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# FROM HECTARES TO TAILOR-MADE SOLUTIONS FOR RISK MITIGATION

## Systems to deliver effective prescribed burning across Australian ecosystems

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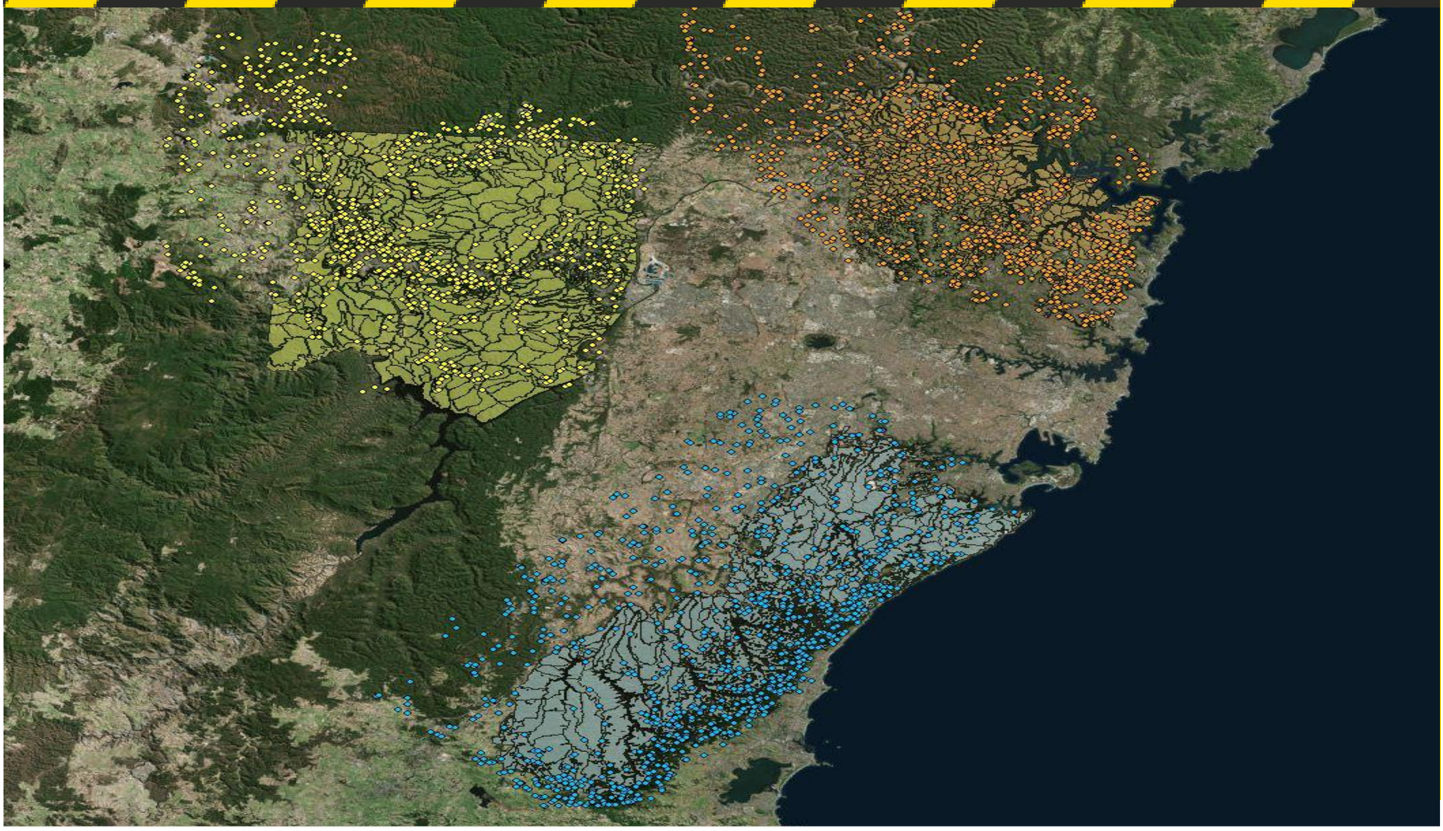

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Cover: Ignition points and burn blocks from three sets of fire spread simulations in the Sydney region.

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# ABSTRACT

## 2016-2017 ANNUAL REPORT

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We are pleased to present the 2016-2017 Annual Report for the Bushfire and Natural Hazards CRC project, *From hectares to tailor-made solutions for risk mitigation: systems to deliver effective prescribed burning across Australian ecosystems*. By undertaking a systematic investigation of the drivers of prescribed burning effectiveness across southern Australia, the project will provide critical support to agency decision makers across the region.

This report describes the project goals, methods and activities since the 2015-2016 Annual Report. The report focuses on initial results from a key project component: fire spread simulations in a range of case study landscapes throughout southern Australia. Results are presented in detail for case studies in East Central Victoria, Adelaide, the ACT and Hobart. This initial suite of simulations provides good evidence that there is substantial variation between case study landscapes in the response of key risks to different rates of prescribed burning. Further simulations in combination with other project methodologies will provide further evidence about this critical issue.

The report also details progress on data acquisition, empirical analyses and stakeholder engagement, which form the other key activities of the project to date. Finally, we are graetful to Naomi Stephens and Felipe Aires, our End User representatives from the NSW Office of Environment and Heritage, for providing an insight into the project's progress from a stakeholder perspective.

