an ambiguous weighting of hazard according to topographic aspect.

The methodology scales bushfire hazard based on the potential fire intensity of a severe bushfire and can be used to predict the vulnerability of areas adjacent to potentially hazardous vegetation. It also provides useful indicators of the level of safety afforded for resident egress and firefighter access.

This improved approach to bushfire hazard assessment and mapping allows Queensland local governments to more accurately identify areas at risk from bushfires and to have greater confidence in the design of mitigation strategies that are proportional to the potential level of threat. The new bushfire hazard mapping and underlying methodology provides a major improvement in the scientific credibility and practical utility of spatial information to mitigate adverse impacts of future bushfires through land use planning.

The mapping system deliberately focused on a unifying approach between both planning and building policy approaches, to support ongoing harmonisation efforts across the two regulatory systems.

1.3.5 Adoption

Tanker Burnover Project

Bushfire entrapment and burn overs are life threating situations for fire fighters. The most dangerous Australian tanker burnovers typically occur on a narrow track in a eucalyptus forest environment. The abundance of fuels between a trapped tanker and the fire front can allow for a sudden escalation of fire intensity (associated with changes in slope or following a wind change of direction and/or strength). Burnovers are characterised by an initial period of strong radiant heat followed by peak flame contact from a fast moving flame front. This initial period is followed by a short intense flame immersion of the tanker (generally for less than two minutes). A fast moving fire allows only a short period of time in which the tanker crew can prepare for a burnover.

In the past there have been multiple tanker burnovers with significant losses of life. The CFA has been improving crew safety on tankers since tragic burnovers occurred in the 1977 Victorian Western District fires. Serious incidents have continued, notably:

— twelve fire fighter fatalities when two tankers were entrapped and burnt over in the 1983 Ash Wednesday fires
— five fire fighters perished when their tanker was entrapped and burnt over in 1998 at the Linton bushfire.

The CFA has undertaken research and development into tanker crew protection methods since 1998, using the Linton fire conditions as a benchmark. Significant developments as part of this program include:

— crew protection systems that use water deluge systems with dedicated tank water combined with drop down radiant heat shield curtains in the tanker cabin and the rollover protection system area on the tanker tray
— adding additional crew protection systems to new tankers such as: crew protection blankets, additional heat shielding protection on the tanker tray; low level water indicators; and reduction in plastics on the vehicle
— retrofitting all medium (2000 litre water capacity) and heavy tankers (3000 litre capacity) in the CFA fleet with crew protection systems
— developing crew protection systems using water enhancement technology, including polymer gel and Compressed Air Foam products, for Ultra-light tanker (400 litre water capacity)
— specific tanker protection systems designed to protect critical vehicle elements (i.e. engine; wheels/tyres; fuel and electrical components) in a burnover.

The outcomes of both the simulator and experimental burnover tests are utilised to take the tanker protection program forward and enable continuous improvement and modification to crew protection systems. The photo/video records are also used for training purposes and to better inform the public on fire safety issues.

Queensland Bushfire Mapping Project

The project has demonstrated the application of a new repeatable method for landscape scale, State-wide mapping of Bushfire Prone Areas in Queensland.

These methods provide useful mapping information for the mitigation of potential bushfire impacts through land use planning. The mapping products provide improved spatial detail and greater confidence in bushfire hazard mapping (compared to previous approaches). This increases the level of confidence for using them to inform the development of localised land use planning measures that can reduce risks to human life. Mapping and associated scientific information generated through the process are used to inform a range of other bushfire mitigation and preparation actions in Queensland.

The QFES continues to work to review and improve the operationalisation of the bushfire hazard mapping products to better meet local planning needs. A key challenge has been the need to ensure that updated mapping products are responsive to local changes in a timely way while ensuring the integrity of the data inputs (especially where data relates to local Government areas experiencing rapid growth).

1.3.6 Impacts

CSIRO's bushfire risk management research has delivered significant benefits which are essentially the same across both the Tanker Burnover Project and the Queensland Bushfire Mapping Project. Those benefits are discussed below.

Reduction in loss of life/injury

CSIRO has undertaken a detailed analysis of the comprehensive bushfire fatality database covering the period 1901 to 2011 – the analysis found that, during this period, there have been 260 bushfires in Australia associated with 733 civilian and 92 firefighter

deaths and just over 11,000 homes destroyed[4]. Since then further losses have occurred. For example, the 2015–16 bushfire season resulted in the loss of 408 houses and 9 fatalities.

