— Centre of Excellence —
PRESCRIBED BURNING

Prescribed Burning Objectives Setting and Analysis

A PRODUCT OF THE NATIONAL BURNING PROJECT

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An Australian Government Initiative

afac

Australian Institute for Disaster Resilience

FFMG

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Australasian Fire and Emergency Service Authorities Council	**AFAC**
Forest Fire Management Group	**FFMG**
Australian Capital Territory	**ACT**
New South Wales	**NSW**
Northern Territory	**NT**
Queensland	**QLD**
South Australia	**SA**
Tasmania	**TAS**
Victoria	**VIC**
Western Australia	**WA**

EXECUTIVE SUMMARY

Natural Decisions was engaged by the Australian Fire and Emergency Service Authorities Council (AFAC) to undertake Sub-project 2 of the National Burning Project: 'Report on an analysis of the tools and methodologies available to balance competing objectives of burning programs and matching these to users'.

The primary objective of the project was to determine the availability and suitability of tools and methodologies to manage objectives for prescribed burning programs. The work was completed in two stages:

- Stage 1 reviewed the availability and suitability of tools and methodologies used by fire management agencies to set objectives, and to measure and evaluate the implementation of prescribed burning programs. Current decision-making tools for prescribed burning have been developed for all states and the ACT. Tools were generally strong in risk assessment and fire simulation but had limited or no inclusion of economic components.
- In Stage 2 a separate benefit: cost analysis tool (hereafter called the Benefit: Cost Tool or BCT) was developed. The BCT was inspired by the principles of a previously developed tool called the Investment Framework for Environmental Resources (INFFER) and previous experience in bushfire management research. Important components of the brief were that the tool should be able to use inputs from existing fire simulation and risk assessment tools, be able to be used by non-economists and to respond to recommendations previously developed, including the need to build capacity of fire managers. The tool was developed in Excel and should be considered as a prototype.

The BCT was applied in a participatory process in two case study areas, the Mount Lofty Ranges in South Australia and the Hornsby-Berowra region in New South Wales. In both South Australia and NSW, the current burning program (baseline) is conducted only on public land. The benefits and costs of alternative scenarios (additional to the baseline) were assessed. In South Australia seven scenarios were assessed, comprising different levels of burning on public and private land. In NSW the current burning program was a mixture of landscape and interface burning and the six scenarios assessed included three different levels of burning in these two zones, retrofitting houses, an increased mechanical treatment option in asset protection zones and a 'do nothing' option. In NSW the use of Phoenix was also a strong feature of the work and results are sensitive to the assumptions made as part of the modelling.

South Australian results suggested that there no clear benefits to be gained by adding to the current burning on public land, by also including burning on private. As the area of private land burning is increased the benefits increase but are outweighed by costs in the scenarios assessed. Compared to the base-case there may be very modest benefits in shifting resources from public land to private land burning. Additional weed control was estimated to be a very poor investment, based on assumptions used.

There were very high calculated Benefit: Costs Ratio values in NSW, especially for increased interface burning and to a lesser extent landscape burning, but still positive results and only modest costs from increased mechanical treatments in asset protection zones. In comparison retrofitting houses was estimated to be a very poor investment because of the huge costs involved. The Rural Fire Service (RFS) were particularly interested in assessing what would happen in the absence of prescribed burning. A maximum fuel scenario was included to try and make this comparison. Under the assumptions made, fuel accumulation over a 20-year timeframe in the absence of a prescribed burning program was estimated to result in very large asset losses due to increased fire incidents.

There is a famous quote which is that 'all models are wrong but some are useful'. This project was as much about developing a model to represent the benefits and costs associated with prescribed burning regimes as it was to report and assess the results themselves. The results of both case-studies will be as good as the assumptions that underpin them, both in terms of the data and knowledge used to generate them, as well as the assumptions that have been made in the BCT in developing a sufficiently simple and hopefully useful tool. Results presented in this report should be considered with these factors in mind. It is also important to note that the findings from this analysis should not be extrapolated to other regions for decision-making purposes as baseline circumstances and contextual factors (e.g. management strategies, landscape attributes, fire behaviour) will be highly situation specific.

In addition to developing and testing the BCT, key learnings are discussed in this report. Overall the BCT was able to assess benefits and costs of prescribed burning strategies in a robust way and provides a new approach for fire agencies to strategically evaluate different options. Many of the concepts involved were new to project participants. Existing fire behaviour modelling proved complementary and the BCT was able to utilise the outputs of fire modelling, although it took some time to be able to determine which parts were useful, whether the way fire simulation modelling is currently used is sound for assessing benefits and costs and decisions about how model outputs could be interpreted as inputs into the BCT.

The project responded to the three previously identified recommendations namely building the capacity of managers to commission and use economic information, integrating analysis of both market and non-market benefits and costs as part of economic evaluation and better integrating economic evaluation within the broader context of integrated decision-making processes. The non-market benefits component of the model have been included but were not tested as part of either case-study because of lack of reliable metrics for such.

In conclusion this project has developed a benefit: cost analysis tool for use by fire agencies. The BCT is a tested prototype and could be made more simple and attractive to use if fire managers decide it to be sufficiently useful for more widespread application. If the BCT is deemed sufficiently useful then training for fire analysts unfamiliar with benefit cost analysis approaches is likely to be important. Training would help enable fire managers to gain familiarity with the tool itself as well as providing guidance about the concepts needed to perform benefit cost analysis.

Source: Department of Environment, Water and Natural Resource, South Australia.

1 INTRODUCTION

Natural Decisions was engaged by the Australian Fire and Emergency Service Authorities Council (AFAC) to undertake Sub-project 2 of the National Burning Project: 'Report on an analysis of the tools and methodologies available to balance competing objectives of burning programs and matching these to users'.

Prescribed burning programs usually come with two main objectives:

- Reducing the risks to the community; and/or
- Protecting biodiversity values.

These objectives may in some cases be complementary, but are often in direct conflict, requiring an understanding of trade-offs. There is also increasing pressure for assessing the outcomes from prescribed burning programs. The outcomes can apply at different scales (single burn, annual program to landscape level) and ideally should be able to be thought about, measured and evaluated in terms of the competing objectives. The work arose because fire agencies recognised that there had been limited consideration of economic thinking in current decision-making associated with the evaluation of sometimes competing objectives arising from prescribed burning programs.

The primary objective of the project was to determine the availability and suitability of tools and methodologies to manage objectives for prescribed burning programs. The work had two stages.

Stage 1 reviewed the availability and suitability of tools and methodologies used by fire management agencies to set objectives, and to measure and evaluate the implementation of prescribed burning programs and the results have been reported in detail by Park *et al.* (2016). In summary, results from the first stage reported that decision-making tools for prescribed burning have been developed for all states and the ACT. The reviewed tools were strong in risk assessment and fire simulation but had limited or no inclusion of economic components. Tools were currently used for tactical, operational or strategic decision-making, with some covering all three levels.

The key recommendation for Stage 2 was to develop a separate benefit: cost analysis tool or tools. A component of the brief was that a benefit: cost analysis tool should preferably be able to use inputs from existing fire simulation and risk assessment tools and processes. This was important because many current tools had a strong degree of ownership within fire agencies.

This final report for Stage 2 presents the results for the analysis of benefits and costs associated with bushfire management options for two case study areas, the Adelaide Hills in South Australia and the Hornsby-Berowra region in New South Wales. The analysis has been undertaken using a Benefit: Cost Tool (hereafter referred to as the BCT) inspired by the principles of the Investment Framework for Environmental Resources (INFFER) (Pannell *et al.*, 2011).

2 METHODS

2.1 Overview of the approach

A conceptual framework was proposed from Stage 1 and provided an initial basis for developing a Benefit: Cost Analysis Tool that included:

1) A general framework for non-expert users to help them understand the elements of the problem and identify data needs; and
2) Inclusion of more detailed components required to assess the full range of benefits and costs associated with prescribed burning programs.

A preliminary version of the BCT was developed, in the form of an Excel spreadsheet, to apply to the assessment of a range of scenarios across the two case study areas.

The BCT has been built on learnings gained in previous work. This included the integrated analysis of bushfire management options in the Adelaide Hills in SA and the Otago region in New Zealand (Gibson and Pannell, 2014) together with more recent work in Western Australia (Florec and Pannell, 2016). It also builds on experience being gained in a current CRC Bushfire project in the East Central Bushfire Risk Landscape in Victoria being conducted by Natural Decisions. Importantly it also responds to the key recommendations of (Clayton *et al.* 2014):

- Building the capacity of managers to both commission and use economic information;
- Integrating analysis of both market and non-market benefits and costs as part of economic evaluation; and
- Better integrating economic evaluation within the broader context of integrated decision-making processes.

The BCT was developed and tested for suitability to assess multiple objectives associated with prescribed burning. Previously developed tools, such as have been built for the Adelaide Hills (Gibson and Pannell, 2014) are relatively complex and can only be used by expert economists with strong technical expertise. As such, whilst useful, they may be limited in use for fire managers.

For the BCT developed in this project we have incorporated the principles of INFFER and developed a more useable and simple benefit: cost analysis-based tool. The tool should be considered as a prototype and looks somewhat formidable for first-time users because there are many cells which potentially require populating. It was important to develop and road-test the core concepts and now this has occurred through the two case-studies the tool could be simplified. Inclusion of features such as using drop down boxes would improve attractiveness and simplicity, assuming fire managers determine it sufficiently useful for application. The characteristics and preferences of users (e.g. participating fire agencies) could be incorporated into the development of a more user-friendly product beyond this prototype stage.

2.2 Features of the assessment approach

In developing the BCT we were cognisant that it needed to integrate fire risk, fire spread, the damage caused by fires of different severities, asset values, weather conditions, impacts of fire-prevention options, and costs of those management options. Our approach has been designed to estimate the benefits and costs of various prescribed burning (and other[1]) management strategies that aim to protect different assets. The benefits of each management option are calculated as reduced damage to the assets and reduced suppression costs compared to a baseline (often, but not necessarily, assumed as the current approach).

The assessment approach is an Excel spreadsheet tool which at this stage has the following features for inputs and specification:

- Clear definition of spatially explicit region (text description in the spreadsheet and an accompanying separate map);
- Agreement on values to be used for statistical loss of life and injury;
- Agreement on asset categories (such as residential properties, other properties, infrastructure, water resources, harvestable forests, agriculture, habitat/biodiversity – the current version accommodates up to 25 specified asset types which can be modified by the user[2]);
- Inclusion of non-monetary indicators (such endangered ecological communities, scar trees, water supply catchments etc.) if important;
- Average annual losses of each asset type, including consequent losses;
- Baseline suppression costs;
- Dynamics (percentage change in number/severity of fires and changes in asset loss);
- Benefits of interventions (reductions in numbers of fires, consequence per fire and reduction in number of assets if applicable in fire-prone areas);
- Timeframe over which analysis is conducted; and
- Discount rate.

From the inputs, Net Present Values (NPVs) and Benefit: Cost Ratios (BCRs) associated with different options are calculated and can be compared with each other and the baseline. BCR values which exceed 1 show that benefits of alternative management strategies outweigh costs and regardless of the size of the number, the largest number of a series of options shows the largest benefits when compared with the specified baseline. Benefit: cost ratios less than 1 indicate the option is less attractive (not cost-effective) compared with the baseline.

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1 While the focus of the BCT has been to evaluate prescribed burning strategies it can accommodate other bushfire management strategies.

[2] A decision for the final product will be the extent to which asset types are specified and/or left open to give users the flexibility to customise their own.

2.3 Criteria for selection of case studies

Initial discussion within the member agencies of AFAC identified five potential case studies, two of which were selected:

- Adelaide Hills, South Australia (leader: Mike Wouters, DEWNR Fire & Flood Management); and
- Hornsby-Berowra, New South Wales (leader: Laurence McCoy, NSW Rural Fire Service).

Case studies were selected based on the following factors:

- Areas where there is a current and ongoing threat from bushfire;
- Areas that contain significant ecological, social and economic values where there is potential to implement and evaluate different bushfire management options;
- Level of institutional interest and support for the study;
- Availability of key personnel to assist the project team in the assessments for the development of case studies, including ability to provide timely provision of required data and participation in expert workshops;
- Potential transferability/application of findings to other environments and jurisdictions; and
- Costs to participants and to the project.

2.4 Process for gathering and assembling data

A structured and iterative process evolved over the project to assist with the gathering and assembly of the required data.

At the outset an inception workshop was held in each case study region:

- Hornsby-Berowra case study, Hornsby NSW, 4 August 2016; and
- Mount Lofty case study, Adelaide SA, 4 October 2016.

The purpose of the inception workshops was:

- To introduce participants the project and the proposed approach to integrated economic assessment of bushfire management;
- To identify and discuss management options relevant to the case study region and agree on scenarios for analysis; and
- To identify key data and information requirements for the analysis, key sources and processes for compilation of data.

2.4.1 Adelaide Hills case study, South Australia

The Adelaide Hills case study was conducted in tandem with a parallel and closely related project, *Integrated Assessment of Prescribed Burning on Public and Private Land in The Adelaide Hills (South Australia),* being undertaken by the University of Western Australia (Veronique Florec, David Pannell and Atakelty Hailu). This project is described in more detail in Appendix 3.

The reason for conducting the SA project in tandem with the UWA study was that it provided an opportunity to compare and contrast the results generated from more complex (UWA) and simpler (Natural Decisions) tools. Because the data requirements were similar there were benefits for both DEWNR and the project teams.

In SA data was gathered from previous studies, relevant databases such as NEXIS (Dunford *et al.*, 2014) and expert opinion, with this work was largely coordinated by Veronique Florec. It could be described as an expert economist driven approach. The approach was more efficient for the Natural Decisions project team and DEWNR staff. The approach lacked the inevitable ‘messiness’ that multi-disciplinary projects invariably experience but also meant that there were limited co-learning opportunities for both the participants and the tool developers. Such co-learning opportunities include understanding how different disciplines think and perceive what is being asked of them.

The project team conducted a second workshop in Adelaide (20 December 2016) at which the preliminary results were presented. This workshop revealed the need for additional follow-up to confirm key data inputs (e.g. intervention costs) and to seek alignment between the complex model and BCT.

2.4.2 Hornsby Berowra case study, New South Wales

In contrast the approach in NSW was more of a ‘bottom-up’ approach, whereby the project team and the NSW RFS co-learnt and began to understand each other’s ways of thinking. The desire to use Phoenix modelling was an important part of the Hornsby-Berowra case study. NSW RFS were keen to use Phoenix modelling to inform and populate the scenarios of interest that were identified. The use of Phoenix modelling to underpin scenarios facilitated more direct interaction between NSW RFS and the project team than in SA. Hopefully both parties learnt more in the process, and it improved our understanding how useful Phoenix is and which parts of the BCT it is useful for.

A second stakeholder workshop was held in Hornsby (13 October 2016). This workshop brought together a broader stakeholder group and covered much of the same ground as the inception workshop.

It became clear following the second Hornsby-Berowra stakeholder workshop that significant guidance would be required to ensure relevant data in an appropriate form was able to be gained from the Phoenix modelling. To assist this process, we developed a draft guidance template (See Appendix 1). This provided step-wise instructions for use with the spreadsheet calculator designed to assess benefits and costs of fire risk mitigation strategies (such as planned or prescribed burning) relative to a defined baseline program.

Two subsequent workshops were held in Sydney for the NSW case study (22 December 2016 and 10 March 2017) to populate as much of the spreadsheet calculator as possible.

The December workshop was conducted after the initial Phoenix modelling results were available. Populating the values of important assets in the case study area was relatively straightforward and was completed using a combination of Phoenix outputs (e.g. number of houses, length of roads etc.), local knowledge, looking for figures on the web and previously published figures (e.g. $4.2 million for the statistical value of a human life (Office of Best Practice Regulation, 2014)). However, once we started to populate the spreadsheet regarding asset losses under different scenarios it became apparent (as is common in innovative and multi-disciplinary projects) that the project team and NSW RFS had different understanding and interpretations regarding use of Phoenix as an input to the BCT.

It also became clear that the understanding of the baseline was unclear between RFS and the tool developers. Natural Decisions hadn't been exposed in a 'hands on' way to Phoenix before and this proved problematic as it meant that we had not been able to provide strong guidance to NSW RFS initially. In contrast, while NSW RFS had significant fire behaviour and modelling experience, and was very comfortable modelling relevant scenarios, they had limited exposure to the sorts of questions that the BCT required.