# END USER STATEMENT

**Naomi Stephens & Felipe Aires,** *National Parks and Wildlife Service, Office of Environment and Heritage, NSW*

NSW National Parks and Wildlife Service (NPWS) currently utilises prescribed burning as part of an integrated approach to manage fuels and reduce bushfire risk across its managed lands. At present NPWS is developing a monitoring, evaluation and reporting framework to measure the effectiveness of prescribed burning at each level of the prescribed burn planning process (strategic, operational and tactical).

Quantifying bushfire risk to environmental, social and economic values through a risk based framework is vital for the improvement of prescribed burning activities. The risk based approach relies on using predictive models which are based on a combination of real data and expert opinion. Utilising such approach allows fire management agencies to better select target areas and achieve the best possible risk reduction outcomes. As such, this project plays a vital role in advancing the current knowledge around prescribed burning effectiveness and will support the development of new policies and procedures in addition to improving evaluation and reporting strategies.

# INTRODUCTION

The Bushfire and Natural Hazards CRC project, *From hectares to tailor-made solutions for risk mitigation: systems to deliver effective prescribed burning across Australian ecosystems*, aims to systematically investigate drivers of prescribed burning effectiveness across southern Australia in order to provide critical support to agency decision makers across the region.

In order to deliver on this overarching goal, the project will need to:

- Compare the performance of different prescribed burning strategies in reducing risk to multiple values;
- Derive fire regime characteristics and risk solutions for individual bioregions;
- Provide results for current conditions and climate change scenarios;
- Organise results in an accessible interface, tailored to agency needs and amenable to updates.

A number of complementary project streams have been designed to meet these project objectives:

1. Fire spread simulations in case study landscapes, designed to sample variation in climate, population and landuse across southern Australia (Years 1-2);
2. Empirical analyses of prescribed burning effects on area burned, severity and other direct impacts of fire (Years 1-2);
3. Risk estimation for case study landscapes (Years 2-3);
4. Multi-criteria decision analysis to investigate trade-offs between key values and cost-benefit (Years 2-3);
5. Modelling of climate change effects on ignitions, fuel, fire regimes and risk (Years 2-4);
6. Data, models, software, testing and launch of the Prescribed Fire Atlas (Years 3-5).

In the 2015-2016 financial year, this project was in an establishment phase, focusing on recruitment, planning and building relationships with stakeholders. 2016-2017 has been a year of consolidation and generation of the data that will form the core of the project. The past year has seen significant progress on data acquisition, empirical analyses, the completion of a large number of fire spread simulations and a deepening of relationships with project end users.

This report concentrates on the design, model output and risk estimation from fire spread simulations in four peri-urban case study landscapes. A large number of simulations are carried out in each case study landscape, exploring the impact of differences in treatment rate, treatment location, fire weather conditions and ignition locations. The results provide the first insight into a critical question: is there variation between case study landscapes in the effectiveness of prescribed fire in reducing risk to key values?

The project is now poised to transition to the next phase, concentrating on risk analysis using the simulation outputs, Multi-Criteria Decision Analysis and climate change effects. This work will then be harnessed to develop the Prescribed Burning Atlas, in consultation with end users. The Atlas will be the vehicle which will enable key research findings to be utilised by the end user community.

# BACKGROUND

Prescribed burning in Australia, currently stands at a cross roads. The 2009 Victorian Bushfires Royal Commission recommended an annual treatment target of 5% of public land in Victoria. Subsequently, concerns have been formally raised (e.g. Bushfires Royal Commission Implementation Monitor 2013 Annual Report) that such an area-based target may not deliver the most effective levels of risk reduction for people and property in Victoria. Concurrently, some other States have adopted such a prescribed burning target, but formal attempts to evaluate its effects on risk to people, property and environmental values across different jurisdictions are lacking. Such extrapolation of the 2009 BFRC recommendation pre-supposes that there is a "one-size fits all" solution to the problem. While many agencies are moving toward planning systems supposedly based on risk assessment, knowledge of the best way to use prescribed fire to reduce risk to key values is generally lacking.

General principles need to be developed about how to apply a risk-based approach across widely varying environments, human communities and combinations of key management values. In essence, the use of prescribed fire for risk mitigation involves understanding how risk to any particular management value will respond to variations in the spatial location and rates of treatment. Managers and policy-makers need to know how these fundamental elements of prescribed burning can be tailor-made to suit the environmental and human context of their local jurisdictions. A variety of fundamental problems need to be overcome in order to deliver effective, tailor-made prescribed burning solutions across different Australian environments.

The Bushfire and Natural Hazards CRC project *From hectares to tailor-made solutions: systems to deliver effective prescribed burning across Australian ecosystems* is designed to address these challenges.

# METHODS

There were four main streams of activity in 2016-2017: data acquisition, empirical analyses, fire spread simulations and end user engagement.

## DATA ACQUISITION

A wide range of data has been acquired to date and is summarised in Table 1.

| Data Type | Purpose | Source |
|---|---|---|
| Phoenix base layers | Fire spread simulations | State & Territory agencies |
| Fire history, fire severity, ignition, burn blocks | Fire spread simulations, empirical analysis of prescribed burning effects on area burned, fire severity and fire frequency | State & Territory agencies |
| Weather observations | Fire spread simulations, empirical analysis of prescribed burning effects on area burned, fire severity and fire frequency | Australian Bureau of Meteorology |
| Infrastructure (e.g. addresses, powerlines, roads) | Fire spread simulations, empirical analysis of prescribed burning effects on area burned, fire severity and fire frequency | Various |
| Biophysical (e.g. elevation, catchments, vegetation type, land use) | Fire spread simulations, empirical analysis of prescribed burning effects on area burned, fire severity and fire frequency | Various |

TABLE 1 SUMMARY OF MAJOR DATASETS ACQUIRED

## EMPIRICAL ANALYSES

The project aims to extend and complement existing research (e.g. Price et al. 2015; Storey et al. 2016) on the relative influence of prescribed burning on fire severity, leverage, ignitions and other key properties and to use these insights to validate the results of simulations.