The Tanker Burnover Project goes to the heart of seeking to reduce firefighter fatalities - tanker vehicle entrapment and fire burnover have historically been the predominant life-threatening situations for fire fighters. The objective of the CSIRO/CFA collaborative crew protection system research has been to develop an evidence-based system that will protect tanker-based fire fighters in a burnover entrapment situation during a bushfire of high intensity. Even with improved situational awareness training, multiple CFA tanker entrapment and burnovers have occurred. However, there has been no serious injury or loss of life in a CFA tanker with the crew protection system installed. The CFA estimated there have been in the order of 12 to15 burnover incidences involving around 70 firefighters where burnovers could have been fatal if the crew protection system had not been present and used[5].

An improved research-based bushfire hazard and risk methodology developed under the Queensland Bushfire Mapping Project allows the QFES and Queensland local governments and the broader community to more accurately identify areas of bushfire risk and hazard and to design mitigation strategies that are proportional to the level of bushfire threat. It has a clear focus on bushfire hazard mapping aligned with national emergency risk assessment guidelines. The methodology is essential to informing bushfire mitigation and response planning as well as informing the delineation of bushfire prone areas needed to implement building standards for construction.

It allows government and the broader community, at all levels, to more accurately identify areas of bushfire risk and hazard and to design mitigation strategies that are proportional to the level of threat from bushfires in Queensland. These improvements help limit potential over-response or under response to bushfires in Queensland. While it is difficult to pinpoint direct causal links, these improvements help to limit potential loss of life (and infrastructure) from bushfires in Queensland – and more widely (if and when other States adopt the methodology).

Reduction in the economic impact of bushfires

The total economic cost of bushfires in Australia is very high. In 2017 Deloitte Access Economics, estimated that the cost of bushfires averaged around $1.1 billion per year[6]. The total economic cost of bushfires includes:

- direct tangible costs, including improved targeting of emergency response efforts and reductions to damage levels of property and infrastructure
- indirect tangible costs, which include flow on effects to businesses and networks such as network outages or disruptions to business or supply chains
- intangible costs, which capture death, injury and impacts on health and wellbeing, employment and community connectedness and are estimated to be as great, or greater than, tangible costs - but they are hard to price.

Infrastructure losses/disruptions include public infrastructure and services that are damaged or destroyed by bushfires, disruptions to transport networks, loss of electricity supply and communication equipment, impact to potable water supply catchments and private infrastructure losses including homes and other private rural infrastructure (sheds, fuel supply, fencing etc), loss of iconic buildings (both public and private) and destruction of fire fighting vehicles and equipment.

The Tanker Burnover Project and the Queensland Bushfire Mapping Project both facilitate improved fire suppression and planning options to enable more effective bushfire control.

Better fire management resource (human and equipment) deployment

More effective use of resources will reduce the risk to both people and property. The Tanker Burnover Project facilitates a greater degree of confidence in the deployment of firefighting resources (both human and equipment) while the Queensland Bushfire Mapping Project provides the detail necessary to enable both better fire risk management (i.e. pre-emptive hazard reduction) and more effective firefighting deployment (i.e. improved understand of access/egress options etc).

[4] https://blogs.csiro.au/ecos/bushfire-loss-data/
[5] David Nichols, CFA Manager of Research and Development; 2017: http://wildfiremagazine.org/article/developing-and-testing-a-tanker-engine-crew-protection-system/
[6] Deloitte Access Economics; The Australian Business Roundtable for Disaster Resilience & Safer Communities *Building resilience to natural disasters in our states and territories*; November 2017

1.3.7 Potential future impacts

Tanker Burnover Project

CSIRO is a global leader in the field of both simulated and actual field trials of tanker burnover testing. The simulator is internationally unique and affords CSIRO a significant opportunity to supply a commercial/semi-commercial service to parties wishing to test their equipment /facilities.

CSIRO has plans to further expand tanker burnover testing to focus on innovative work with light weight slip-on units as well as improved understanding of the performance of heavy tankers under more extreme fire burnover conditions. There is also scope to expand the simulator role beyond tankers and to run simulations on a wide range of infrastructure. CSIRO's simulator testing methodology is increasingly recognised as the leading edge fuel scale burnover methodology. It is seen as the reference approach. CSIRO's simulator results are now being used to question and challenge the validity of smaller scale testing methods referenced in regulation.

The CSIRO results are being used more widely. For example, burnover exposure curves are referenced in the National Construction Code (NCC).

There is the potential for CSIRO to develop a niche export market for products and/or services based on the sale or use of the simulator. The USA is already engaged in discussions with CSIRO to test their fire trucks in Australia. Southern Europe is another strong possibility.

Queensland Bushfire Mapping Project

Given the successful implementation of a state-wide approach to bushfire hazard assessment and mapping in Queensland, CSIRO is in discussion with some other States regarding the adoption of a similar integrated methodology. While CSIRO may not necessarily be involved as a collaborative partner in all States, they do draw on and use a number of products developed under the Queensland project (i.e. national climate adjusted regression curves developed from weather datasets which have been published and are in the public domain, the *Decadal Forest Fire Danger Index (2006-2096)*)[7]. CSIRO, in its role as a 'trusted advisor' and given the expertise developed during the Queensland project, may well be called upon as this State Government work expands and progresses.