NSW RFS had used extremely high fuel loads in the initial modelling runs because their main interest was in evaluating the success of their current prescribed burning programs. Whilst in theory a baseline different to the current burning program could be used, the tool developers were uncomfortable about this because the implications of doing so were that it requires assessment about suppression costs for which there was no available data. In addition the estimated losses looked exceptionally large and impossible to verify against any relevant experience. The tool developers felt that given the project was about developing a useable method and that there are already many unknowns, it was important to start with a baseline which represented current practice and for which suppression costs could be developed.

Following this setback, David Pannell was involved in discussion with NSW RFS to discuss how best to resolve some of the issues around the basis of the base-case and the scenarios.

At this point there were two main possibilities to move forward:

- Abandon modelling and proceed with expert opinion; and
- Re-do the modelling with shared understanding from both the project team and NSW RFS about using a realistic baseline.

To NSW RFS's credit they decided to re-embark on the modelling. The tool developers provided additional guidance to assist with being clear about the assumptions behind the scenarios. A positive outcome was also that RFS were able to automate some aspects of the modelling which will prove useful for NSW overall.

Source: Queensland Parks and Wildlife Service

3 RESULTS FOR CASE STUDY 1 – ADELAIDE HILLS SA

3.1 Overview of case study area and bushfire management issues

The case study area is in the Adelaide Hills to the east of Adelaide. The area is a total of 62,987 hectares of which 14,521 hectares is public land (23%) and 48,466 hectares is private land (77%). Native vegetation cover is 33% across the study area, 23% on private land.

The predominant land uses are grazing, horticulture (grapes and fruit), forestry (softwood plantations), nature conservation, and water supply and lifestyle/amenity properties. The area is experiencing rapid urban expansion and rural residential development.

A significant proportion of bushland (high fuel hazard & high conservation value) occurs on private land. The area has a high bushfire risk with recent significant bushfires (Pinery 2016, Sampson Flat 2015, Eden Valley 2014) either within or adjacent to study area. The case study area is essentially the same for a previous study (Gibson and Pannell, 2014) that undertook an integrated assessment of bushfire management options.

Currently bushfire risk is managed via a mix of asset protection (clearing around houses), community engagement, prescribed burning (currently only on public land) and rapid bushfire suppression. A key driver for the current study is to achieve the highest reduction in risk of impacts from bushfires (to human life and built assets) in the study area whilst maintaining catchment values (water quality) and conservation of species/habitat. Detailed fire management plans have been developed for the area to guide where public land burning should occur, with the use of tools including the Bushfire Risk Assessment Tool (BRAT), to identify where prescribed burning may pose unacceptable risks. The main risks associated with current decision-making processes were identified as:

- Burn escapes;
- Impact to environmental values;
- Smoke impacts (urban areas & vineyards); and
- Visual/amenity impacts.

The following benefits were seen as worthwhile for improved decision-making:

- Reduced fire spread and reduced fire severity;
- Reduced asset loss (life, property, significant habitat, water quality and water quantity impacts);
- More effective use of resources and dollars (reduced or avoided costs); and
- Greater community support & participation.

Currently a range of agencies are involved in bushfire management decision making including; DEWNR, Country Fire Service, SA Water and Forestry SA.

3.2 Scenario evaluation

At present prescribed burning is undertaken only on public land within the Adelaide Hills with an average of 214 hectares treated annually. This represents the baseline against which alternative scenarios were assessed.

Seven scenarios were assessed (summarised in Table 1 below):

Scenario 1: Prescribed burning on 2.5% of private land. Prescribed burning on public land as for baseline.

Scenario 2: Prescribed burning on 5 % of private land. Prescribed burning on public land as for baseline.

Scenario 3: Prescribed burning on 8 % of private land. Prescribed burning on public land as for baseline.

Scenario 4: Total area of prescribed burning as for baseline, except that 30 hectares (14%) is shifted from public to private land

Scenario 5: Total area of prescribed burning as for baseline, except that 60 hectares (28%) is shifted from public to private land

Scenario 6: Total area of prescribed burning as for baseline, except that 105 hectares (49% is shifted from public to private land

Scenario 7: Base-case prescribed burning plus additional weed spraying in other areas

Figure 1 Map of Adelaide Hills (SA) case study area

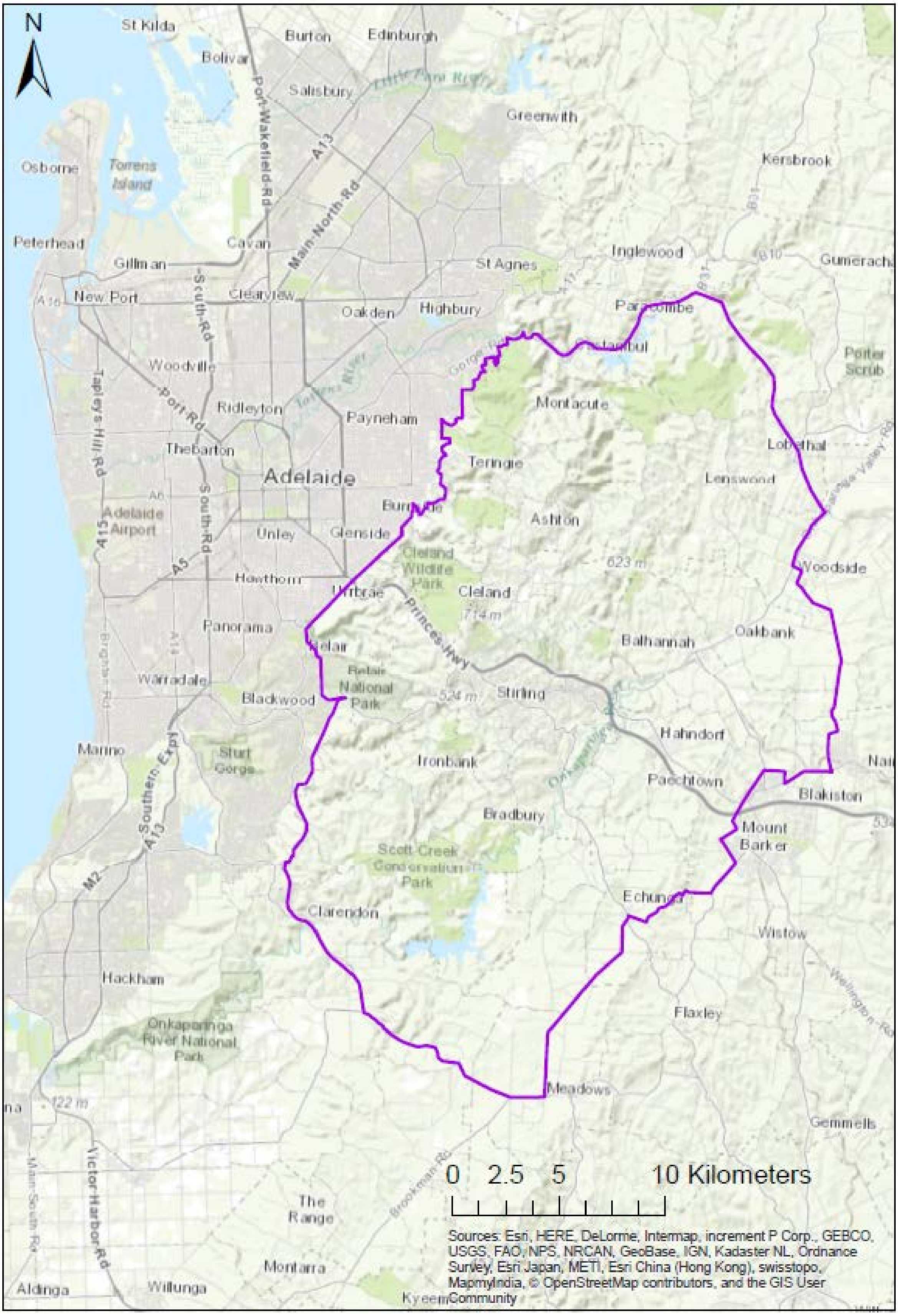

Table 1 Summary of area treatments for scenarios for Adelaide Hills case study

Scenario	Area of public land treated (ha/%)	Area of private land treated (ha/%)	Total area treated (ha/%)
Baseline	214 (1.5%)	0 (0%)	214 (0.3%)
1	214 (1.5%)	658 (2.5%)	872 (1.3%)
2	214 (1.5%)	1170 (5%)	1384 (2.2%)
3	214 (1.5%)	1603 (8%)	1817 (2.9%)
4	184 (1.3%)	30 (0.06%)	214 (0.3%)
5	154 (1.1%)	60 (0.12%)	214 (0.3%)
6	109 (0.7%)	105 (0.22%)	214 (0.3%)
7	214 (1.5%)	32 (0.07%)	246 (0.3%)

3.3 Data assembly

The process for gathering and assembly of data is described in Section 2.4. Following submission of the draft Final report it became evident that additional work was required to accurately estimate intervention costs. Tim Groves and Karen Philp (DEWNR) developed a detailed spreadsheet-based assessment of costs associated with prescribed burning on both private and public land which revealed that the original figures significantly underestimated the costs. Their analysis revealed that based on an average 30 hectare burn the cost of public land burning is $1898/ha and private land burning is $2000/ha. Based on these estimates Table 2 below summarises the intervention costs for each scenario.

Table 2 Intervention costs for SA case study

Scenario	Area of public land treated (ha/%)	Area of private land treated (ha/%)	Total area treated (ha/%)	Intervention cost
Baseline	214 (1.5%)	0 (0%)	214 (0.3%)	Not applicable
1	214 (1.5%)	658 (2.5%)	872 (1.3%)	$1,316,000
2	214 (1.5%)	1170 (5%)	1384 (2.2%)	$2,340,000
3	214 (1.5%)	1603 (8%)	1817 (2.9%)	$3,206,000
4	184 (1.3%)	30 (0.06%)	214 (0.3%)	$3,060
5	154 (1.1%)	60 (0.12%)	214 (0.3%)	$6,120
6	109 (0.7%)	105 (0.22%)	214 (0.3%)	$10,710
7	214 (1.5%)	32 (0.07%)	246 (0.3%)	$304,758

It is important to note that Scenarios 1-3 involve a significant increase in the overall area of prescribed burning, whereas Scenario 4-6 maintain the current level of burning but shift different proportions from public to private land. As the difference in intervention cost for prescribed burning between private and public land is small ($102/ha cheaper to burn on public land than private land), the overall costs of these interventions are modest, especially when compared with Scenarios 1-3.

3.4 Results for Adelaide Hills case study

Table 3 below provides an overview of the key results for the Adelaide Hills case study. The effect of each intervention is presented in terms of:

- The proportional reduction in fire incidents;
- The proportional reduction in loss of life;
- The proportional reduction in loss of houses;
- The proportional reduction in overall asset losses;
- The reduction is suppression costs;
- The cost of the intervention; and
- The benefit: cost ratio.

The results from scenarios 1-3 show that the benefits to be gained by adding to the current burning on public land to also include private land burning (BCRs ranging from 0.55 to 0.93) are outweighed by the costs, although as the area of private land burning increases the BCR approaches break-even.

Compared to the base-case there appear to be significant benefits (BCR 9.34 in scenarios 4, 5.59 in Scenario 5 and 3.44 in Scenario 6) in shifting resources from public land to private land burning, although these benefits decrease relative to costs as the transitional amount increases. Additional weed control was estimated to be a very poor investment (BCR 0.01).

As discussed later in the report these results are highly sensitive to the input parameters. Preliminary estimates of intervention costs associated with Scenarios 1-3 were much less than finally estimated and the BCRs for these options initially looked quite favourable (greater than 1), highlighting the need to carefully compile and scrutinise input data.

Table 3 SA Results (not for official use)

Intervention	Δ in fire incidents % reduction	Δ Lives lost % reduction	Δ Houses lost % reduction	Δ Asset losses (reduction)	Δ Suppression cost (reduction)	Intervention cost	BCR
1. Prescribed burning on 2.5 % of Private land	1.03%	0.67%	0.69%	$851,108	$57,616	$1,316,000	0.55
2. Prescribed burning on 5 % of Private land	3%	2%	2%	$2,508,200	$169,792	$2,340,000	0.91
3. Prescribed burning on 8 % of Private land	4%	3%	3%	$3,531,932	$239,093	$3,206,000	0.93
4. 14% of prescribed burning shifted to private land	0.07%	0.02%	0.02%	$33,706	$2,282	$3,060	9.34
5. 28% of prescribed burning shifted to private land	0.07%	0.02%	0.02%	$40,316	$2,729	$6,120	5.59
6. 49% of prescribed burning shifted to private land	0.08%	0.02%	0.03%	$43,401	$2,938	$10,710	3.44
7. Weed control	0.0072%	0.003%	0.0034%	$4,390	$297	$304,758	0.01

4 RESULTS CASE STUDY 2 – HORNSBY BEROWRA NSW

4.1 Overview of case study area and bushfire management issues

The Hornsby/Ku-ring-gai BFMC area is located in the northern suburbs of Sydney, New South Wales and includes the Local Government Areas of Hornsby Shire and Ku-ring-gai. The study area accounts for a total land area of 59,300 hectares. Of the total case study area of 59,300 ha, 54% is part of the national Parks estate (managed by NSW National Parks and Wildlife Service – NPWS), 9% is managed by Local Government and 28% is private land (largely urban and peri-urban settlement). There are large amounts of native vegetation close to urban interface. 266,000 people live within the case study area.

The area has a typically uniform rainfall pattern throughout the year, although higher rainfall can be experienced in the months from February to March. The bushfire season generally runs from October to March when prevailing weather produces strong northwest winds, low humidity and high temperatures. The highest probability of bush fires occurs in December and January.

Historical data indicates that there are on average 420 fires per year, greater than 100 hectares (see Table 5) with an expectation that a major bushfire will occur every 7-10 years on average.

4.2 Scenario evaluation

At present prescribed burning is conducted across the case study area, in both interface and landscape zones on public land. A number of scenarios were identified by representatives from the Bushfire Management Committee (BFMC) for analysis, these encompassed increasing the extent of prescribed burning within both interface and landscape zones, along with additional scenarios for house retrofitting and mechanical treatment. These were compared to the baseline of the current fuels which includes the current prescribed burning effort.

The current baseline was calculated to be 256 hectares/annum of interface burning and 556 hectares/annum of landscape burning. Six scenarios were assessed, and these are described below (summarised in Table 4).

Scenario 1: Increase interface burning from 256 ha/year to 586 ha/year while maintaining the current level of landscape burning.

Scenario 2: Increase landscape burning from 556 ha/year to 1271 ha/year while maintaining the current level of interface burning.

Scenario 3: Increase interface burning to 586 ha/year and landscape burning to 1271 ha/year.

Scenario 4: Retrofitting houses to meet new standards. This involves upgrading construction standards of all dwellings on the interface.

Scenario 5: Increased mechanical treatments in Asset Protection Zones (APZs).

Scenario 6: Do no prescribed burning and allow fuel to accumulate to maximum level.