This year research has focused on the drivers of fire severity, based on a large Victorian dataset of fires where severity has been mapped, as well as a smaller number of Tasmanian and South Australian case studies. ACT has also provided severity mapping for prescribed, rather than wildfires. A Generalised Linear Modelling approach has been used to weigh the influence of various factors on the overall probability of crown fire.

Ignition data from South Australia and Tasmania is also being used to test existing ignition models (e.g. Penman et al. 2014; Collins et al. 2015) developed for southeast Australia, which draw on factors such as proximity to roads and fire weather conditions.

# FIRE SPREAD SIMULATIONS

## Case Study Regions

Fifteen candidate Bioregions have been selected as the locations for detailed landscape-scale simulation case studies, based on the project criteria of exploration of climatic, population and land use variations across southern Australia (Table 2; Figure 1).

| Terrestrial Ecoregion | Bioregion | Notes |
|---|---|---|
| Temperate Broadleaf and Mixed Forest | Southeastern Queensland | These form a gradient of mainly forested landscapes along the east coast, ranges and slopes, encompassing wide variations in population and land uses. These complement existing risk modelling exercises done in the Sydney region and Otways. |
| | Victoria Midlands | |
| | South East Corner | |
| | South Eastern Highlands | |
| | Tasmanian Southern Ranges | |
| Mediterranean Forests, Woodlands & Scrub | Murray Darling Depression | These form a mixed gradient of dry vegetation from western Victoria to south western WA |
| | Flinders Lofty Block | |
| | Jarrah Forest | |
| | Swan Coastal Plain, Esperance Plains | |
| Temperate Grasslands, Savannas and Shrublands | Murray Darling Depression | Case studies in these Bioregions represent the spectrum of mixed agriculture and remnant vegetation that typifies these moderately populated inland regions in Victoria and NSW. |
| | Nandewar | |
| | NSW South Western Slopes | |
| Deserts and Xeric Shrublands | Great Victoria Desert | Case studies situated in SA and NSW explore effects in these sparsely populated rangelands and conservation reserves. |
| | Broken Hill Complex | |

TABLE 2 CASE STUDY LANDSCAPES

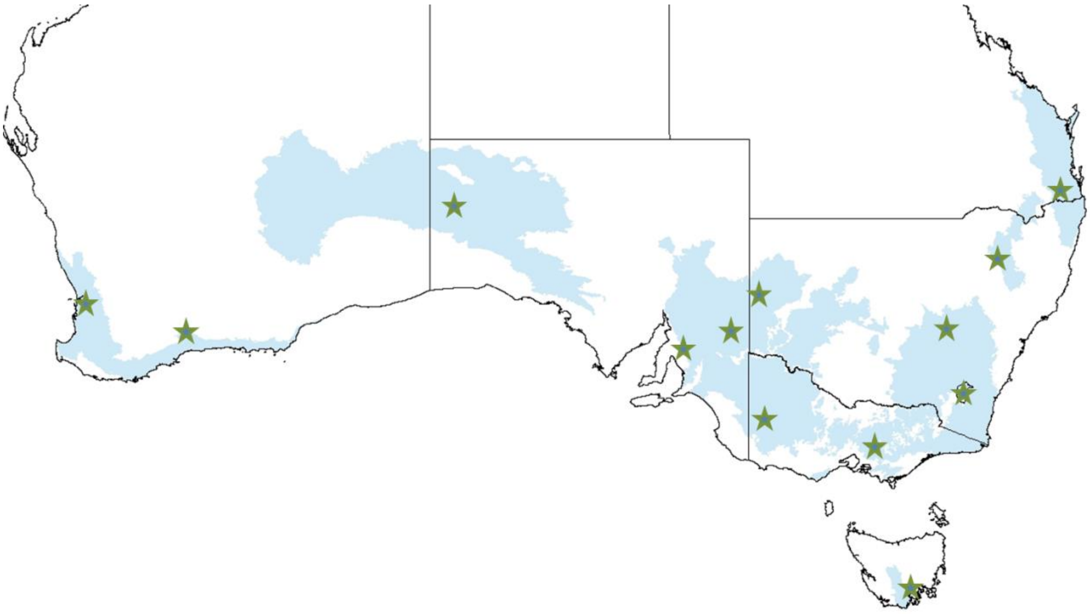

FIGURE 1 LOCATION OF CASE STUDY LANDSCAPES (STARS) AND IBRA BIOREGIONS (SHADED)

## Simulation Information

The PHOENIX RapidFire model (hereafter PHOENIX) (Tolhurst et al., 2008) was used to examine the interactive effects of fuel treatment and location under various weather scenarios. PHOENIX simulates two dimensional fire growth over complex variable landscapes using Huygen's propagation principle of fire edge (Knight and Coleman 1993). Surface fire behaviour is based on adapted versions of the CSIRO southern grassland fire spread model (Cheney et al. 1998) and McArthur Mk5 forest fire behaviour model (McArthur 1967; Noble et al. 1980). PHOENIX also includes a sub-model for spot fire propagation which incorporates ember production, distribution and ignition. PHOENIX is a dynamic fire spread model which predicts the spread of fire from ignition points using inputs of weather, fuel load and terrain. The model outputs fire behaviour metrics of value for risk analysis, namely intensity, rate of spread, flame height, ember density and convection.