There is also scope for greater CSIRO interaction with the insurance industry. The weather datasets and national climate adjusted regression curves are already used by insurance agencies as part of their bushfire risk analysis. The mapping products and hazard assessment enable the insurance industry to better assess bushfire risks and more accurately differentiate is insurance premium charges via a direct correlation between risk and premium. A reduction in the economic impact arising from bushfires achieved through better planning and more effective suppression (thus less private and public infrastructure loss) should ultimately result in lower insurance premiums.

CSIRO's Queensland bushfire mapping methods and expertise already has been applied by CSIRO in a global application through the development of a bushfire hazard module for the World Bank's *ThinkHazard!* website[8]. *ThinkHazard!* enables users to identify if there is a bushfire hazard in a particular location globally, and whether it has the potential to cause loss, damage or disruption to a development project in the area. Applying the lessons learnt in Australia can help others internationally when it comes to the understanding and mitigating bushfire impacts. Besides giving location specific advice, it provides links to additional resources such as local risk assessment approaches and highlights how each hazard may change in the future as a result of climate change.

1.4 Counterfactual and Attribution

1.4.1 Counterfactual

There are no other research groups in Australia or elsewhere with the capability and data access to undertake the full range of research and development essential to delivering the BRM work. The products developed under the project would not exist without the efforts of CSIRO and the other project partners. The approach used by CSIRO can be (and has been) used by others. However, CSIRO is best positioned to deliver a 'fit for purpose' product that fully meets the requirements of state-wide bushfire planning. Similarly, only CSIRO has the background IP, models and simulation capacity to undertake the Tanker Burnover Project.

[7] https://data.csiro.au/dap/landingpage?pid=csiro:16672&v=1&d=true
[8] http://thinkhazard.org/en/

1.4.2 Attribution

While they are clearly significant, it is difficult to quantify the benefits arising directly from this project. In the absence of other data, one option is to adopt the ratio of project inputs as a reasonable proxy – that is around 40 per cent attribution of benefits to CSIRO.

While CSIRO does actual testing/simulation work for tanker burnover project, the fire agencies/collaborative partners design and operationalise the work program and build the systems to be tested, which suggests that attribution is probably closer to 50:50 in this case. However, this is potentially an over estimate if the capital costs associated with upgrades of the tanker fleet (borne by the CFA and others) resulting from the test outcomes are considered. This would be in line with the proposed 40 per cent attribution of benefits to CSIRO discussed above.

The mapping outcomes of the Queensland Bushfire Mapping Project reflect heavily applied science. While CSIRO utilised/integrated fundamental datasets put together/managed by others (ie Queensland Herbarium, BoM) in the mapping project, these datasets but these are in the public domain. CSIRO has value added value to these datasets by:

- converting the weather datasets into national climate adjusted regression curves (these have been published into the public domain and are used by insurance, agencies etc)
- creating improved digital elevation models for Queensland
- creating an improved approach to state wide bushfire fuel availability linked to the statewide vegetation mapping.

Accordingly, ACIL Allen proposes that 100 per cent of the benefits from the Queensland Bushfire Mapping Project can be attributed to CSIRO.

1.5 Evaluating the Impacts

1.5.1 Cost-Benefit Analysis

Costs

R&D Costs: The costs of BRM projects considered were shown previously at **Table 1.1**. CSIRO made an in-kind co-contribution of $455,660 (39.3 per cent) towards the total BRM project budget of $1,159,807. Costs associated with the Tanker Burnover Project totalled $477,761, while those for the Queensland Bushfire Mapping Project were $682,046.

Tanker fire protection equipment costs: The CFA purchases 50 to 80 new tankers a year. ACIL Allen has assumed that the additional cost of installing protection systems as a result of implementing the learnings from the Tanker Burnover Project is $2,000 per vehicle[9], and that an average of 65 new tankers are purchased each year. This results in an annual incremental equipment cost of $130,000 a year.

Benefits

Tanker Burnover Project

There is a considerable body of research examining the concept of the value of statistical life which is often used to estimate the benefits of reducing the risk of death. The value of statistical life is an estimate of the financial value society places on reducing the average number of deaths by one. The Commonwealth Government has prepared a guidance note – '*Best Practice Regulation Guidance Note Value of statistical life; December 2014*'[10] which provides guidance on how officers preparing the cost-benefit analysis in Regulation Impact Statements should treat the benefits of regulations designed to reduce the risk of physical harm.

The Guidance Note concludes that "Willingness to pay is the appropriate way to estimate the value of reductions in the risk of physical harm – known as the value of statistical life. Based on international and Australian research a credible estimate of the value of statistical life is $4.2 million and the value of a statistical life year is $182,000 in 2014 dollars." Adjusted for inflation, the value of statistical life is $4.47 million in 2017-18 dollars.