Figure 2 Map of Hornsby-Berowra (NSW) case study area

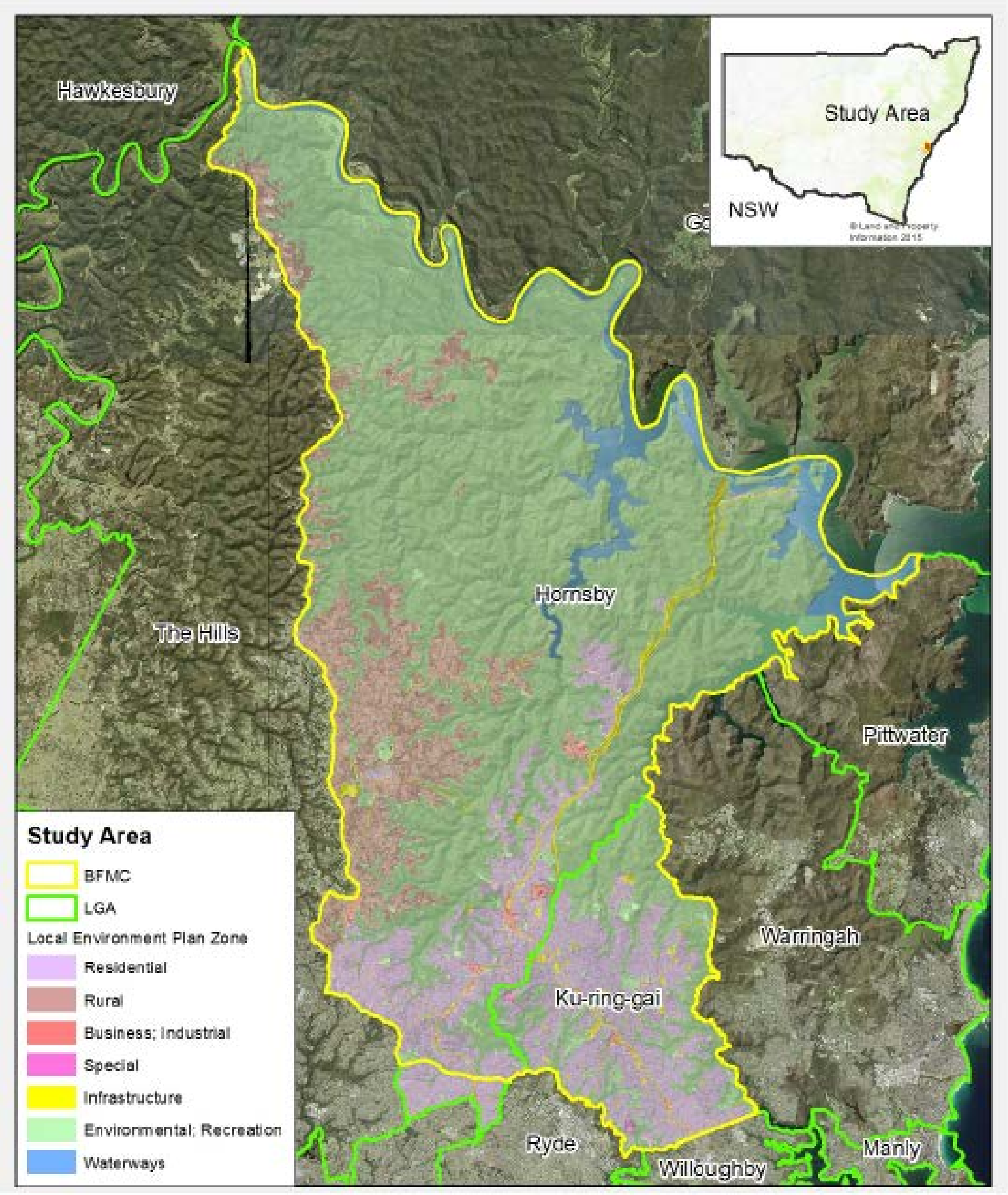

Table 4 Summary of treatments for Hornsby-Berowra case study

Scenario	Area of interface burning (ha/%)	Area of landscape burning (ha/%)	Total area treated (ha/%)
Baseline	256	556	812
1	586	556	1142
2	256	1271	1527
3	586	1271	1857
4	256	556	812
5	256	556	812
6	0	0	0

4.3 Data assembly

The approach is summarised here (see Appendix 4 for more details).

Phoenix RapidFire v.4.0.0.7 was used to simulate potential fire behaviour from multiple ignition locations. Data from the multiple simulations was further analysed in ArcMap GIS to assess potential asset impacts. The output was expressed as expected annual losses under the baseline, and proportional reduction in asset loss under the prescribed burning interventions. Assumptions about asset loss under the mechanical APZ and house retro-fit scenarios can also be made from the baseline loss values.

The results from Phoenix are highly dependent on the scenario input data used. These inputs are summarised below.

Study Area: Property impact was assessed within the BFMC boundary. Fires were modelled from a broader landscape, within a 10 km buffer of the BFMC boundary.

Ignitions: An ignition grid (uniform grid of ignition locations spaced at 1 km intervals) was created within the BFMC and 10 km buffer area. Ignition points in areas with little or no fuel (water or urban areas) were removed from the grid. This provides a total of 1379 ignition points. The concept of the grid is to simulate a random ignition that could occur at any location in to the landscape. It would be preferable to create a weighted ignition grid using a probability model; however, this product was not available for application at the time of modelling. This product is currently under development. Independent fires were simulated from each ignition point, with each fire allowed to run for 12 hours (10:00 to 22:00).

Base Layers: Phoenix requires spatial base layers for fuel type, fire history, topography (DEM), wind modifiers, and linear disruption features. Standard NSW Phoenix input layers (as current at the time of modelling) were used except as described below. Modification to the state fuel type map was required to improve accuracy at the local scale. Some areas of Crown Land (e.g. the south-west interface of Berowra Heights) are mapped as cleared in the Keith vegetation layer, and hence the fuel type map. These were identified by overlaying with the Bushfire Prone Land Map which has accurate interface mapping. The identified areas were reclassified to Sydney Coastal Dry Sclerophyll Forest in the fuel type map. Reclassification of rural-residential properties from fuel type 69 (urban no tree cover) to fuel type 70 (urban low tree cover / rural residential) was required to represent grass fuel more accurately in these areas.

Fire history input was varied to represent the different burning scenarios (see details below).

Fire History: The baseline scenario is the current mix of hazard reduction and wildfire history. This was represented by the standard fire history layer as at 30 June 2016.

Target annual hectares for the intervention scenarios were calculated such that performing the combination of interface and landscape prescribed burning would represent a significant increase to the area of the bushfire prone land (BFPL) treated annually within the BFMC, a total of 1857 ha.

The last five years of the hazard reduction program for the BFMC area was analysed to provide mean values of hectares burnt under the baseline scenario.

Figure 2 in Appendix 4 (AFAC National Burning Project INFFER Berowra Valley V0.5.pdf) displays the classification, location and timing of burns. They were classified as either interface or landscape based on their proximity to urban or rural-residential properties. The current balance between interface and landscape burning was maintained for the interventions.

The spatial arrangement of intervention burns was based on burn block polygons provided by the BFMC. The landscape burns were taken from the potential (draft) program for the next 5 years supplied by NSW National Parks and Wildlife Service (NPWS). The burn blocks for interface burns were selected based on time since last burnt; these represented a mixture of NPWS and other (e.g. Council, Crown land) tenure. The timing of burns was allocated such that the year of the burn exceed the minimum allocated fire interval for the burn block, and the distribution throughout the year was based on the mean number of burns per month from the last five years of the hazard reduction program.

Weather: A combined weather data set representing a 1 in 10-year forest fire danger index (FFDI) was used, which is a peak FFDI of 42 (Very High) within the study area.

Assets: Address Point data was used to represent the location of assets. Address Point data was overlayed with Local Environment Plan (LEP) zone boundaries to classify the points by land use. Filtering of the data was done to remove points from undeveloped land parcels (e.g. environmental management, public recreation zones). Points were then classified in to urban residential, rural residential, business, industrial and special fire protection use (education and health facilities). For the construction standard upgrade scenario (Scenario 4), only urban-residential properties within the mapped bush fire prone land buffer (within 100m of the bushland-urban interface) were considered, a total of 26,338 properties. The location of major infrastructure (Sydney-Newcastle motorway, main Northern rail line, overhead transmission lines) was identified by linear data.

4.3.1 Cost estimates

Prescribed burning

NSW RFS prescribed burning costs are estimated at $912/ha, this figure has been used for increased interface burning.

NSW NPWS prescribed burning costs are estimated at $1016/ha, this figure has been used for increased landscape burning. Further details on the assumptions underpinning these estimates are provided in Appendix 4.

Suppression costs

Baseline costs for suppression were estimated at $5.5 million per year. This is the estimated annual cost to operate the NSW RFS Hornsby-Kuring-Gai District. It does not include the operating costs of other fire agencies within the BFMC, namely National Parks and Fire and Rescue NSW.

The project assumed in the 20-year period there would be 2 large (section 44 fires). This is based on historical analysis compared to Phoenix modelling. These large fires are expected to increase annual cost of suppression to $10 million per year. This would leave 18 regular years at $5.5 million/year. Average cost for baseline suppression assumed as $5.95 million/year.

Intervention costs

In addition to the costs of increased prescribed burning (described above) costs were required for implementation of house retro-fitting (Scenario 4) and required Asset Protection Zone (APZ) mechanical treatment (Scenario 5).

However, it is worth noting that the suppression benefits provided by having maintained asset protection Zones are recognised by fire services; however at this stage there were not suitable data metrics to include the additional benefits (Laurence McCoy, *pers comm*.).

It is also recognised that maintained Asset Protection Zones when combined with good building maintenance and basic ember protection measures greatly increase the benefits of these zones; However, an assessment of uptake up of the ember protection measures was outside the scope of this project (Laurence McCoy, *pers comm.).*

For Scenario 4 cost estimates for building upgrades have been based on consultation with Council building surveyors and anecdotal evidence. This indicated that to bring properties to a BAL29 standard – estimated to be sufficient to remove properties from the 'flame zone' – would cost $20,000 per property. It is estimated that there are 26,338 urban-residential properties within BFPL buffer. Further detail is provided in Appendix 4.

For Scenario 5 costs were determined by assessing each BFRMP Asset ID to determine the APZ distance to meet 19kw benchmark based on supplied slope and separation. It was estimated that the cost of this intervention would be $146,000 per/year.

4.3.2 Estimating asset losses

Individual fires were modelled under the same weather conditions (very high fire danger) from a regular grid of ignition locations. While the total ignition grid (1379 ignitions) included ignition locations outside of the study area (BFMC), not all of these fires entered the study area. Only those fires that burnt within the study area were deemed to cause asset losses

Under the baseline scenario (current fire history) 628 fires affected the study area, with a mean size of 632 ha. Under the prescribed burning interventions the mean fire size, the number of fires that spread beyond 100 ha (considered to represent significant suppression effort), and the number of fires greater than 3,500 ha (considered to represent a bushfire emergency situation) was reduced. Greater reductions in fire size occurred with landscape treatment.

Table 5 below summarises the effect of the different prescribed burning scenarios on the frequency of fires according to three different fire sizes.

Table 5 Effect of prescribed burning interventions on fire frequency

	Baseline	Interface (Scenario 1)	Landscape (Scenario 2)	Combined (Scenario 3)
No. fires	628	627	627	627
No. fires >100 ha	420	407	382	376
No. fires >3,500 ha	3	2	1	1
Mean fire size (ha)	632	606	528	522

Table 6 describes the asset losses across selected categories for the baseline, while Table 7 describes the proportional reduction in asset loss for each scenario compared to baseline.

Table 6 Estimated level of asset losses for baseline

	Urban-residential	Rural-residential	Special fire protection	Business & Industrial	Motorway	Railway	Power line
No./km assets	1.612	0.525	0.002	0.090	0.008	0.010	0.115
% of assets	0.002	0.017	0.001	0.002	0.027	0.03	0.044

Table 7 Predicted asset losses (proportional reduction from baseline) for interventions

Scenario	Urban-residential	Rural-residential	Special fire protection	Business & Industrial	Motorway	Railway	Power line
1. Interface	0.60	0.15	1.00	0.74	0.44	0.35	0.16
2. Landscape	0.50	0.30	0.67	0.59	0.45	0.39	0.36
3. Combined	0.73	0.35	0.92	0.84	0.43	0.34	0.41
4. Retrofitting	0.66	n/a*	n/a	n/a	n/a	n/a	n/a
5. Asset Protection Zones	0.04	0.11	0.00	0.05	n/a*	n/a	n/a

** Mechanical APZ treatment not applicable to infrastructure assets; Retro-fit treatment only applicable to urban-residential properties*

All intervention scenarios gave overall a very large reduction in asset losses compared to the baseline (for example interface burning predicted 60% less urban residential loss than the baseline). For prescribed burning interventions, increased interface burning resulted in a greater reduction of loss of buildings in all categories except rural-residential (Table 7). Reduction of impact on infrastructure was similar for the motorway and railway, while landscape burning had a greater influence on transmission line impact. This reflects the location of these infrastructure assets in the landscape.

The reduction in losses under the mechanical APZ intervention are low as this treatment is assumed only to protect assets from intensity impact, and a greater proportion of property impacts are from embers. Ember impact also penetrates further into urban areas than the 100m buffer of BFPL considered for the retro-fit intervention.

The NSW results are summarised in Table 8. Scenarios 1-3 had impressively high BCR values, particularly for interface burning (BCR 12.19). Retrofitting houses was estimated to be a very poor investment because of the huge costs involved ($105.434 million).

Increasing the APZ width was also a worthwhile enhancement on the baseline prescribed burning, generating a BCR value of 2.40 for only a modest intervention cost increase ($146,000/year).

The maximum fuel scenario generated a BCR value of 0.01, which assuming the assumptions used are reasonable, shows that allowing fuel to accumulate in the absence of a prescribed burning program would result in very large losses (close to 600% increase in lives and houses lost) due to the prediction for increased severity of fire behaviour and a 51% increase in fire incidents.

4.4 Hornsby–Berowra results

Table 8 below provides an overview of the key results for the Hornsby-Berowra case study.

Table 8 NSW results

Intervention	Δ in fire incident % reduction	Δ Lives lost % reduction	Δ Houses lost % reduction	Δ Asset losses (reduction)	Δ Suppression cost (reduction)	Intervention cost/year	BCR
1. Increase Interface burning	3.1%	60%	60%	$997,913	$3,370,406	$299,970	12.77
2. Increase landscape burning	9%	50%	50%	$943,668	$3,187,196	$726,440	4.98
3. Increase interface + landscape burning	10.5%	73%	73%	$1,227,369	$4,145,483	$1,026,410	4.59
4. Retrofitting	0%	66%	66%	$768,265	$2,594,781	$105,434,000	0.08
5. Increase mechanical APZ	0%	4%	4%	$53,649	$181,197	$146,000	2.52
6. Max. Fuel	+51.2%	+595%	+595%	+$15,104,339	+$51,014,205	-$1,026,410	0.02

5 DISCUSSION

There is a famous quote attributed to statistician George Box which is that ‘all models are wrong but some are useful’ (https://en.wikipedia.org/wiki/All_models_are_wrong). This project is as much about developing a model to represent the benefits and costs associated with prescribed burning regimes as it is to report and assess the results themselves.

The results of both case-studies will be as good as the assumptions that underpin them, both in terms of the data and knowledge used to generate them, and also the assumptions that have been made in the BCT. Results should be read with these factors in mind. Key questions to be asked of the reader include:

- Do they make intuitive sense?
- Do they pass the ‘laugh test’ otherwise known as the ‘test of common sense’?
- Are some of the simplifying assumptions made likely to seriously compromise the integrity of the results?

Depending upon the outcome of these questions, the future of this work could range from changing the data input assumptions used in the model, changing the model structure (e.g. reducing simplifying assumptions and making it more complex), increasing awareness and capacity amongst fire agencies to become more familiar with the concepts of benefit: cost analysis or even deciding that benefit: cost analysis has not really been a useful exercise overall.

5.1 Discussion of SA results

The results indicate that as the level of prescribed burning increases by undertaking additional treatment on private land (Interventions 1, 2 and 3) there is a small reduction in the number of fire incidents (1-4% estimated from Table 2) and as a result a reduction in the loss of lives and assets. As the level of asset losses decreases with these interventions the suppression costs have also been estimated to decrease in proportion. Note that this is an important simplifying assumption in the model and AFAC and fire managers need to think about whether it is reasonable. If such a simplifying assumption is not sensible then changes in suppression costs would need to be estimated individually for each scenario.

Clearly there is an additional cost associated with undertaking additional prescribed burning on private land, this increases by $1,316M for Intervention 1, by $2.34M for Intervention 2 and $3.206M for Intervention 3.

Interventions 4, 5 and 6 maintain the current level of prescribed burning at 214 hectares but shift a progressively increasing area from public land to private land. As a result, the proportion of fire incidents decreases as does the estimated proportion of life and asset losses. As explained above, this also results in reduced suppression costs. Interventions 4-6 also incur additional implementation costs ($3.06K, $6.12K and $10.71K respectively), although these are very modest when compared with Interventions 1-3.

The results indicate that undertaking prescribed burning on private land, while maintaining the level of prescribed burning on public land is not cost-effective (BCR in excess of 1). Scenario 1 involves an additional 658 hectares of treatment (2.5% of private land) when compared with the baseline and this results in a BCR of 0.55, indicating that the costs exceed the benefits of treatment almost twofold. Scenario 2 involves an additional 1170 hectares of treatment (5% of private land) and has a BCR of 0.91, while Scenario 3 involves an additional 1603 hectares of treatment (8% of private land) and has the most favourable BCR (0.93) of all the first three options but is still not cost-effective.

Interventions 4, 5 and 6 all maintain the total treatment area at the baseline level, 214 hectares, but shift an increasing proportion of treatment to private land. For Intervention 4, 14% (30 hectares) of the public land treatment is shifted to private land, in Intervention 5, 28% (60 hectares) of the public land treatment is shifted to public land, while in Intervention 6, 49% (105 hectares) of the public land treatment is shifted to public land. The results indicate that shifting prescribed burning from public land to private land is cost-effective in all three cases examined (Interventions 4, 5 and 6) although the relative cost-effectiveness declines as the proportion of private land treatment increases. Not surprisingly the results are sensitive to input values, including intervention costs. Preliminary data for intervention costs in SA were much lower than the final agreed costs (for Interventions 1-3) which led to the favourable BCRs (e.g. greater than 1) in each of these cases, while for Interventions 4-6 the final agreed costs were actually lower than the initial estimates.