All simulations were run in PHOENIX 4.0.0.7 the current operational release and the version currently used by the Department of Environment, Land, Water and Planning (DELWP). Input data layers were provided by relevant agencies in each State and Territory. Simulations were run at 180m resolution to optimise model performance based on recommendations of Tolhurst (2008) and consistent with current risk analysis undertaken by DELWP.

## Weather

Fires were modelled under a series of fire weather scenarios based on the McArthur Forest Fire Danger Index (FFDI). This study used a selection of Automatic Weather Station (AWS) weather streams based on the 3pm FFDI. Where available, for each FFDI category (low, high, very high, severe, extreme, catastrophic), three weather types were selected based on the predominant FFDI driver; wind, windy with a change and temperature. Within each of these driver categories up to three replicates were be chosen. The result of this process created up to 54 weather streams (6 FFDI x 3 drivers x 3 replicates).

### Ignitions

One thousand ignition points were used per case study landscape. To achieve this, a set of 10,000 random points were generated from a uniform distribution across the study area. For each of these points, an ignition probability was calculated using a Bayesian network (BN) developed for ignitions in Victoria (Penman et al. 2014). This BN has been found to be robust for NSW. The 1,000 points with the highest ignition probability were selected as ignition points for each case study landscape. This approach provided a realistic distribution of ignition likelihood compared with a regular ignition grid.

## Fuel Treatment Options

To represent fuel management in the landscape, simulated wildfire history and prescribed fire treatment history spatial layers were created. These fires histories were then combined to create a series of fire history datasets.

Wildfires were modelled for a period of 30 years. For each year, wildfires were randomly selected from the wildfire history database until the threshold value was crossed. The threshold was the average area burnt which was calculated over the created wildfire history. Five unique fire histories were created for use in each study landscape.

To create a prescribed burning history, landscapes were first divided into treatment blocks supplied by agencies or calculated based on a series of selection criteria: e.g. agency rankings of treatability (i.e. suitability for being treated with prescribed fire), extent of native vegetation, bushfire management zone and land tenure. Two burn-block datasets were then created: one for public land and one for both public and private land.

Six levels of prescribed burning effort were used; one, two, three, five, ten and fifteen percent per annum. A zero case was also used. Five replicate treatment history layers were generated for each treatment level for a 20 year period by constrained random selection until the treatment level was within 0.05% of the target burn level.

Prescribed fire and wildfire histories were then merged to develop 30 (six prescribed burning levels x five replicates) fire history layers. Fire history layers were checked individually to ensure they represented realistic scenarios, both temporally and spatially.

To explore spatial effects, results were partitioned into edge (i.e. wildland urban interface) and landscape (i.e. more remote) burns. This allowed a 7 x 7 matrix to be constructed with 6 prescribed burning levels + the zero case for both edge and landscape burns.

### Total Replicates

Up to 882,000 fires were simulated in each case study landscape. This is based on 1,000 ignition points, 6 FFDI categories, 3 FFDI drivers and 49 spatial treatment options. Due to regional differences in vegetation, population density and fire weather, not all levels of all of treatment conditions were possible in every case study landscape.

### Key Outputs and Risk Estimation

A range of direct and estimated values were calculated for simulations, depending on end user needs and the availability of relevant datasets for each case study landscape. Some variables were defined in a pilot study with the Victorian Department of Environment, Land, Water and Planning (DELWP). Preliminary descriptions of these are listed below.

#### Area Burnt

Output value: The area burnt per fire (hectares).

Method of calculation: Direct PHOENIX output. All cells affected by fire.

#### House Loss

Output value: The number of houses lost per fire.

Inputs: PHOENIX prediction of convection, flame length and embers combined with address point layer.

Method of calculation: House loss was calculated in coordination with DELWP. For all cells affected by fire (flames, embers and / or convection), house loss probability was calculated based on the equations presented in Tolhurst and Chong (2011). Probability of house loss was then multiplied by the number of houses in that cell based on the address point layer. This gave a house loss per cell, which was then summed across the fire to provide a total number of houses predicted to have been lost in that fire.

Limitations: The equations of Tolhurst and Chong (2011) are based on a small set of fires in which house loss events occurred. These equations have not been tested on an independent data set due to the infrequent nature of such events.

Reliability: On a relative scale this metric is considered reliable as it was developed based on PHOENIX output for real fires. As noted above, the metric was derived from a small subset of fires and the absolute values of these outputs are less reliable. It should be noted that actions of fire agencies or residents at individual properties and house construction standards were not explicitly considered in this metric.

### Life Loss: Ratio Method

Output value: The number of lives lost per fire.

Inputs: House Loss metric.

Method of calculation: A simple ratio calculation was used based on the house loss metric described above. This assumes approximately one life is lost for every twenty houses burnt.

Limitations: The method is a coarse estimate of life loss and mirrors the house loss metric. It does not incorporate population data or actions of agencies or individuals.

Reliability: As this is based on the house loss metric, the same reliability issues apply.

### Life Loss: Harris Method

Output value: The number of lives lost per fire.