Suppose that the implementation of learnings from the Tanker Burnover Project results in one firefighter death avoided every 5 years (that is, 0.2 deaths avoided per year). The expected value of firefighter lives saved is $894,000 a year in 2017-18 dollars.

[9] In 2010, the CFA retrofitted 2,000 tankers with additional protection systems for $2.5 million. The CFA was unable to provide ACIL Allen with a precise estimate of the cost of additional protection systems that have been specified for new tankers as a result of learnings from the Tanker Bunover Project, but indicated that this is less than the per-tanker cost of the 2010 retrofit.

[10] Department of Prime Minister and Cabinet; Office of Best Practice Regulation; *Best Practice Regulation Guidance Note Value of statistical life*; December 2014; https://www.pmc.gov.au/sites/default/files/publications/Value_of_Statistical_Life_guidance_note.pdf

Queensland Bushfire Mapping Project

As noted previously in Section1.3.6, the total economic cost of bushfires in Australia is very high, estimated to average around $1.1 billion per year in 2017 prices[11]. In Queensland, the cost of bushfires is much lower. While bushfires contribute substantially less to disaster costs in Queensland in comparison to tropical cyclones, floods and severe storms, work by the Bureau of Transport Economics in 2001 suggests that it is in the order of $16 million per year in 1998 dollars (or $26.7 million in 2017-18 dollars), the equivalent of 0.2 per cent of total Queensland disaster costs between 1967 and 1999 [12]. However, climate change may have already increased these costs and is likely to result in the potential for higher costs in the future[13].

Assuming that the Queensland Bushfire Mapping Project reduces the annual cost of bushfires in Queensland by 5 per cent (and conservatively assuming that these annual costs remain at $26.7 million in 2017-18 dollars) results in a benefit estimate of $1.335 million per year in 2017-18 dollars. In addition, the project is assumed to reduce the cost of bushfires in the rest of Australia by 0.1 per cent a year, which results in additional annual benefits of $1.1 million per year. The total benefits from the Queensland Bushfire Mapping Project are thus projected to be $2.435 million per year in 2017-18 dollars.

Assessment of benefits against costs

The present value of total costs to 2027-28 is estimated at $2.42 million in 2017-18 dollars under a 7 per cent real discount rate. The present value of total benefits to 2027-28 is projected to be $24.96 million in 2017-18 dollars under the same discount rate.

The estimated net present value (NPV) of the Tanker Turnover Project and Queensland Bushfire Mapping Project (combined) is $22.55 million in 2017-18 dollars under a 7 per cent real discount rate. The benefit-cost ratio of the combined projects is estimated at 10.33.

Sensitivity analysis

In the central case of the cost-benefit analysis, it is assumed that 0.2 firefighter deaths are avoided each year due to fire protection equipment installed on tankers as a result of learnings from the Tanker Burnover Project. If 0.5 firefighter deaths are avoided each year, the BCR increases from 10.33 to 14.50. Conversely, if only 0.1 firefighter deaths are avoided each year, the BCR decreases to 8.95.

In the central case of the cost-benefit analysis, it is assumed that the Queensland Bushfire Mapping Project reduces the annual cost of bushfires in Queensland by 5 per cent. If the project reduces the annual cost of bushfires in Queensland by 10 per cent, the BCR increases from 10.33 to 14.48. Conversely, if the project reduces the annual cost of bushfires in Queensland by only 2 per cent, the BCR decreases to 7.85.

In the central case of the cost-benefit analysis, it is assumed that the Queensland Bushfire Mapping Project reduces the annual cost of bushfires in Australia by 0.1 per cent. If the project reduces the annual cost of bushfires in Australia by 0.5 per cent, the BCR increases from 10.33 to 23.99. Conversely, if the project reduces the annual cost of bushfires in Australia by only 0.01 per cent, the BCR decreases to 7.26.

1.5.2 Externalities or other flow-on effects on non-users

Positive externalities will accrue to the broader community as a result of applying the tools developed for predicting bushfire behaviour to save lives and limit damage. The human, economic, social and environmental impact of bushfires is significant and affects both government and the broader community at all levels. The Tanker Burnover Project and the Queensland Bushfire Mapping Project both generate significant externalities that accrue to the broader community.

[11] Deloitte Access Economics; The Australian Business Roundtable for Disaster Resilience & Safer Communities *Building resilience to natural disasters in our states and territories*; November 2017

[12] Bureau of Transport Economics Report 103; *Economic costs of Natural Disasters in Australia*; Bureau of Transport Economics Report 103; Commonwealth of Australia 2001

[13] Climate Council; 2016: *BE PREPARED: CLIMATE CHANGE AND THE QUEENSLAND BUSHFIRE THREAT*