Scenario 7 does not appear to be a cost-effective strategy as the very small benefits achieved through weed control on 32 hectares of private land are outweighed significantly by the cost.

5.2 Discussion of NSW results

As shown in Table 8, scenarios 1-3 had impressively high BCR values, particularly for interface burning (BCR 12.19). Results were strongly driven by the very high estimated reduction in houses and lives lost (noting that the BCT assumes a simple direct relationship between house and life loss) resulting from a reduction in the number of bushfire incidents.

Retrofitting houses (Scenario 4) had a very low BCR (0.07). This result is largely driven by the massive costs (over $105 million) associated with reducing the vulnerability of houses in the urban-residential zone (26,338 properties) to a standard (BAL 29) where they will be effectively protected. Scenario 5 involves mechanical treatment to reduce fuel loads within the asset protection zones in addition to the baseline prescribed burning regime. This scenario appears to be cost-effective with a BCR of 2.40 for only a modest intervention cost increase ($146,000/year).

Scenario 6 examined the effect of ceasing prescribed burning across interface and landscape zones, thereby allowing fuels to accumulate to their maximum levels. Assuming the assumptions used are realistic this strategy is predicted to result in extremely high asset losses ($15,104,339/year) and suppression costs (+$48,013,469/year) which would significantly outweigh the cost savings from not undertaking prescribed burning.

This scenario generated a BCR value of 0.01 and illustrates that allowing fuel to accumulate in the absence of a prescribed burning program would result in very large losses (close to 600% increase in lives and houses lost) due to a 51% increase in fire incidents.

5.3 Comparison of SA and NSW results

Clearly there are significant differences in both context (e.g. landscape characteristics, fire behaviour and institutional arrangements) and the interventions that have been assessed, between the two case studies. The following discussion focuses on aspects of the analysis where these differences appear significant enough to warrant more detailed examination and potentially partly corroborate or help question some of the results.

5.3.1 Asset numbers and asset values

While the respective case study areas are similar at around 60,000 hectares there are some significant differences in asset numbers and overall asset values. In terms of case study populations, in NSW there are 266,144 people compared with 29,499 in SA. In terms of residential properties there are 97,320 in NSW (94,315 urban and 3,005 rural) and 11,771 SA. The overall asset value across all categories is $59,037,902,707 in NSW, an eight-fold difference compared to SA ($7,292,122,484). If other factors (burning regimes, climate/topography, costs etc.) were equal then overall higher BCR numbers could be expected in NSW than SA due to the values of assets which might be lost.

5.3.2 Baseline losses

There are significant differences in the average level of losses under existing prescribed burning regimes (the baseline) between the two case studies. For example, in NSW the average annual losses of residential properties is 2.137/year (1.612/year for urban-residential and 0.525/year for rural residential) while in SA this is estimated to be 10/year, almost five times as great. Thinking through whether this seems reasonable might be useful. Likewise, the average annual loss of life in NSW is estimated to be 0.064 lives/year while in SA this is estimated to be 0.2, more than three times greater. When all assets are considered, the average annual asset losses in NSW are estimated to be $1.76 million/year compared with SA at $35.45 million/year which is more than twenty times greater. This is somewhat surprising given that the current level of treatment through prescribed burning is not hugely different in terms of the proportion of native vegetation. In NSW the annual average area of prescribed burning is currently 812 ha which represents approximately 2 % of current native vegetation, while in SA the average annual level of prescribed burning is currently 214 ha which represents approximately 1 % of current native vegetation. From our discussions in each region it is apparent that SA has a long history of major fires that have caused very significant loss of life and other assets, while this has not been the case in NSW, where major fires have been successfully controlled and the overall loss of assets has been relatively low, especially when compared with SA.

5.3.3 Effect of interventions

Table 9 compares the effect of the different strategies in both SA and NSW in terms of the number of fire incidents and asset losses.

The results indicate that in both SA and NSW increasing the extent of prescribed burning leads to a decrease in the number of fire incidents and the proportional reductions are of similar magnitude. For example in SA undertaking prescribed burning on 2.5% of private land, increases the extent of prescribed burning from 214 to 872 hectares (Intervention 1) and is estimated to generate a 1.03% reduction in the number of fire incidents, while in NSW increasing the extent of prescribed burning from 812 to 1142 hectares (Intervention 1 – an increase of 330 hectares of interface burning) is estimated to generate a 3.1% reduction in the number of fire incidents.

In contrast, the proportional reductions in terms loss of lives and built assets is very different. For example, Intervention 1 in SA is estimated to generate a 0.67% reduction in loss of life and 0.69% reduction in loss of houses, while Intervention 1 in NSW is estimated to generate a 60% reduction in loss of life and loss of houses. A similar pattern of difference exists across all prescribed burning scenarios in both case studies, where the effect of prescribed burning treatment is estimated to be much greater in NSW compared with SA. This difference is so large that it warrants some further scrutiny, for example are the reductions in lives lost in NSW too large, or conversely are the SA results too conservative, or do inherent fire behaviour and weather differences play a part?

Table 9 Comparison of SA and NSW interventions

Scenario	Total area treated (ha)	% reduction in fire incidents	% reduction in lives lost	% reduction in houses lost	Reduction in total asset losses
SA Case Study					
1. prescribed burning on 2.5% of Private land	872	1.03%	0.67%	0.69%	$851,108
2. prescribed burning on 5% of Private land	1384	3%	2%	2%	$2,508,200
3. prescribed burning on 8% of Private land	1817	4%	3%	3%	$3,531,932
4. 14% of prescribed burning shifted to private land	214	0.07%	0.02%	0.02%	$33,706
5. 28% of shifted to private land	214	0.07%	0.02%	0.02%	$40,316
6. 49% of shifted to private land	214	0.08%	0.02%	0.03%	$43,401
7. Weed control	246	0.0072%	0.003%	0.0034%	$4,390
NSW Case study					
1. Increase Interface burning	1142	3.1%	60%	60%	$997,913
2. Increase landscape burning	1527	9%	50%	50%	$943,668
3. Increase interface + landscape burning	1857	10.5%	73%	73%	$1,227,369
4. Retrofitting	812	0%	66%	66%	$768,265
5. Increase mechanical APZ	812	0%	4%	4%	$53,649
6. Max. Fuel	Nil	+51.2%	+595%	+595%	+$15,104,339

5.3.4 Suppression costs

A simplifying assumption in the current model is that the suppression costs are a constant proportion of the asset losses. In NSW the average annual suppression costs were estimated to be $5.95 million/year (approximately 340% of the average annual asset losses), compared with 2.4 million/year in SA (approximately 15% of the average annual asset losses). This is a very significant difference and appears difficult to explain on face-value.

As a result of this assumption, where various interventions are predicted to reduce the level of asset losses the suppression costs are estimated to decrease in constant proportion. Clearly this relationship is unlikely to be linear in 'real life'; The literature says suppression costs tend to be well correlated with fire size (e.g., Calkin *et al.*, 2005; Gebert *et al.*, 2007; Liang *et al.*, 2008) rather than asset loss and is an ongoing topic of current investigation by bushfire researchers at the University of Western Australia. Input from AFAC and the Project Steering Group is important if potential future development in the BCT is decided upon.

5.3.5 Intervention costs

As has been the case with suppression costs, the study has revealed some major challenges in determining the costs and expenditure associated with different prescribed burning and other bushfire management interventions.

The model has been developed to incorporate a number of different types of costs associated with prescribed burning, including direct costs (e.g. aircraft, machinery, personnel, meals and accommodation) and indirect costs (e.g. administration, management, planning and if relevant the public and private costs of additional regulation).

Table 10 shows the estimated costs of prescribed burning in SA and NSW. Overall costs in SA were estimated as higher in SA than NSW, the reasons for which might be worth thinking through. In SA prescribed burning is undertaken by DEWNR on both public land and private land and thus the hourly labour rate would be expected to be similar. We were somewhat surprised that in SA the costs were assumed as quite similar on both private and public land, having assumed that costs of burning on private land would be significantly higher (smaller burn areas, more community education and resources being needed to protect built assets than on public land). Additional work by DEWNR staff provided detailed justification for these costs.

In NSW prescribed burning is undertaken by NSW RFS on private land and NSW NPWS on public land, while RFS also assists land managers with prescribed burning across all tenures within a Rural Fire District. While the actual methods of accounting for these costs proved complex and challenging the ultimate cost/ha was also fairly similar ($909/ha for private land and $1016/ha for public land) (Table 10). One issue that arose was how NSW RFS values volunteer labour, which ideally should be valued according to the number of volunteer hours multiplied by an agreed $ value per hour.

Table 10 Comparison of costs associated with prescribed burning on private land and public land in NSW and SA case studies

Case study	Cost of private land burning ($/ha)	Cost of public land burning ($/ha)
SA	$2000	$1898
NSW	$ 909	$1016

5.4 Key learnings from the project

While very different approaches were taken in gathering and assembling the data for the two case studies the BCT proved effective in providing a structured and guided approach to the analysis. The use of Phoenix resulted in a high level of effort expenditure in NSW to gather and organise data, while in SA a more expert-opinion based approach was used.

Key learnings that emerged are summarised below.

5.4.1 Different mind sets associated with the disciplinary expertise of project participants

The BCT provides an integrated economic analysis tool for evaluating the costs and benefits associated with different bushfire management interventions. While the tool developers had extensive experience in applying economic approaches to structured decision making, the project participants had little or no expertise in economics. This meant that a number of the concepts associated with the tool were at first mystifying to the participants. The expertise of participants included high level understanding of fire planning, ecology, risk assessment and fire behaviour modelling but limited familiarity with the principles of benefit: cost assessment. Furthermore, two of the Natural Decisions team are relatively new to the realm of bushfire management planning and faced a steep learning curve to understand the planning and decision making context, together with the application of complex bushfire modelling tools, such as Phoenix.

Different disciplines think very differently. Economists think about benefits in a particular way that might not be intuitive to another discipline. Benefit conceptualisation can include changing the value of assets as a result of an intervention, reduced or delayed investment in costs (such as suppression costs) and potentially other benefits (such as indirect benefits). Thinking about benefits also includes concepts such as time at which the benefits start, time when benefits reach their maximum, overall time-frame for the analysis and the appropriate discount rate to be used. Some of these concepts can take time to understand by non-economists.

5.4.2 Time and effort required to develop a shared understanding

For multi-disciplinary projects to work time and effort is required to develop a shared understanding of the problem being faced, to develop a sensible conceptual framework and to assess how specific components of the model can be populated using available information.

Using and populating the BCT proved challenging, both in terms of the conceptual framework and also some of the specific data requirements. The most challenging aspects were:

- Developing a shared understanding of the baseline concept. This proved difficult and time consuming to reach a joint understanding particularly in NSW but also to some extent in SA. In

NSW it took some time to gain clarity about specifying the baseline in a way that makes sense from the perspective of reality and within the constraints of what Phoenix can do;
- Development of relevant interventions proved challenging in both case studies; and
- The apparent complexity of the spreadsheet model led the project team to develop detailed guidance and instructional information; however, it is unclear how useful this has proved to be.

5.4.3 Information limitations, data gaps and integration with fire modelling

While the conceptual framework and information requirements of the BCT were outlined at the outset of the project a number of key data items proved difficult to gather. This included:

- Average annual suppression costs;
- The number and values of current assets – this was relatively straightforward for items including human population and residential/business/industrial properties but more difficult for others including infrastructure (freeway, utilities etc.);
- Estimating benefits of the interventions – the spreadsheet tool has three different types of benefits[3]. Thinking about these benefit types was new for both the project team and participants and took considerable time to work out how to assess. This is discussed further below in relation to integration of Phoenix modelling;
- Intervention costs – these proved difficult to estimate due to a lack of recorded information within agencies, along with challenges such as accounting for how labour and machinery costs were calculated;
- While the BCT allows for the estimation of additional losses associated with a) direct loss of profits or utility associated with actual asset loss and b) consequent (flow-on) losses, these proved difficult to estimate in practice;
- The use of a standard ignition grid in the accepted methodology of Phoenix modelling developed by Kevin Tolhurst and used by multiple agencies for similar analysis. This has some limitations when using for economic analysis, for example in helping assess asset losses. A realistic ignition pattern (fires being lit closer to roads etc.) could produce very different results. A more realistic assessment of benefits would be gained by weighting ignition cells with differing probabilities but was not possible to do in the timeframe. Results from this project (uniform ignition grid) could under-estimate benefits;
- Using a single weather scenario (FFDI 42, as has been done in this study) was an expedient approach given the resources available for this study, but this has some limitations as it doesn't cover the full dynamic range of fire conditions that occur in practice. It is important to understand that the benefits and costs may be different under more dynamic weather; conditions, for example prescribed burning is likely to have little or no benefit under catastrophic conditions;

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[3] 1) Proportional reduction in number of fire incidents once the intervention has fully kicked in (relative to baseline), allowing for the estimated number of extra fires that are generated by the new intervention (e.g. escapes from prescribed burning); 2) Proportional reduction in consequences (losses) per fire once the intervention has fully kicked in, due to reduced spread and reduced intensity; 3) Proportional reduction in numbers of assets expected to be in fire-prone areas due to the intervention, or reduced vulnerability of the assets

- In the NSW case study Understanding the extent to which Phoenix is useful to populate the model. Neither the project team nor NSW RFS had a sufficiently good grasp on how Phoenix results could be translated into the benefits parameters that the BCT needs which are:
  - Proportional reduction in number of fire incidents once the intervention has fully matured (relative to baseline), allowing for the estimated number of extra fires that are generated by the new intervention (e.g. escapes from prescribed burning). After discussion we decided that the proportional reduction in number of fires exceeding 100 ha compared to baseline would be used from Phoenix;
  - Proportional reduction in consequences (losses) per fire once the intervention has fully kicked in, due to reduced spread and reduced intensity. Phoenix produces asset losses which can easily be calculated as proportional losses; and
  - Proportional reduction in numbers of assets expected to be in fire-prone areas due to the intervention, or reduced vulnerability of the assets. For the scenarios Phoenix can model there will be no change in vulnerability as this is only relevant to planning scenarios which were not being tested in this case-study.

The exercise itself however proved a valuable exercise in co-learning and participation – it helped tool developers understand more about Phoenix and helped both groups start to see the links between Phoenix and the BCT.

5.4.4 Flexibility of the BCT to receive data inputs

Despite the different approaches taken to gathering input data in the two case studies the BCT proved particularly robust and effective in handling the received data, although it is important to acknowledge that considerable effort has gone into assembling and manipulating the data, especially in the NSW case study.

5.4.5 Believability of the results

The general pattern of BCR results was seen to be intuitively correct by project participants and aligned with their expectations. In NSW the effect of concentrating prescribed burning close to high value assets in the interface zone was predicted to be the most cost effective strategy and this was borne out by the high BCR of 12.19, while in SA increasing the overall extent of prescribed burning by undertaking additional treatment on private land was shown to be cost-effective with the BCR increasing as the extent of prescribed burning increased from 2.5% to 8% of private land.

The results are, of course, highly sensitive to the input data and in the case of strategies that involve prescribed burning on either public land close to urban areas, or on private land it is possible that the intervention costs have been under-estimated. For instance, in NSW the cost of additional interface burning was deemed to be very similar to that incurred for landscape burning whereas evidence from other jurisdictions (e.g. Victoria) suggest that the risks (real or perceived) associated with this strategy require a higher than usual level of effort and investment than landscape burns.

Overall the project team feels that the BCRs are higher than expected due to both an overestimation of the benefits (e.g. the proportional reduction in asset losses is very high in NSW) and/or an underestimation of the intervention costs (e.g. the additional costs associated with increased levels of prescribed burning in both NSW and SA).

Given that there are lots of uncertainties with different data inputs; sensitivity analysis is a useful way to test the robustness of the results. A common approach is to rerun the model with a 25% increase and 25% decrease in selected parameter values. If this results in significant changes to the

BCR results, for example if the BCR changes from greater than 1 to less than 1 (meaning that an intervention now appears to not be cost effective), greater scrutiny and effort should be made to ensure the parameter values are as accurate as possible.

5.4.6 Incomplete use of the BCT

A number of the BCT elements were not utilised or underutilised during the case studies. This included:

- Non-monetary indicators – the BCT has capacity to explore the impact of different interventions on assets where market values are either not available (e.g. biodiversity assets) or inappropriate (e.g. cultural assets). This is discussed further in the section 5.5;
- Dynamic factors – the BCT has the ability to explore temporal change in a series of factors including:
  - Annual proportional change in number of fires, for example, due to climate change or population growth);
  - Annual proportional change in losses per asset hit by fire, for example, due to climate change (affecting fire intensity) or increasing real values of assets (factoring out inflation);
  - Annual proportional change in population (used to adjust numbers of injuries and lives lost); and
  - Annual proportional change in assets present in region.