Inputs: PHOENIX based prediction of houses exposed to fire using the address point layer and population density.

Method of calculation: The number of houses exposed and people exposed to fire (flames embers or convection) per cell was calculated. The people and houses exposed were then used to calculate expected fatalities using the formulas from Harris et al. 2012.

Limitations: There are several limitations to the method. Firstly, the equations have been developed from empirical data for a limited set of fires. These fires have not been run in PHOENIX for comparison. Secondly, the equations have a relatively poor fit. Finally, the population density layer has been derived from the mesh-block dataset obtained from the Australian Bureau of Statistics (ABS). Individual mesh-blocks are not consistent in size or shape and the underlying data on population and house density is based on the 2011/2012 census. As a result, there are unavoidable spatial inaccuracies in this data set.

Reliability: As a relative measure, the metric is considered reasonably robust and more reliable than the ratio method (see above) as it considers the houses and population exposed. However it has the unavoidable limitation of not considering the actions of agencies or people in response to fires.

### Roads

Output value: The length of road or powerline infrastructure lost per fire.

Inputs: Road and Powerline lengths per cell, obtained from agencies, and PHOENIX output for fire intensity (kW/m).

Method of calculation: To calculate loss, a threshold based calculation was used where roads and powerlines were considered destroyed if they were exposed to a fire with intensity greater than 10,000 kW/m (Deloitte 2015).

Limitations: The output of this calculation is binary; the infrastructure is either destroyed or not-destroyed. No consideration was given to the level of destruction, which will influence the repair cost. Additionally, road / powerline construction is not the same across all assets and their durability will be different. Furthermore, the length of loss is not necessarily equal to the impact. For example, one hundred metres of loss could be one road for one hundred metres or fifty metres for two separate roads. The consequences of these two scenarios are potentially very different.

Reliability: The locations from the infrastructure data are considered to be reliable and the thresholds used are based on observations and expertise from real fires. However, not all roads and powerlines will be captured in every agency dataset and some locally important roads may be excluded.

### Powerlines

Output value: The length of road or powerline infrastructure lost per fire.

Inputs: Road and Powerline lengths per cell, obtained from agencies, and PHOENIX output for fire intensity (kW/m).

Method of calculation: To calculate loss, a threshold based calculation was used where roads and powerlines were considered destroyed if they were exposed to a fire with intensity greater than 10,000 kW/m (Deloitte 2015).

Limitations: The output of this calculation is binary; the infrastructure is either destroyed or not-destroyed. No consideration was given to the level of destruction, which will influence the repair cost. Additionally, road / powerline construction is not the same across all assets and their durability will be different. Furthermore, the length of loss is not necessarily equal to the impact. For example, one hundred metres of loss could be one road for one hundred metres or fifty metres for two separate roads. The consequences of these two scenarios are potentially very different.

Reliability: The locations from the infrastructure data are considered to be reliable and the thresholds used are based on observations and expertise from real fires. However, not all roads and powerlines will be captured in every agency dataset and some locally important roads may be excluded.

### Fuel Consumed

Output value: Total mass of vegetation consumed by the fire (tonnes).

Method of calculation: Calculated using the direct PHOENIX outputs of fire intensity, rate of spread and burnt area.

### Tolerable Fire Interval (TFI)

Output value: The area (hectares) of vegetation burnt below its minimum tolerable fire interval per fire.

Inputs: PHOENIX outputs of intensity and fire rate of spread, fire history layer of each scenario, spatial map of vegetation types and agency information on the minimum tolerable fire interval (TFI).

Method of calculation: Fire history layers for each scenario were converted to a time since fire (TSF) spatial layer. For each fire, the fire intensity and rate of spread values from PHOENIX were overlayed with the TSF and minimum TFI layers. A cell was considered affected if it was burnt before the minimum TFI was reached.

Limitations: This metric considers all fires equally and does not account for fire intensity.

Reliability: The reliability of the metric is dependent on the quality of the underlying spatial layers and the estimation of TFI for each vegetation type.

### Carbon Released

Output value: The mass of carbon released by the fire (tonnes).

Method of calculation: Total carbon released was calculated as a fixed proportion of total fuel consumed. The value used was 0.5.

### Environmental Cost

Output value: Environmental cost of fires.

Inputs: PHOENIX hectares burnt per fire.

Method of calculation: Environmental cost was calculated at $1,000 per hectare burnt based on the values presented in Stephenson (2012).

Limitations: Values were based on a sample of only five large fires. While two of these fires occurred in the East Central Victoria case study landscape, the spatial layout of resources is likely to have been a major driver of this estimate of the social, economic and environmental costs of wildfire.

Reliability: These values have not been derived for fires less than 100,000 ha in size and therefore the metric is considered untested for such fires.

### Life Value Cost

Output value: Social and economic cost of fires.

Inputs: Life Loss (Harris Method).

Method of calculation: To calculate the social cost of fires, the value of $3,652,000 per life loss was applied (Stephenson 2010). While this was a simple metric, Stephenson stated "While many social impacts are important e.g. psychological trauma, loss of memorabilia and family photographs), it is currently not possible to value them in dollar terms"

Limitations: Values were based on a sample of only five large fires. While two of these fires occurred in the East Central Victoria case study landscape, the spatial layout of resources is likely to have been a major driver of this estimate of the social, economic and environmental costs of wildfire.

Reliability: These values have not been derived for fires less than 100,000 ha in size and therefore the metric is considered untested for such fires.