Apart from the inclusion of some simple projected demographic changes (e.g. population growth) these elements of the BCT were not explored because there was sufficient difficulty with estimating some of the other parameters and coming to grips with some of the concepts.

5.4.7 Appropriate scale for BCT application

The BCT has been designed to evaluate alternative options to inform policy development, as opposed to exploring the benefits and costs of specific prescribed burns. This distinction is important to appreciate as there has been a keen interest from some agencies during the project to apply the BCT at a finer scale than what it has been currently developed for. In its current form it is highly context specific, requiring clear specification of input parameters, but it is important to understand that it is not spatially configured. That said it can be used in tandem with spatial techniques (e.g. GIS) and spatially configured fire simulation tools (e.g. Phoenix) to gain insights into the benefits and costs of alternative bushfire management options, especially prescribed burning.

It may be possible to further develop and refine the BCT for use at a finer scale, for example at the individual burn level. This would require the tool developers and fire managers to develop a shared understanding of the decision-making problem and the important contextual factors. As has been evident in this study, the estimates of benefits, through either expert judgment or fire simulation modelling, is an inexact science and results need to be interpreted with caution.

5.4.8 Annual time step

The BCT operates on an annual time step whereas fires operate on much shorter durations. Fire managers are comfortable dealing with individual fire incidents and the extent to which users felt that a tool operating on an annual time step was useful was not well discussed. From the perspective of developing the tool itself we noted that it was very difficult getting information overall and on this basis it seems unrealistic to reduce the time-step from annual. The extent to which fire managers think the annual time-step is suitable for analysis is worth considering.

5.4.9 Strategic and long-term decision making

Participants found the concept of using the tool as an aid to evaluate policy options over a long time period (such as 20 years) challenging. Usually planning is undertaken over shorter time-frames. For example, in NSW Bushfire Risk Management Plans are 5 yearly with targets reviewed annually. In addition, some participants commented that it may be more useful to looking backwards to demonstrate program effectiveness. It is very important that the BCT is not used for short-term (several years) or tactical responses such as planning a burn or assessing actual burn plans, as the model is configured to accept input data based on probabilities over time (e.g. average annual reduction in the frequency of fires associated with an intervention) and space (e.g. average annual losses of assets distributed across a landscape area to which an intervention is applied).

5.5 Responding to key recommendations from previous work

Previous work by Clayton *et al.* (2014) made three recommendations, each of which are discussed briefly below.

5.5.1 Building the capacity of managers to commission and use economic information

Fire agencies recognise that there will be increasing pressure to justify prescribed burning program expenditure and as a result there is a need for increased understanding about the principles of economics, benefit: cost approaches in particular. Our experience in this study has been that while the bushfire managers with whom we worked had little exposure to economics-based decision frameworks they were enthusiastic about their potential development and application to bushfire decision making problems. There was interest, especially evidenced in the NSW case study, to integrate existing risk assessment and fire simulation tools (e.g. Phoenix), with economic information and approaches to evaluate the benefits and costs of fire management strategies.

This project could be considered as a first step in building the capacity of fire managers to commission and use economic information. Given the lack of familiarity with economics, it is likely that training and hands-on guidance will be needed for the BCT or other economic approaches to be used. This has been the case in many other natural resource management projects we have been involved in.

5.5.2 Integrating analysis of both market and non-market benefits and costs as part of economic evaluation

The BCT has been configured to handle input data that includes market values (e.g. $ values of residential buildings) and non-market values for intangible assets such as native vegetation and threatened species. In both the SA and NSW case studies there was not a high level of interest in the latter feature overall. This is likely to be partly because of the lack of available metrics to define their values and partly because agencies are understandably driven by the need to protect life and built assets. Our view is that it is very important for the BCT to retain the feature of being able to incorporate both market and non-market benefits within it. As confidence amongst fire managers grows in understanding the concepts of economics and in other study areas where there are particularly iconic and valued species and ecosystems, this feature may become better utilised.

5.5.3 Better integrating economic evaluation within the broader context of integrated decision-making processes

As highlighted by a number of recent studies (Clayton *et al.*, 2014; Milne *et al.*, 2014) there has been a lack of application of economic approaches to bushfire management decision making and the need for readily available and practical tools to assess the benefits and costs of different policy options. Bushfire managers work in a complex and challenging environment and routinely deal with difficult decision problems. These problems typically involve integration of information on bushfire risk, fire-behaviour simulation, asset values and resource allocation for fire control and suppression. The decision-making environment often requires consideration of trade-offs within the context of different stakeholder views and strongly held views about the benefits of various bushfire management strategies.

We have found, as evidenced by the NSW case study, and also through other work in Victoria, that tools such as Phoenix are widely used and have strong institutional ownership. It was important to develop the BCT as a complementary tool which could use inputs from other tools. As outlined earlier, for multi-disciplinary projects to work effectively, time and effort is required to develop a shared understanding of the problem being faced and develop a sensible conceptual framework within a broader decision-making process. It took both Natural Decisions and project participants a considerable amount of time to figure out where Phoenix inputs were able to be used.

Phoenix outputs provided valuable estimates of assets in the landscape and asset losses in response to burning regimes (due to changes in numbers of fire incidents and reductions in consequences as a result of a changed management regime). That said, it took some time to work out which of the model outputs produced by Phoenix were useful for the BCT. Discussion and judgement were required to decide how to use outputs. For example, a decision was needed regarding the threshold fire size to use to represent the reduction in fire incidents. 100 ha was used in the NSW case-study. As has been our experience in other natural resource management projects the outputs of a particular model often do not fit neatly into an economic analysis (uniform fire grids which are used routinely by fire analysts are not very sensible to use in economic analysis). Dialogue between economists and fire behaviour modellers is critical to make the best use of existing modelling to make sure it is suitable for the decision problem.

5.6 Participant reflections

An important part of developing such a tool as the BCT is to evaluate how useful and useable the tool is. The tool has not had sufficient testing beyond initial development in the two case studies for this to be comprehensively performed. In order to gain some evaluative early insights into the utility and useability of the BCT, participants were invited to respond to a series of structured questions. Their responses are summarised below in Table 11. If AFAC decides to develop the tool further, then along with making modifications to make the tool look more user-friendly, evaluating its usefulness and useability will be an important thing to do.

Table 11 Summary of feedback from project participants to evaluation questions

Question	NSW case study responses	SA case study responses
What have been the most valuable aspects of your involvement in this project?	Examining fire mitigation concepts that are often discussed, but rarely quantified.	Attempt to quantify costs Consider what we are mitigating & how Understand what benefits/costs we are 'generating'
What have been the most frustrating/difficult aspects?	Trying to unpack data. It often existed, but in a form that needed analysis and processing.	Costing what we do (in sufficient detail) - What is in & out Developing the baseline case
In hindsight what might have been done differently?	Greater guidance and clarity up front about how to describe and set up the baseline and treatment scenarios. Spent more time to dig deeper into the real costs associated with prescribed burning, There are many costs that take time to unpack and were not able to be considered in this version of the study.	Better define baseline, current & future objectives Improve costing models
What is your reaction to the case study results? Do they look sensible?	I think the case study results make sense, although I'm not confident the magnitude of the cost-benefit is realistic.	Subject to clarifying the PB cost model, yes. I'm surprised that the benefit is so high for most scenarios
Can you see the spreadsheet tool being used in the future? • **For what decision problems?** • **What could be done to make the tool usable? Who would use it?** • **Would you be brave enough to use it by yourself (assuming some training/guidance material)?**	Yes I would use the tool for analysis of cost/benefit analysis in conjunction with fire behaviour modelling. I think the tool may have application at some point in the future for evaluating mitigation strategies. It could be used by state or regional fire behaviour analysts to help under pin decisions that state coordinating or District Bush Fire Management Committees may have regarding their strategies.	Yes, the tool can be used in conjunction with other risk analysis (e.g. modelling, community engagement) to evaluate proposed changes to burning (or other mitigation) programs. Results can be used in Bushfire Risk Planning to better understand what risk reduction can be achieved with existing/proposed budgets. Can also use to add cost/benefit information to policy development (changes to policy or shifts in policy direction). Cost/benefit information is now required for all Cabinet Submissions (e.g requests for increased funding)

6 CONCLUSIONS

A BCT was successfully developed and trialled in case-study regions in SA and NSW. The BCT was able to assess benefits and costs of different prescribed burning strategies. Some of the prescribed burning strategies had greater benefits than costs (more cost-effective) compared with the current (baseline) strategy and others were less cost-effective. As such the BCT provides a new approach for fire agencies to strategically evaluate different burning strategies.

Many of the concepts involved were new to project participants. Existing fire behaviour modelling proved complementary and the BCT was able to utilise the outputs of fire behaviour modelling although it took some time to determine which parts were useful and how they could be used.

There were a number of key learnings and the project responded to three previously identified recommendations, namely: building the capacity of managers to commission and use economic information, integrating analysis of both market and non-market benefits and costs as part of economic evaluation and better integrating economic evaluation within the broader context of integrated decision-making processes.

The BCT could be made simpler and more attractive to use if fire managers determine it sufficiently useful for application beyond this prototype stage.

Source: Department of Environment, Water and Natural Resources, South Australia

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Source: Department of Environment, Water and Natural Resources, South Australia

APPENDIX 1: OVERVIEW OF THE BCR CALCULATOR

Parameters					
		1			
Define region:	Text description and map				2
Baseline fire management/policy:	Define the existing fire management and policy regime to serve as the baseline in the analysis.				
Interface + Landscape burning					
	Units				
Current population	People	0			
Value of a statistical life	$	$4,200,000	3		
Value of injury and mental health losses (per statistical life lost)	$	$2,100,000			
Total per statistical life lost		$6,300,000			
4					
Assets (current)	**Units**	**No of units**	**Replacement cost**	**Direct loss of profits or utility as a result of losing the asset**	**Consequent indirect losses per asset unit lost (e.g. loss of profits to other businesses)**
Residential properties	Number	0	$450,000	$22,500	$0
Industrial and business	Number	0	$1,500,000	$75,000	$0
Infrastructure	Number	0	$1,100,000,000	$55,000,000	$0
Water resources	Number	0	$0	$0	$0
Harvestable forest	ha	0	$0	$0	$0
Habitat/biodiversity/native veg	ha	0	$0	$0	$0
Agric: horticulture	ha	0	$45,000	$10,000	$0
Agric: vineyards	ha	0	$0	$0	$0
Agric: grazing	ha	0	$1,000	$50	$0
Agric: vegetable growing	ha	0	$5,000	$10,000	$0
Infrastructure: Freeway	km	0	$42,500,000	$0	$0
Infrastructure: Rail corridor	km	0	$573,221	$0	$0
Infrastructure: Gas Pipeline	km	0	$464,400	$0	$0
Infrastructure: Tranmission Lines OH	km	0	$1,000,000	$0	$0
Infrastructure: Tranmission Lines UG	km	0	$0	$0	$0
Special purpose protection zones; Schools etc	Number	0	$0	$0	$0
Agric: Horse studs	Number	0	$20,000,000	$2,000,000	$0
Residential - urban	Number	0	$450,000	$0	$0
Residential - rural	Number	0	$500,000	$0	$0
Asset type 20		0	$0	$0	$0
Total					
Non-monetary indicators (baseline)	**Units**				
Cultural values: scar trees etc 6	Number	0			
Endangered ecological communities	ha	0			
Water catchments	ha				
		7			
Average annual losses for each asset type (baseline - mean of distribution)			**Total value at risk per unit**	**Value of losses**	
Average losses of lives per year	People	0.05		$210,000	
Injury and mental health multiplier	Proportion	0.5		$105,000	Based on values spec
Total				$315,000	
Residential properties	Number	1	$472,500	$472,500	
Industrial and business	Number	1	$1,575,000	$1,575,000	
Infrastructure	Number	0.001	$1,155,000,000	$1,155,000	
Water resources	Number	0	$0	$0	
Harvestable forest	ha	0	$0	$0	
Habitat/biodiversity/native veg	ha	0	$0	$0	
Agric: horticulture	ha	0	$55,000	$0	
Agric: vineyards	ha	0	$0	$0	
Agric: grazing	ha	0	$1,050	$0	
Agric: vegetable growing	ha	2	$15,000	$30,000	
Infrastructure: Freeway	km	0	$42,500,000	$0	
Infrastructure: Rail corridor	km	0	$573,221	$0	
Infrastructure: Gas Pipeline	km	0	$464,400	$0	
Infrastructure: Tranmission Lines OH	km	0	$1,000,000	$0	
Infrastructure: Tranmission Lines UG	km	0	$0	$0	
Special purpose protection zones; Schools etc	Number	0	$0	$0	
Agric: Horse studs	Number	0	$22,000,000	$0	
Residential - urban	Number	0	$450,000	$0	
Residential - rural	Number	0	$500,000	$0	
Asset type 20		0	$0	$0	
Total				$3,232,500	8
Baseline total including life and injury				$3,547,500	

			Data source A or assumption
			Latest census data
			Anon., 2014. Best Practice Regulation Guic
			Rough estimate at this stage
Total value at risk per unit	5 ue		
$472,500		$0	
$1,575,000		$0	
$1,155,000,000		$0	
$0		$0	
$0		$0	
$0		$0	
$55,000		$0	
$0		$0	
$1,050		$0	
$15,000		$0	
$42,500,000		$0	
$573,221		$0	
$464,400		$0	
$1,000,000		$0	
$0		$0	
$0		$0	
$22,000,000		$0	
$450,000		$0	
$500,000		$0	
$0		$0	
		$0	

cified above.

This is the first part of the worksheet 'parameters'

Key elements

A. Data sources, assumptions and explanatory notes should be added here

1. A clear description and map of the region
2. A description of the baseline fire management/policy
3. Population estimate and value of a statistical life/injury health multiplier
4. Inventory of current assets – this is where the number of each asset, its replacement cost, direct and indirect profit loss can be entered. The names of specific categories (e.g. water resources) can be altered and/or additional asset categories can be entered
5. The total value at risk is automatically calculated
6. The current number of non-monetary indicators can be entered here
7. Average annual losses – the expected average annual losses of lives and assets are entered into the blue cells
8. The total value of losses under the baseline are automatically calculated

Worksheet – Parameters (2)

Suppression costs				
Baseline (current) suppression costs	9	$	$5,000,000	
Baseline (current) suppression costs		Proportion of asset losses	1.40944327	Simplifying assumption: suppression costs are a constant prop
Dynamics				
Annual proportional change in number of fires (e.g. due to climate change or population growth)	10	Proportion	0	Assumption is that losses increase in proportion
Annual proportional change in losses per asset hit by fire (e.g. due to climate change (affecting fire intensity) or increasing real values of assets (factoring out inflation))	11	Proportion	0	
Annual proportional change in population (used to adjust numbers of injuries and lives lost)	12	Proportion	0	
Annual proportional change in assets present in region			Assets are assumed to grow at this rate throughout the time period for the analysis.	
Residential properties		Number	0	
Industrial and business	13	Number	0	
Infrastructure		Number	0	
Water resources		Number	0	
Harvestable forest		ha	0	
Habitat/biodiversity/native veg		ha	0	
Agric: horticulture		ha	0	
Agric: vineyards		ha	0	
Agric: grazing		ha	0	
Agric: vegetable growing		ha	0	
Infrastructure: Freeway		km	0	
Infrastructure: Rail corridor		km	0	
Infrastructure: Gas Pipeline		km	0	
Infrastructure: Tranmission Lines OH		km	0	
Infrastructure: Tranmission Lines UG		km	0	
Special purpose protection zones; Schools etc		Number	0	
Agric: Horse studs		Number	0	
Residential - urban		Number	0	
Residential - rural		Number	0	
Asset type 20			0	
Asset type 21			0	
Asset type 22			0	
Asset type 23			0	
Asset type 24			0	
Asset type 25			0	
Discount rate (real)			0.05	14

ortion of the value of asset losses.

. Could be positive or negative.