### Economic Cost

Output value: Economic cost of fires.

Inputs: PHOENIX hectares burnt per fire.

Method of calculation: Economic cost was calculated at $2,000 per hectare burnt based on values in Stephenson (2012). Note that environmental costs and social costs were not included in this value.

Limitations: Values were based on a sample of only five large fires. While two of these fires occurred in the East Central Victoria case study landscape, the spatial layout of resources is likely to have been a major driver of this estimate of the social, economic and environmental costs of wildfire.

Reliability: These values have not been derived for fires less than 100,000 ha in size and therefore the metric is considered untested for such fires.

### Refugia, Wet Forest, Leadbetters Possum Habitat, Nature Print Critical Habitat

Output value: The area (hectares) of each biodiversity spatial layer affected per fire.

Inputs: PHOENIX outputs of intensity and fire rate of spread, spatial layers for Refugia, Wet Forest, Leadbetters Possum habitat and Nature Print critical habitat.

Method of calculation: The relevant spatial layer is overlayed with the fire intensity and fire rate of spread values from PHOENIX. If either intensity or rate of spread is greater than 0, the area is considered affected by fire.

Limitations: These metrics are simplistic, only considering if the area is affected by fire. No measure of fire severity is incorporated so the level of impact cannot be derived.

Reliability: As this metric considers all cells that are affected by fire, much of the reliability is dependent on the quality of the underlying spatial layers.

### Debris Flow Risk: 50th, 95th percentile

Output value: Debris flow probability for the 50th and 95th percentile of fires.

Inputs: Spatial data for the headwaters (a collection of points with slope and aridity index attributes), I12 value (one per annual return interval), catchment ID, canopy height and depth, PHOENIX outputs of fire intensity and flame length.

Method of calculation: The distribution of values of annual exceedance probability (AEP) of the critical I12 value (which would initiate a debris flow) was calculated for all simulation cells in each catchment.

Limitations: The estimate of debris flow probability is an important risk metric but does not translate directly to change in water quality. The magnitude of the debris flow will vary between sub-catchments and the ability of this flow to continue into the reservoir depends on the size of the flow and the topography between the point of origin and where the stream network reaches the reservoir. Estimating this accurately requires a far more complex stream network model coupled with a probabilistic storm cell model.

Reliability: The model is reasonably robust having been developed from data collected within the Victorian East Central case study landscape.

## END USER ENGAGEMENT

A quarterly end user update is sent to all end users, detailing recent events, project news and other information. The Research Advisory Forum in Canberra and Research Showcase in Adelaide provided opportunities to meet and discuss things with end users. Formal meetings took place with representatives from NSW RFS, ACT Government and SA DEWNR, but the vast majority of end user interactions were regular *ad hoc* phone, email and face to face conversations concerning data acquisition, project methods, recent findings and any other issues.

# PRELIMINARY RESULTS AND DISCUSSION

## FIRE SPREAD SIMULATIONS

### East Central Victoria, Adelaide, ACT, Hobart

Preliminary results are available for four peri-urban case study landscapes in East Central Victoria, Adelaide, ACT and Hobart.

Ignition locations are shown at Figure 2 to Figure 5 for the study landscapes.

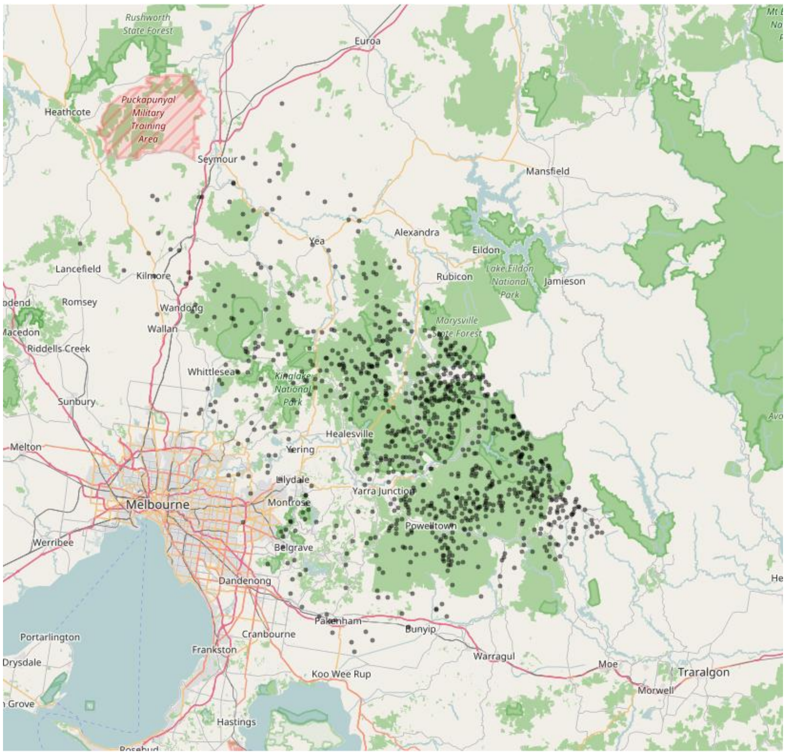


FIG 2 IGNITION POINTS, EAST CENTRAL VICTORIA

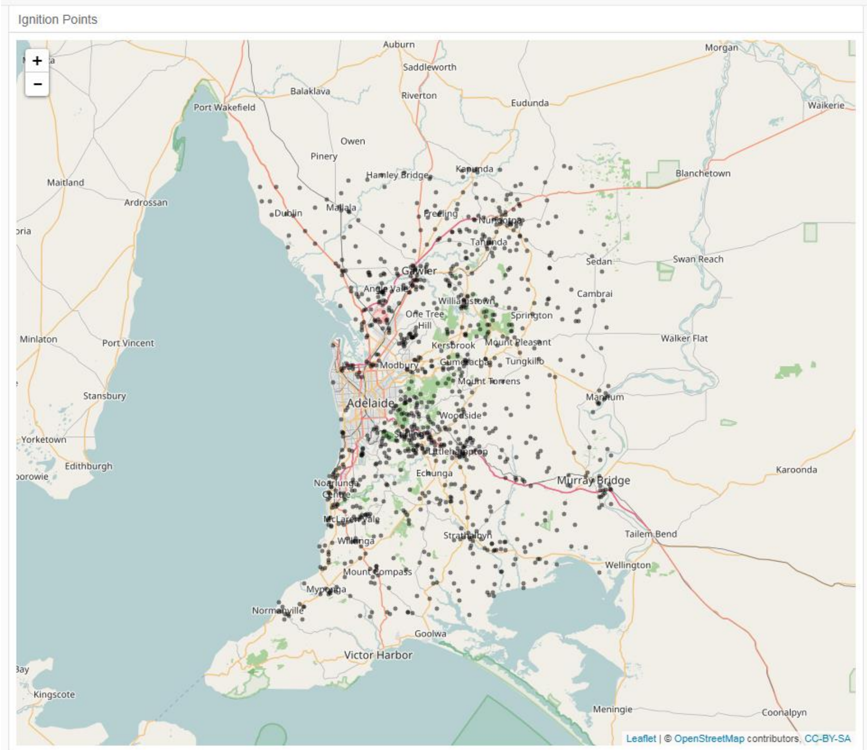


FIG 3 IGNITION POINTS, ADELAIDE

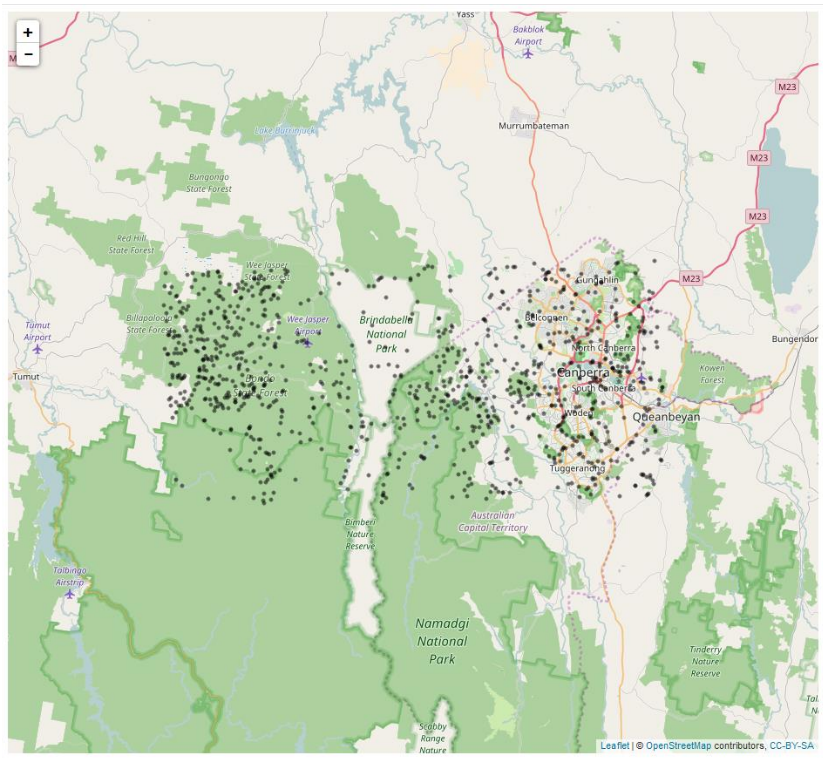


FIG 4 IGNITION POINTS, ACT

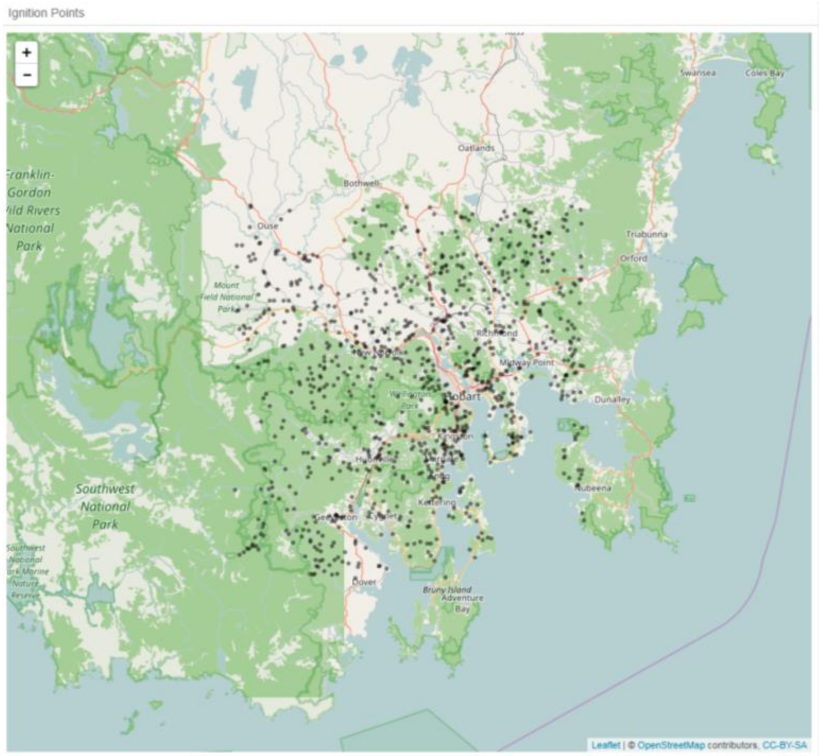


FIG 5 IGNITION POINTS, HOBART

Complete details of the analysis are expected to be reported in the 2017-2018 annual report, although work utilising this dataset will continue well beyond that. While formal analysis of these simulations is not complete, there are clear preliminary observations.

Across all case study landscapes, greater levels of prescribed burning tend to result in reduced wildfire impacts, regardless of variable, fire weather category or FFDI driver. However, there is considerable variation in the rate of reduction in risk i.e. the slope of the curves formed by the markers in each Figure and panel. For example, the relative impact of increasing amounts of prescribed burning on subsequent area burnt by wildfire is much smaller in Adelaide than in Hobart of East Central Victoria. This relative insensitivity to prescribed burning in the Adelaide case study landscape is apparent for all other variables analysed. A similar reduction in the sensitivity of area burnt to increasing amounts of prescribed burning is apparent when comparing mean area burnt in three case study landscapes with 90$^{th}$ percentile area burnt. In all three landscapes, the relative impact of prescribed burning on area burnt is smaller at these upper extremes of the distribution of all case study simulations.

Another consistent finding from these initial simulations is that the particular combination of weather factors underpinning a given FFDI value can substantially impact the overall level of risk, as well as the response to prescribed burning. For example, in the ACT case study landscape there are greater amounts of area burnt under temperature- and wind speed-driven FFDI values than under wind change-driven FFDI values. This is particularly apparent for FFDI at High or Very High categories. A similar spread in the response of area burnt to FFDI driver can be seen in Adelaide, although the specific pattern is quite different to the ACT. In Adelaide, the highest levels of area burnt are associated with wind speed-driven FFDI values, with the exception of FFDI in the severe category. At low FFDI levels, area burnt is lowest when FFDI values are driven by relatively high temperatures. However, as FFDI increases, the influence of temperature on area burnt approaches that of the other drivers and at the catastrophic FFDI level, the only FFDI driver remaining is temperature.

There are distinct regional patterns in the amount of prescribed burning required to reduce overall area burnt by 50%. In East Central Victoria, prescribed burning rates of 15% are required to achieve a 50% reduction in area burnt, although even this high figure does not reduce area burnt by 50% when FFDI conditions are Catastrophic. In Tasmania a 50% reduction in area burnt is possible with prescribed burning rates of 10%. In South Australia, as noted above, the total area burnt is relatively insensitive to prescribed burning rates and a 50% reduction in area burnt is not reached under any prescribed burning scenario.