This is the second part of the worksheet 'parameters'

Key elements

9. Suppression costs – this is an estimate of the annual costs of suppression under the baseline regime
10. The number of expected fires may change over time due to factors such as climate change or population growth – enter the annual % increase from the baseline
11. The % of asset losses may be affected by factors such as increased fire intensity (eg due to climate change) or an increase above baseline inflation in asset values.
12. You can account for population growth (or decline) by entering a % annual change here.
13. The number of assets (e.g. residential properties) may increase (or decrease over time) – enter the % annual change here.
14. Discount rate – this can be varied according to preference – it is set by default at 5%

Worksheet – benefits and costs assumption (1)

Benefits of interventions		15	**Intervention 1**	**Intervention 2**	**Intervention 3**
			Interface burning only	Landscape burning only	Do nothing
Proportional reduction in number of fire incidents once the intervention has fully kicked in (relative to baseline), allowing for the estimated number of extra fires that are generated by the new intervention (e.g. escapes from prescribed burning)	Proportion	16	0.00	0.02	0.05
Proportional reduction in consequences (losses) per fire once the intervention has fully kicked in, due to reduced spread and reduced intensity.	Proportion	17			
Life/injury			0.0100	0.0191	0.0240
Residential properties			0.0300	0.0308	0.0415
Industrial and business			0	0.46	0.002
Infrastructure			0.001	0.0100	0.0300
Water resources			0	0	0
Harvestable forest			0	0.0003	0.0040
Habitat/biodiversity/native veg			0	0.0076	0.0062
Agric: horticulture			0	0.0397	0.0550
Agric: vineyards			0	0.0397	0.0550
Agric: grazing			0	0.0397	0.0550
Agric: vegetable growing			0	0.0397	0.0550
Infrastructure: Freeway			0	0	0
Infrastructure: Rail corridor			0	0	0
Infrastructure: Gas Pipeline			0	0	0
Infrastructure: Tranmission Lines OH			0	0	0
Infrastructure: Tranmission Lines UG			0	0	0
Special purpose protection zones; Schools etc			0	0	0
Agric: Horse studs			0	0	0
Residential - urban			0	0.6	0.09
Residential - rural			0	0.15	0.06
Asset type 20			0	0	0
Asset type 21			0	0	0
Asset type 22			0	0	0
Asset type 23			0	0	0
Asset type 24			0	0	0
Asset type 25			0	0	0
Proportional reduction in numbers of assets expected to be in fire-prone areas due to the intervention, or reduced vulnerability of the assets	Proportion	18			
Life/injury			0	0	0
Residential properties			0	0	0
Industrial and business			0	0	0
Infrastructure			0	0	0
Water resources			0	0	0
Harvestable forest			0	0	0
Habitat/biodiversity/native veg			0	0	0
Agric: horticulture			0	0	0
Agric: vineyards			0	0	0
Agric: grazing			0	0	0
Agric: vegetable growing			0	0	0
Infrastructure: Freeway			0	0	0
Infrastructure: Rail corridor			0	0	0
Infrastructure: Gas Pipeline			0	0	0
Infrastructure: Tranmission Lines OH			0	0	0
Infrastructure: Tranmission Lines UG			0	0	0
Special purpose protection zones; Schools etc			0	0	0
Agric: Horse studs			0	0	0
Residential - urban			0	0	0
Residential - rural			0	0	0
Asset type 20			0	0	0
Asset type 21			0	0	0
Asset type 22			0	0	0
Asset type 23			0	0	0
Asset type 24			0	0	0
Asset type 25			0	0	0
19					
Time at which benefits start to emerge	years	This may be at the er	2	5	5
Time at which benefits reach their maximum	years	Benefits reach maxir	5	1	1
Time frame for the analysis	years	Up to 20 is allowed.	20	20	20

Intervention 4	Intervention 5		Data source or basis for assumption
Retrofitting houses to meet new standards	Increased mechanical treatments in APZs		
0.06	0.00		
0.0007	0.0007		
0.0008	0.0008		
0.34	0.0010		
0.0008	0.0008		
0	0		
0.0004	0.0004		
0.0007	0.0007		
0.0008	0.0008		
0.0008	0.0008		
0.0008	0.0008		
0.0008	0.0008		
0	0		
0	0		
0	0		
0	0		
0	0		
0	0		
0	0		
0.52	0		
0.08	0		
0	0		
0	0		
0	0		
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0	0		
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0	0		
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0	0		
0	0		
0	0		
0	0		
5	2		
1	5		
20	20		

This is the first part of the worksheet 'benefits and costs assumptions' – this part relates to the benefits associated with the selected scenarios.

Key elements

15. Describe the different intervention scenarios – these should be documented as precisely as possible here or elsewhere
16. For each intervention you need to estimate the % reduction in number of fire incidents
17. For each intervention estimate the proportional reduction in consequences (losses)
18. The number of assets expected to be in fire prone areas may change as a result of the intervention or due to reduced vulnerability (e.g. retrofitting)
19. There are three time factors to consider:
    - The time in years when the benefits start to emerge
    - The time when they reach a maximum
    - The overall time frame for the analysis – a max. of 20 years is allowed

Worksheet – benefits and costs assumption (2)

Costs of interventions					
Time frame for initial phase of intervention costs	years 20	Up to 20 is allowed.	2	3	20
Direct costs of intervention, initial phase					
Aircraft	$/year		1000000	0	0
Machinery	$/year		100000	100000	0
Personnel 21	$/year		200000	250000	100000
Meals/accommodation	$/year		25000	25000	50000
Other	$/year		0	0	0
Total	$/year		1325000	375000	150000
Direct costs of intervention, maintenance phase					
Aircraft	$/year		50000	0	0
Machinery	$/year		10000	10000	0
Personnel 22	$/year		150000	187500	75000
Meals/accommodation	$/year		18750	18750	37500
Other	$/year		0	0	0
Total	$/year		228750	216250	112500
Indirect costs of intervention, initial phase					
Administration/management	$/year		50000	60000	30000
Public and private costs of additional regulation	$/year 23		0	0	0
Other	$/year		0	0	0
Total	$/year		50000	60000	30000
Indirect costs of intervention, maintenance phase					
Administration/management	$/year		25000	30000	15000
Public and private costs of additional regulation	$/year 24		0	0	0
Other	$/year		0	0	0
Total	$/year		25000	30000	15000
Non-monetary indicator 1	Number 25		0	0	0
Non-monetary indicator 2	ha		0	0	0
		Baseline	**Intervention 1**	**Intervention 2**	**Intervention 3**
BCR (calculated on the next sheets)	26		**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Non-monetary indicator 1	Number	0	0	0	0
Non-monetary indicator 2	ha	0	0	0	0

5	5
0	0
50000	0
50000	50000
0	10000
0	0
100000	60000
0	0
5000	0
37500	37500
0	7500
0	0
42500	45000
20000	10000
80000	0
0	0
100000	10000
10000	5000
40000	0
0	0
50000	5000
0	0
0	0
Intervention 4	**Intervention 5**
#DIV/0!	**#DIV/0!**
0	0
0	0

This is the second part of the worksheet 'benefits and costs assumptions' – this part relates to the costs associated with the selected scenarios.

Key elements

The intervention costs include both the direct costs and indirect costs, over two phases, an initial implementation phase followed by a maintenance phase.

20. Specify how long (in years) the initial phase will take – the length of the maintenance phase is automatically calculated as Tine frame for analysis minus the initial phase
21. Annual direct costs during the initial phase
22. Annual indirect costs during the initial phase
23. Annual direct costs during the maintenance phase
24. Annual indirect costs during the maintenance phase
25. Non-monetary indicators
26. BCR results are automatically calculated together with the estimated non-monetary benefits

The spreadsheet includes a series of additional worksheets that show the calculations for the baseline and intervention scenarios. These calculations are automated and it is therefore not possible to enter data, only to view the results of data entered in the 'parameters' and 'benefits and cost assumptions' worksheets.

APPENDIX 2: GUIDANCE FOR THE SPREADSHEET CALCULATOR

This document provides guidance for a spreadsheet calculator designed to assess benefits and costs of fire risk mitigation strategies (such as planned or prescribed burning) relative to a defined baseline program. The assessment is over a 20-year time frame, because the tool is designed for longer-term strategic decision making rather than shorter term more tactical or reactive decision making. The tool currently is partially populated with NSW data as an example for illustration (which can be replaced) and has the following sheets:

- *Cover* – lists the version and date of the model;
- *Parameters* – these are the input parameters required by the model for the baseline fire management. We allow for the fact that the baseline may change over time. Values are to be entered in the blue cells;
- *Benefit & cost assumptions* – the idea of the tool is to calculate the benefits and costs of alternative interventions (can also be termed as scenarios) compared to the baseline. After defining the alternative interventions, each intervention is represented by a column in this sheet, and values are provided in the green cells;
- *BCRs* – this stands for Benefit: Cost Ratios. The BCRs of each intervention are summarised on this sheet. They are also shown at the bottom of the *Benefit and cost assumptions* sheet; and
- *Intervention calculations* – this shows the calculations over 20 years for each intervention (1 sheet per intervention).

This document provides guidance for using and interpreting the spreadsheet calculator and is arranged in order of the sheets in the accompanying spreadsheet tool.

Blue cells (found in the *Parameters* sheet and also a few in the *Benefit & cost assumptions* sheet) are cells that you can modify. These are either values used to calculate outcomes in the baseline scenario, or labels for asset types or cost types. Once entered, the values or labels are copied/used in other parts of the spreadsheet.

The green cells (found in *Benefit & cost assumption* sheet) also require populating – these are specific impacts associated with interventions.

COVER SHEET

The version and date of the model is listed. An overview of instructions will be added to the final version.

PARAMETERS SHEET

Definition of the case study area

Definition of the geographic extent of case study area is required (row 3). Clarity about this helps to avoid confusion when entering numerical values for the analysis. An accompanying map (PDF and/or. kml file) showing the boundary of the case study region helps all team members have a clear understanding of the study area. The area within the boundary is where management interventions are planned to occur, for both baseline and alternative interventions. The following information would be valuable to display on a map or maps:

- Major land use types (e.g. conservation areas, public land, urban areas, agricultural land, rural living areas, significant infrastructure assets etc.);
- Bushfire management zones (e.g. Asset Protection Zones, Strategic Fire Advantage Zones, Land Management Zones etc.); and
- Bushfire Management Treatment areas (e.g. prescribed burn history etc.).

In addition it would be useful to have a brief description of the case study area.

At this stage, we recommend that this information be recorded in separate files. If we convert the tool to be web based, it would include room for this information.

Baseline fire management regime/policy

The baseline fire management regime needs to be clearly defined (write it in row 5). ***It is extremely important to be clear about what the baseline management scenario is,*** including any changes expected in the baseline over the coming 20 years. All of the intervention scenarios are measured relative to the baseline. The project team and fire simulation modellers need to work closely together and both understand the baseline and interventions being assessed, so that the information collected is appropriate for the analysis. This is true both for cases where the information is generated by fire simulation modelling and where it is obtained from other research or from expert judgements.

As part of the baseline definition, define the starting fuel load. The fuel load may evolve over time depending on the management scenario.

Thinking about the baseline

The baseline needs to be a management regime which participants identify with (a realistic, and hopefully, recognisable regime). It is the scenario against which alternative scenarios will be assessed. Whilst in theory the baseline does not have to represent current fire prevention and management regimes, it commonly makes sense for this to be the case, in which case the baseline can also be called the 'business-as-usual' or 'current practice' scenario.

Whatever the baseline is, it needs to be defined specifically enough to be able to provide a range of information about it, including:

- The numbers and values of assets of various types;
- Average annual losses for each type of asset under the baseline regime, that is the baseline level of expected losses under this regime;
- Any consequent losses – other losses that flow on from asset losses (e.g. loss of electricity poles might cause losses of stock or sales to businesses in the region) that would be expected under the baseline regime; and
- Suppression costs – this is the average expenditure on fire suppression under the baseline regime. It is important to differentiate this from the costs associated with implementing the baseline (e.g. current levels of prescribed burning).

Specifying the baseline needs to include factors such as:

- Area and frequency of burns in asset protection zones and the resources needed to achieve this;
- Area and frequency of burns in landscape burns and associated usual resources;
- Amount of other hazard reduction strategies such fuel removal, fire trails, etc.;
- Community education measures;
- Other management such as prosecution, permits , manning towers, closure of recreation areas, monitoring, and whether houses are required to be built to new standards; and
- Suppression strategies – resources (number and type) for fire suppression, including in bad fire years.

An example baseline defined for a case study area in NSW was *'The current mix of asset protection zone interventions and landscape prescribed burning regimes'.* This implicitly encompasses all of the factors listed above. However, it would probably be advisable to spell out the various factors in a bit more detail, so that participants have clarity about what the baseline includes when parameter values are being generated.

Human life factors

We come to the first of the numerical values required. In rows 8-11 of the *Parameters* sheet, provide the current population, the value of a statistical life and value of injury and mental health losses.

The current population can be estimated based on census data or other knowledge.

The value of a statistical life is the amount that an individual or a government is willing to spend to avoid the loss of a life. It is not the value of preventing a particular person dying at a particular time. Rather it is probabilistic and non-specific, but that is appropriate for long-term planning to protect lives in general. To specify a value, we recommend following the guidance of (Anon. 2014).

We provide the facility to enter a value for injury and/or mental health losses. In the current model, these are specified as a value per statistical life lost. In other words, they are assumed to be proportional to the number of lives lost. Options for providing this number include: past research, expert opinion, assuming it is zero or assume it is a simple proportion of the value of a statistical life.

For these values, and all other values, we recommend that you record the source and/or basis for the estimate. We provide a space in column J for you to do so. Alternatively, you can enter comments within the spreadsheet behind the relevant cells.

Assets (current)

There is a default set of names for asset types in the spreadsheet. These can be altered if desired, in the blue cells A14 to A38 of the *Parameters* sheet. The units of measure for each of the asset types also need to be defined (column B). For example, depending on the type of asset, the units could be numbers, hectares or kilometres.

The current number of units of each asset type in the case study area needs to be defined (column C).

For each asset type, there are three different types of costs that can occur if the asset is lost. The three types of costs are additive.

- Replacement cost (column D). This is the cost of replacing the asset if lost (for example, for residential properties it would be the house replacement cost, not the land plus house value);
- Direct loss of profit or utility as a result of losing the asset (column E). This represents additional losses of profit or utility for the owner of the asset, beyond the replacement cost for the asset. There is often limited information about this. For some assets there will be no additional losses of profit or utility. If you think there are likely to be such losses then it could be estimated as a proportion of the replacement cost of the asset. Alternatively it could be set at zero with the understanding that the overall results will be conservative (under-estimate the benefits); and
- Consequent indirect or flow-on losses as a result of losing the asset (column F). This represents losses of profit or utility for people other than the owner of the asset. An example loss of infrastructure (e.g. a phone line or mobile phone tower) that results in a loss in profit to businesses. Another is blockage of a major road due to fire, preventing customers from reaching a business. The figures required here are long-term average annual levels of consequent losses. These losses are even harder to estimate than direct losses.

Non-monetary indicators

There may be indicators of loss that are not expressed in monetary terms, but which nevertheless can be predicted and measured. An example might be hectares of habitat loss for a particular critically endangered species. The tool includes the facility to capture and report on these indicators and the difference that is made by the various strategies. Each indicator should be named (column A) and the unit's specified (column B) along with the number for the baseline (column C).

Average annual losses for each asset type (baseline)

For each asset the average annual losses under the baseline need to be estimated. Where fire simulation modelling is used, this could be the mean loss of the distribution. Alternatively it could be losses based on the historical data from fires in relevant areas. Ideally, loss estimates would consider the range of possible fire severities, and the frequencies of fires for each level of severity. Remember that results need to be expressed per year. For example, if there is on average one catastrophic fire every five years, the annual loss due to catastrophic fires will be 20% of the expected loss from one fire. If there are 20 moderate sized fires per year, the annual losses for moderate should be calculated as the expected loss from one moderate fire times 20.

Annual losses are specified in column C in terms of the specified units for each asset type (column B). These units are copied down from the previous table. The total value lost is calculated (column E) and summed for all asset types for which monetary values have been estimated.

Suppression costs

Provide an estimate of the average annual suppression costs for the baseline burning regime***. It is important to note that this is the cost associated with putting out fires that occur with the baseline regime in place, not the cost of implementing measures associated with the baseline regime (e.g. current levels of prescribed burning).*** This represents the total cost for the whole area. These costs include all costs related to suppression, including costs of equipment, salaries of fire fighters, food and accommodation, and other required support (e.g. administration).

Suppression costs vary from year to year depending on the severity of the fire season. The figure included here should be the average across a run of seasons, including relatively good and relatively severe seasons.

Preferably, this value would be estimated from historical information on actual suppression costs over a number of years.