The impact of prescribed burning on house and life loss, road and powerline damage, environmental and economic cost, and other variables is broadly similar to its impacts on prescribed burning i.e. a general tendency for increased rates of burning to reduce risk, variation between regions in the rate of decrease in risk due to prescribed burning and a sensitivity to FFDI drivers that depends on the overall FFDI category.

# CONCLUSION

2016-2017 has been an important year for the *Hectares to tailor-made solutions* project. Substantial progress has been made on data acquisition, fire spread simulations and empirical analysis. Engagement with end users has been regular and fruitful, with positive feedback from agencies and opportunities to incorporate end user comments into overall project design.

It should also be noted that there are a range of recent publications by project team members that are directly relevant to project methodologies but completed external to the project. These are highlighted in the References.

## FIRE SPREAD SIMULATIONS

Some tentative conclusions may be drawn from the preliminary fire spread simulations. Increasing rates of prescribed tend to result in reduced risk of various impacts, such as area burnt, house loss and economic costs. However, the effect of increased prescribed burning on reducing risk generally declines under the worst fire weather conditions. Further, the relative effect of increased prescribed burning varies markedly between regions and is notably weaker in Adelaide than in East Central Victoria, Hobart or the ACT. Relatively high levels of prescribed burning are required to achieve large (50%) reductions in impact for most values and under the most extreme fire weather conditions, even the highest scenario of 15% prescribed burning was not sufficient to achieve a 50% decrease in area burnt and some other impacts such as economic cost.

Further work is required to understand these results. The project is generating an immense amount of data with the potential for uncovering distinct patterns in prescribed burning effectiveness at reducing risk across highly divergent landscapes in southern Australia. As the results are explored in more depth and more results are added from the remaining case studies, it will be possible to draw a more robust and comprehensive set of conclusions from these simulations.

## NEXT STEPS

2017-2018 will see the culmination of the fire simulations and empirical analysis and their summary in the form of journal articles and presentations to key stakeholders. The project focus will turn to Multi-Criteria Decision Analysis and the incorporation of climate change effects. This all serves as a lead-up to the final stage of the project, where results from various project streams will be integrated and the Prescribed Burn Atlas will be developed and tested in close consultation with end users, before being released upon project completion.

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**Note**. Relevant publications from project team members are marked with an asterisk (*).