As well as local knowledge key findings from published papers might be useful to prompt thinking about suppression costs. We aren't suggesting the findings will apply to a particular situation, more to prompt some of the things which need to be thought about:

- Suppression costs were found to be most strongly related (58% variation explained) to fire size and private land in the north-western United States. Sixteen non-managerial factors were considered, covering fire size and shape, private properties, public land attributes, forest and fuel conditions, and geographic settings (Liang *et al.* 2008);
- Variables having the largest costs in other United States study were fire intensity, area burned and total housing value within 20 miles of ignition (Gebert, Calkin, and Yoder 2007);
- Another United States study (Mangan, 1999 page 32 cited in (Anon. 1999) estimated that average spending in aviation resources including equipment, food, showers, and toilets was 56.6% of total costs, with personnel being 31.7%;
- In Spain, fire prevention strategies costed around 33% and fire suppression 67% of the total fire management budget (Velez, 1999 page 171, cited in Anon. 1999);
- Fire managers increase suppression spending in areas where there is increased newspaper coverage and political pressure in response to increase risk of adverse wildfire outcomes (Dononvan, Prestemon, and Gebert 2011);
- Suppression costs are driven by the amount and type of firefighting resources used and the duration of the incident. The deployment of these resources is in turn influenced by a multitude of factors including incident management strategies and tactics, proximity to human communities and private property, weather and landscape conditions driving fire behaviour, and sociopolitical issues (Thompson and Anderson 2015); and
- More houses equate to increases in suppression costs. In California the expected increase in the log daily cost with each unit increase in the log count of homes within 6 miles (9.7km) of an active fire is 0.07 (P=0.005) (Gude *et al.* 2013).

Dynamics

Because the benefits and costs of fire management interventions are being considered over a 20-year time frame, in some case study areas considerable changes (e.g. population growth) could occur. These can be included where relevant.

Dynamics can be included in the following areas:

- Annual proportion in the number of fires that occur, for example, due to climate change or population growth;
- Annual proportional change in losses per asset hit by fire, for example, due to climate change which affects fire intensity or increasing real value of assets (factoring out inflation);

- Annual proportional change in population, which is used to adjust the numbers of lives lost and injury impacts; and
- Annual proportion change of assets in the case study region. Separate numbers can be entered for each type of asset.

These can be left as zero if no particular changes are expected or can be estimated.

Discount rate (real)

We recommend the use of 5% as a suitable real discount rate, but another rate can be used if desired.

BENEFIT AND COST ASSUMPTIONS SHEET

This sheet deals with the benefits and costs of the interventions being considered.

Benefits of the interventions

Just as was done for the baseline, each intervention being considered needs to be clearly defined and specified. Each intervention will differ from the baseline scenario, and the aim of the analysis is to determine whether the additional benefits (relative to the baseline) outweigh the additional costs.

Defining the interventions

Each intervention (also called scenarios) needs to be defined and a summary title put in row 2. It should be sufficiently well specified in an accompanying document that the assumptions are clear enough to enable the reader to follow the logic about the assumptions about benefits and costs.

Each intervention needs to be described clearly enough to enable the benefits to be estimated. The three types of benefits to be estimated are the:

- Proportional reduction in number of fire incidents once the intervention has fully kicked in (relative to baseline), allowing for the estimated number of extra fires that are generated by the new intervention (e.g. escapes from prescribed burning);
- Proportional reduction in consequences (losses) per fire once the intervention has fully kicked in due to reduced spread and reduced intensity; and
- Proportional reduction in number of fire incidents once the intervention has fully kicked in (relative to baseline), allowing for the estimated number of extra fires that are generated by the new intervention (e.g. escapes from prescribed burning).

Example interventions (each of which would need more specific information to be included) could be:

- Increased prescribed burning at a landscape scale. The area of increase and location would need to be specified so that the additional benefits and costs can be estimated;
- New houses in specified vulnerable locations could be built to an improved standard to reduce fire damage;

- Increased interface burns in asset-protection zones. The amount and location of these would need to be defined specifically to enable the additional benefits and costs to be estimated; and
- Increase mechanical interventions to reduce/remove fuel. The locations would need to be specified as well as whether the intervention is in addition to or at least partly replaces the current (baseline) management regime.

Note that it is possible to define an intervention scenario that involves less intense management and higher losses than the baseline. In this case, the reduction in losses (in the benefits section) would be negative, signifying that losses increase, and the additional costs would also be negative, signifying that costs are less than the baseline.

Guidance on adding new interventions is provided at the bottom of the Benefits and costs assumptions sheet and reproduced below.

To add in a new intervention, follow these steps:

1. Add in a green column of numbers for the intervention, in rows 3-93 above;
2. Enter appropriate numbers in the new green cells;
3. Create a new sheet for this intervention by copying one of the existing intervention sheets;
4. On that new sheet, in the benefits section, for each asset type, do a search and replace for $D (or whichever green column has the original green numbers for the sheet you copied) to $E or whichever green column contains the new parameters);
5. In the row of BCRs (just above here), link to the BCR result in the new sheet; and
6. Add the new intervention into the BCRs sheet.

Estimating the benefits of interventions

There are three main concepts in considering the benefits of the intervention:

- The proportional reduction <u>in number of fire incidents</u> once the intervention has fully kicked in (row 3). This needs to allow for the estimated number of extra fires that are generated by the new intervention (e.g. escapes from prescribed burning);
- The proportional reduction in consequences per fire once the intervention has fully kicked in, due to reduced spread and reduced intensity (row 6 onwards for each relevant asset type); and
- The proportional reduction in numbers of assets expected to be in fire-prone areas due to the intervention, or reduced vulnerability of the assets (row 35 on). Note that this is only likely to be relevant for interventions involving changed planning standards or building regulations.

Note: Reduced suppression costs will be a benefit associated with interventions. A simplifying assumption is that the suppression costs will be a constant proportion of the asset losses; that is if the intervention is predicted to reduce asset losses, the suppression costs will be decreased in proportion.

Timeframes

There are three concepts here based on a concept of an initial period of intervention implementation (or roll out phase), followed by a maintenance phase:

- Time at which the benefits start to emerge (row 61). For some interventions this might correspond to the end of the initial phase of implementing the intervention (see row 66) and for other interventions there may be a delayed effect. The benefits of the intervention will be calculated after this time;
- Time at which benefits reach their maximum level. Depending upon the intervention this may well occur some years after the initial phase of the project; and
- Time frame for the analysis – up to 20 years. Less can be specified if required.

Costs of the interventions

These are the costs, additional to the baseline, that are required to implement the intervention.

The time frame for the initial phase of the intervention costs is listed in row 66. It is assumed that a different (probably higher) level of costs is borne in this period, relative to the maintenance phase. For interventions which don't have an initial start-up phase, the time frame for the initial phase would be set at zero.

There are four components to considering annual costs, direct and indirect costs and initial and maintenance phases of the costs.

Direct costs: For the direct costs there are some suggested headings in the blue cells (aircraft, machinery, personnel, meals/accommodation and other; these can be modified to reflect the scenario better as required) to help think about cost items involved. These are summed to give a total annual cost for the initial phase. These same cost headings are used to estimate the maintenance phase direct costs.

Indirect costs: Headings of administration/management and public and private costs of additional regulation are suggested as headings to help think about indirect costs in each of the initial and maintenance phases.

Non-monetary indicators under each scenario

If non- monetary indicators have been specified, the indicator levels for each scenario need to be provided. There are absolute levels of the indicators, not changes relative to the baseline.

The benefit: cost ratios for each scenario and non-monetary indicators are summarised at the end of this sheet (rows 96-98).

BCR SHEET

This sheet repeats the calculated benefit: cost ratios and non-monetary indicators.

BASELINE CALCULATION SHEET

This sheet shows the asset values and losses for the baseline scenario, over time. The values and losses are all shown in real terms, meaning that inflation has been factored out of them.

INTERVENTION CALCULATION SHEETS

These sheets show the benefits and costs for each scenario over time, broken down into asset types and cost types. The benefits and costs are all shown in real terms, meaning that inflation has been factored out of them. If the numbers are going up over time, it means they are increasing at more than the rate of inflation.

At the bottom of each sheet, the benefits and costs of the intervention are summarised as total present values, based on standard discounting methods.

Source: Tasmanian Parks and Wildlife Service

APPENDIX 3: INTEGRATED ASSESSMENT OF PRESCRIBED BURNING ON PUBLIC AND PRIVATE LAND IN THE MOUNT LOFTY RANGES, SOUTH AUSTRALIA

Researchers

David Pannell, Veronique Florec and Atakelty Hailu (University of Western Australia)

End user

Mike Wouters, Department of Environment, Water and Natural Resources

Aims

a) To identify the costs and benefits of incorporating prescribed burning in private land as part of the landscape fire management strategy in the Mount Lofty Ranges;
b) To provide an integrated economic assessment of various prescribed burning strategies across public and private land;
c) To quantify trade-offs between social and environmental outcomes from various prescribed burning strategies (i.e. identify situations where protecting the environment and protecting communities are compatible goals and where there is conflict and fire managers need to make trade-offs between them; quantify those trade-offs);
d) To identify circumstances where prescribed burning in a particular type of land (private land, public land or both) is likely to be a preferred strategy, and how that strategy should vary in different circumstances; and
e) To integrate research on fires, ecology, human behaviour, values and economics, together with expert opinion from fire-service professionals, to inform management and policy.

Background

Recent increases in the frequency and severity of bushfires in Australia have prompted increased attention in prescribed burning as a possible strategy to mitigate the impacts of bushfires. Those responsible for making prescribed burning decisions face the challenge of reconciling objectives for the reduction of bushfire risk to human life and assets with objectives of biodiversity conservation. In the case of the Mount Lofty Ranges region in South Australia, these trade-offs are assessed in a landscape characterised by high bushfire risk, increasing land use fragmentation and areas of environmental significance. Given the challenges presented by the application of prescribed burning, it is important for fire managers to have a clear picture of the trade-offs between different options for prescribed burning in the region.

At present, there is a coordinated approach to prescribed burning in public land in the Mt. Lofty Ranges. The Department of Environment, Water and Natural Resources (DEWNR), SA Water and Forestry SA have partnered together to develop an integrated and collaborative approach for fire management on public lands in the region. However, the Government mandate on prescribed burning is limited to public lands, and there is no policy or mandate for private landowners to prescribe burn in their properties. As a result, there is no coordinated approach to fire management in private land. But private land constitutes a large proportion of the Mt. Lofty Ranges, and fuel levels in private properties may significantly influence overall fire risk levels for the region. Thus, depending on how the fuels are managed in private properties, the effectiveness of treatments in adjacent public land may be increased or decreased.

This raises an important question: what would be the benefits of extending the prescribed burning mandate to private land and what would be the expected costs? Little is known about the costs and the benefits of prescribed burning in private land. DEWNR is interested in exploring this question and assessing whether extending the prescribed burning mandate to private lands would generate benefits in excess of the costs.

To assess the potential benefits of prescribed burning in private land, it is necessary to weigh the pros and cons of implementing such a strategy. On the one hand, prescribed burning in private land may reduce bushfire risk for the region and contribute to reducing potential damages from bushfires. On the other hand, there are risks associated with its implementation. The success is dependent upon landholder cooperation and compliance, which in turn depends on their attitudes towards prescribed burning. There is also the risk of bushfires caused by escaped burns from private properties, which may increase potential damages and offset the benefits of its application. The challenge is to quantify these pros and cons appropriately for different circumstances, to weigh them up and quantify trade-offs. The appropriate balance between pros and cons may be different in different places and different times, depending on local conditions.

Currently, there is not such an analysis available that integrates information on fire risk, the effects of prescribed burning, human behaviour, different types of values and economic data to evaluate the costs and benefits of prescribed burning concurrently in public land and private land. This type of analysis will help develop strategies that may further reduce the impacts of bushfires in the region.

Management options to be evaluated

This project will evaluate the following management options against the status quo (i.e. current practice, where prescribed burning is carried out by DEWNR and occurs primarily in public land):

1. Adopt a tenure blind approach to prescribed burning and implement prescribe burning in private land (with the same amount of resources, in which case some of DEWNR's investment in public land will be go instead to private land);
2. Change the combination of fuel management strategies to include more weed control (in public land only and in public and private land); and
3. Explore community preferences and engagement. The options above would assume no barriers to implementation of the treatments in private land. In a second stage of the project, we will evaluate different delivery models for implementing the treatments in private land with the purpose of identifying the best model for community engagement and participation. This could be: landowners apply the treatments by themselves, or DEWNR apply the treatments with some work done by the landowners, or DEWNR do all the preparation and application of the treatments. The questions to be explored include:
   a) What are the implications of different payment arrangements?
   b) Regulation to be part of heritage agreements (which are already in place) or implemented in another way?

Other questions that may be explored (but they are not the focus of the project)

1. What is the level of investment that maximises benefits to society (or minimises the sum of costs and damages)?

2. How much should we invest in prescribed burning/fuel treatments in public land only and in public and private land?
3. If there was an increase in the amount of resources available for prescribed burning, how to allocate them (how to prioritise investment of those additional resources across the landscape)?

Methods

This project will undertake an integrated assessment of prescribed burning in a particular region. Steps in the process will be as follows.

1. Identify location for case study, and partner organisations for the analysis;
2. Identify and understand the decision options to be studied. Options may include different frequencies, timings, and scales of burning, different on-ground fire-management options, and so on. Discuss considerations that are relevant to choosing among these decision options. Identify the various outcomes (positive and negative) that could be affected by the choices made, including social, environmental and financial outcomes;
3. Collate and evaluate existing information about the impact of various prescribed burning regimes in different types of land (private and public land) on reducing bushfire risk, the condition of the environment, cost of implementation, and impacts on communities, particularly information relevant to the case-study region. Existing information will be considered, and expert judgements required to fill the gaps;
4. Develop a quantitative decision framework that calculates results for the various outcomes identified in step 2 as a consequence of specific combinations of fire-management options. The framework will integrate all of the above information to allow what-if testing of decision options;
5. Meet with end-user to consider preliminary results from the decision framework;
6. Revise the framework, as required;
7. Apply optimisation algorithms to identify the best possible packages of management options to meet specific objectives or to balance trade-offs in particular ways;
8. Peer review of the decision framework and its results;
9. Work with partners to identify implications of the study for policy and management; and
10. Identify priorities for research to fill gaps in technical or socio-economic knowledge.

Case-study region

The project will be undertaken in the Mt. Lofty Ranges, between Mount Barker and Uraidla. It encompasses 63,000 hectares of public and private land. The land uses include residential, agricultural, water catchment and conservation reserves. The case study area has been divided into 10 sub-regions of 4 different categories (urban, rural living, agricultural, conservation), according to their main land use.

Inputs from end-user and partner organisation

Particularly important will be the commitment of relevant experts. The project will require several workshops to provide information to undertake the analysis. Some of these meetings may be able to be held at or around the CRC conference in Brisbane in August-September 2016, and some could be held in conjunction with the National Burning Project (Subproject 2) being coordinated by Natural Decisions. We would like the end-user and partner organisations to participate in the following. (Specific information requirements in *italics*.)

1. Half-day workshop to identify and understand the decision options to be studied. Options may include different frequencies, timings, and scales of burning, different on-ground fire-management options, and so on;
2. Half-day workshop to identify and understand the impacts of the decision options on fire risks and outcomes. Outcomes of interest could be positive or negative and could be social, environmental or financial;
3. Half-day workshop with ecologists and fire experts on environmental outcomes from the fire-management options. Consider existing information, and provide expert judgements to fill gaps;
4. A meeting with fire managers to estimate the financial cost of implementing each proposed bushfire management option;
5. A meeting with landholders to estimate the financial cost of implementing prescribed burning in private land;
6. Half-day workshop with experts and landholders to consider the human behavioural responses under each of the fire-management options, the value to communities of outcomes, and socio-political risks; and
7. Provision of feedback to the research team about the analysis and its results.

Benefits of the approach

Benefits of the approach include the following:

1. A high level of engagement with relevant organisation and experts;
2. Integration of diverse information types into one framework;
3. Provides a synthesis of current knowledge in a management context, including both published information and expert judgements;
4. Identifies and deals with knowledge gaps and uncertainties;
5. A strong focus on decision making;
6. Transparency of assumptions and their impacts on outcomes; and
7. Indications about future research priorities.

Data requested

The data requested is shown in Table 12.

Additional data will be requested. Some of it is already in the model and only needs to be checked (if it is still relevant or needs updating). Some information requires further discussion and data collection in workshops/meetings (e.g. cost data for weed management, cost data for prescribed burning in private land, cost data for community engagement).

Table 12 Data requested in Mount Lofty Ranges project

Item	Data type
Quantity of private land in each sub-region	Number of hectares
Zoning of public land (A, B and C zones)	Shapefile if possible, otherwise number of hectares in each sub-region
Update on prescribed burning options currently applied in public land. Update on the options to be evaluated (in public land only). Currently the model has: 1. Prescribed burn 100% A + 10% B each year 2. Prescribed burn 100% A + 10% B + 5% C zone each year 3. Prescribed burn 100% A + 10% B + 10% C zone each year	Number of hectares or percentage of land to be prescribed burned per year in public land only (either across the whole study region, in which case the proportions will be generalised equally to all sub-regions or as indicated by the end-user; or a different number of hectares or different percentage treated for each sub-region)
Amount of prescribed burned in private land to be evaluated + amount in public land if different from those above	Number of hectares or percentage of land to be prescribed burned per year in private land (and indicate how treatments in public land are to change)
Bmap (bushfire management plan tenure blind)	GIS layer if available and any documentation that could be useful for us to look at
Current quantity of weeds in each sub-region	Number of hectares affected by weeds in each sub-region
Treatment options for weed management (can be several options)	Number of hectares treated per year for weeds in each sub-region (for each option if there are several options to be evaluated)
Biodiversity data and maps	GIS layers of biodiversity sensitive areas/protected areas in the Mount Lofty Ranges if available (or any documentation that would allow us to identify the areas where there could be a conflict between protecting the environment and protecting communities)
Historical fire data	Number of bushfires in each sub-region in the last 10 years (private and public land combined; and if possible, number of incidents in each type of land separately)
Proportion of prescribed burns that escape their boundaries (and become bushfires; i.e. a prescribed burn that burns a relatively small area beyond its planned boundary but does not cause major damage is not to be counted here)	Proportion of burns out of all prescribed burning treatments applied per year that escape their boundary and cause damage (if this is different between the sub-regions, then the proportion of escaped burns per sub-region)

APPENDIX 4: SUB PROJECT 2 INFFER ANALYSIS BEROWRA VALLEY METHODOLOGY TO DERIVE MODEL INPUTS – PREPARED BY NSW RFS

Introduction

Australasian Fire and Emergency Service Authorities Council (AFAC) has commissioned Natural Decisions to prepare a report using the INFFER model as part of National Burning Project: 'Report on an analysis of the tools and methodologies available to balance competing objectives of burning programs and matching these to users'.

INFFER™, the Investment Framework for Environmental Resources is an approach to developing, assessing and prioritising activities and projects aimed at addressing environmental issues. It models cost benefits over a 20 year timeframe.

The NSW RFS volunteered to run a case study applying INFFER to the Berowra Valley (Hornsby/Ku-ring-gai BFMC). A number of scenarios have been identified by representatives from the BFMC for analysis. These are to be compared to the baseline of the current fuels which includes the current prescribed burning effort:

1. To increase interface burning. Target level of interface and baseline level of landscape burning
2. To increase landscape burning. Target level of landscape and baseline level of interface burning
3. To increase both landscape and interface burning. Target level of both interface and landscape burning and current baseline.
4. Increasing Asset Protection Zone size with no further burning.
5. Upgrading construction standards of all dwellings on the interface (and not carrying out any land management activities)

The method for analysis involved the use of the Phoenix fire behaviour simulator and a spreadsheet designed to calculate the cost benefit analysis of intervention strategies.

Inputs required for the cost benefit analysis include:

- Description of baseline scenario, i.e. current mix of hazard reduction strategies
- Baseline costs of management and suppression
- Costs of interventions
- Value of properties by category
- Expected baseline loss of assets by category
- Benefits of interventions in terms of relative reduction in loss of assets

The expected loss of assets under baseline and intervention scenarios has been modelled in Phoenix.

The following information relates to assumptions and estimates that have been made to populate the INFFER model.

Definitions of scenarios

Baseline is defined as the current levels of both interface and landscape burning (in the project area this was calculated to be 256 ha interface and 556 ha landscape burning (Table 1)).

Increased interface seeks to increase annual target level of interface to 586 ha and baseline level of landscape burning remaining at 556 ha.

Increase landscape seeks to increase annual target level of landscape to 1274ha and retain baseline level of interface burning (256 ha).

Increase both landscape and interface burning increases target level of both interface and landscape burning (landscape 1274 and interface 586).

Case Study Area

Hornsby Ku-ring-gai BFMC area has been chosen as the NSW study area as shown in Figure 2 (Pg 20) Study Area.

The Hornsby/Ku-ring-gai BFMC area is located in the northern suburbs of Sydney, New South Wales and includes the Local Government Areas of Hornsby and Ku-ring-gai.

The study area accounts for a total land area of 59 300 hectares, of which 54% is National Park estate.

Methods

Phoenix RapidFire v.4.0.0.7 was used to simulate potential fire behaviour from multiple ignition locations. Data from the multiple simulations was further analysed in ArcMap GIS to assess potential asset impacts. The output has been expressed as expected annual losses under the baseline, and proportional reduction in asset loss under the prescribed burning interventions. Assumptions about asset loss under the mechanical APZ and house retro-fit scenarios can also be made from the baseline loss values.

Note that results from Phoenix are dependent on the scenario input data used. See also disclaimer information in section 3.

Data Inputs

Study Area

Property impact was assessed within the BFMC boundary. Fires were modelled from a broader landscape, within a 10 km buffer of the BFMC boundary.

Ignitions

An ignition grid (uniform grid of ignition locations spaced at 1 km intervals) was created within the BFMC and 10 km buffer area. Ignition points in areas with little or no fuel (water or urban areas) were removed from the grid. This provides a total of 1379 ignition points.

The concept of the grid is to simulate a random ignition that could occur at any location in to the landscape. It would be more preferable to create a weighted ignition grid using a probability model, however this product was not available for application at the time of modelling. This product is currently under development.

Independent fires were simulated from each ignition point, with each fire allowed to run for 12 hours (10:00 to 22:00).

Base Layers

Phoenix requires spatial base layers for fuel type, fire history, topography (DEM), wind modifiers, and linear disruption features. Standard NSW Phoenix input layers (as current at the time of modelling) were used except as described below.

Modification to the state fuel type map was required to improve accuracy at the local scale. Some areas of Crown Land (e.g. the south-west interface of Berowra Heights) are mapped as cleared in the Keith vegetation layer, and hence the fuel type map. These were identified by overlaying with the Bushfire Prone Land Map which has accurate interface mapping. The identified areas were reclassified to Sydney Coastal Dry Sclerophyll Forest in the fuel type map. Reclassification of rural-residential properties from fuel type 69 (urban no tree cover) to fuel type 70 (urban low tree cover / rural residential) was required to represent grass fuel more accurately in these areas.

Fire history input was varied to represent the different burning scenarios (see details below).

Fire History

The baseline scenario is the current mix of hazard reduction and wildfire history. This was represented by the standard fire history layer as at 30-June 2016.

Target annual hectares for the intervention scenarios were calculated such that performing the combination of interface and landscape prescribed burning would represent a significant increase to the area of the bushfire prone land (BFPL) treated annually within the BFMC, a total of 1857 ha.

The last five years of the hazard reduction program for the BFMC area was analysed to provide mean values of hectares burnt under the baseline scenario. The mean annual area burnt is currently 812 ha, with a greater proportional focus on interface burning (Table 1).

Figure 2 displays the classification, location and timing of burns. They were classified as either interface or landscape based on their proximity to urban or rural-residential properties. The current balance between interface and landscape burning was maintained for the interventions.

The spatial arrangement of intervention burns was based on burn block polygons provided by the BFMC. The landscape burns were taken from the potential (draft) program for the next 5 years supplied by NPWS. The burn blocks for interface burns were selected based on time since last burnt; these represented a mixture of NPWS and other (e.g. Council, Crown land) tenure. The timing of burns was allocated such that the year of the burn exceed the minimum allocated fire interval for the burn block, and the distribution throughout the year was based on the mean number of burns per month from the last five years of the hazard reduction program.

Table 133 Mean annual hectares for baseline and intervention scenarios

Scenario	Fire History	Interface ha	Landscape ha
Baseline	Current fire history (hazard reduction and wild fires) at 30th June 2016	256	556
Interface	Additional burns adjacent to residential or rural properties	586	556
Landscape	Additional burns in broader landscape (not adjacent to residential or rural properties)	256	1274
Combined	Additional interface and landscape burns	586	1274

Weather

A combined weather data set representing a 1 in 10 year return interval forest fire danger index (FFDI) was used, which is a peak FFDI of 42 (Very High) within the study area.

Weather sets were supplied by the Bureau of Meteorology for the 10 highest FFDI days for Hornsby between 2011-2015 (Table 2). The extent of the available NetCDF gridded weather covers the BFMC area, but not the full ignition grid extent (BFMC with 10 km buffer).

Hourly weather data was extracted from all weather sets at the location of Hornsby Fire Control Centre, located close to the centre point of the data set on a ridge.

Table 14 Recent historical peak FFDI days within the study area

Date	Peak FFDI	Fire Danger Rating
23/11/2014	28	Very High
5/02/2011	33	Very High
12/01/2013	34	Very High
21/11/2014	35	Very High
17/10/2013	36	Very High
23/10/2013	36	Very High
11/12/2015	38	Very High
26/11/2015	39	Very High
18/01/2013	40	Very High
8/01/2013	51	Severe

Hourly weather data (Table 3) was combined from the 6 days with the highest FFDI in the following way:

- Temperature, Wind Direction, Drought Factor averaged between the 6 days
- Relative Humidity averaged between 5 days (16-Nov-15 excluded due to unusual RH profile)
- Wind Speed averaged between the 6 days then increased so the peak wind speed (15:00) matched the maximum 15:00 wind speed from the 6 days (multiplied by 1.2)

A number of previous internal studies have addressed the impact of variation to the severity of weather.

Table 15 Hourly weather data used for Phoenix modelling

Time	Temp	RH	Wind Dir	Wind Speed	DF	Curing	Cloud	FFDI
6:00	19.2	77.6	W	12.8	7.6	100.0	0.0	2
7:00	20.5	73.5	W	14.0	7.6	100.0	0.0	2
8:00	22.9	65.4	W	18.8	7.6	100.0	0.0	3
9:00	25.6	53.4	NW	21.0	7.6	100.0	0.0	6
10:00	28.8	39.7	NW	24.7	7.8	100.0	0.0	12
11:00	31.6	29.3	NW	26.5	7.8	100.0	0.0	19
12:00	33.9	22.2	NW	26.5	7.8	100.0	0.0	26
13:00	36.0	15.8	NW	26.4	7.8	100.0	0.0	35
14:00	36.7	12.9	WNW	27.4	7.8	100.0	0.0	41
15:00	36.3	13.2	WNW	30.0	7.8	100.0	0.0	42
16:00	35.8	13.2	W	28.4	7.8	100.0	0.0	40
17:00	34.3	14.0	W	24.7	7.8	100.0	0.0	34
18:00	31.2	17.4	WSW	22.4	7.8	100.0	0.0	26
19:00	29.0	21.7	WSW	21.9	7.8	100.0	0.0	20
20:00	26.8	24.8	SW	18.6	7.8	100.0	0.0	16
21:00	23.2	44.2	SW	21.5	7.8	100.0	0.0	8
22:00	22.0	48.8	SW	22.7	7.8	100.0	0.0	6
23:00	21.2	49.4	SW	21.6	7.8	100.0	0.0	6

Assets

Address Point data was used to represent the location of assets. Note that this data is the centroid of a cadastral parcel, and so does not always accurately reflect the location of a building. This is considered adequate for small lots (i.e. urban areas) but can be inaccurate for rural areas.

Address Point data was overlayed with Local Environment Plan (LEP) zone boundaries to classify the points by land use. Filtering of the data was done to remove points from undeveloped land parcels (e.g. environmental management, public recreation zones). Points were then classified in to urban residential, rural residential, business, industrial and special fire protection use (education and health facilities).

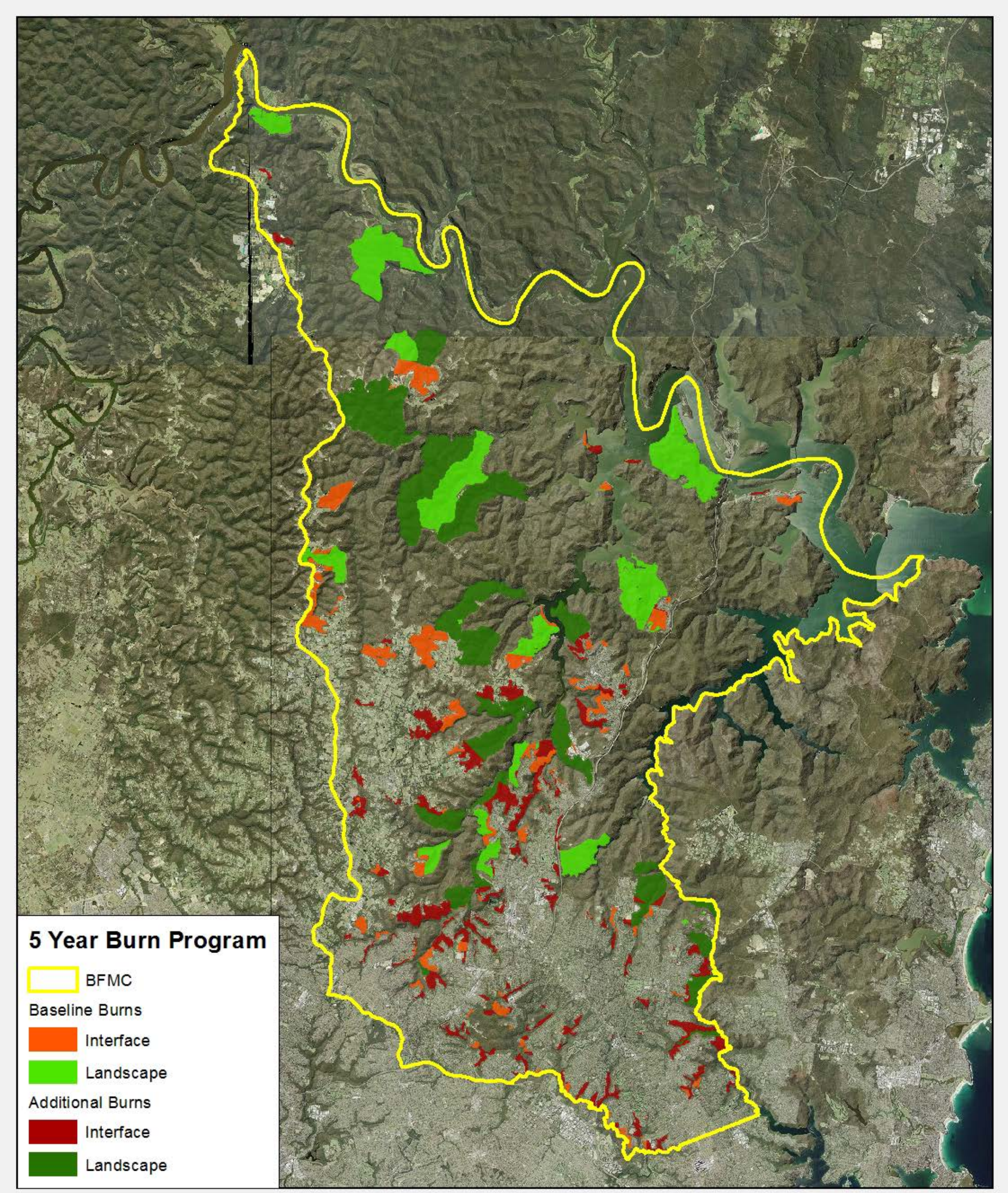
For the construction standard upgrade scenario, only urban-residential properties within the mapped bush fire prone land buffer (within 100m of the bushland-urban interface) were considered, a total of 26,338 properties.

The location of major infrastructure (Sydney-Newcastle motorway, main Northern rail line, overhead transmission lines) was identified by linear data.

Table 16 Asset numbers

	Urban-residential	Rural-residential	Special fire protection	Business & Industrial	Motorway	Railway	Power line
No./km assets	95,834	3,005	170	5,488	23	27	215

Figure 3 Simulated works program indicating classification (landscape or interface). Note we simulated draft proposals for the purposes of the study. Timing and area of implementation may vary


5 Year Burn Program
BFMC
Baseline Burns
Interface
Landscape
Additional Burns
Interface
Landscape

Cost Estimates

Prescribed burning

NSW RFS prescribed burning costs are estimated at $912/ha. This number was used as the assumed costs of increased interface burning interventions. It includes an estimate of cost for volunteers time of $31.15 per hour. NPWS prescribed burning costs are estimated at $834/ha. This number will be used as the assumed basis of increased landscape burning interventions)

Estimated suppression costs:

Baseline costs for suppression were estimated at $5.5 million per year. This is the estimated annual cost to operate the NSW RFS Hornsby-Kuring-Gai District. It does not include the operating costs of other fire agencies within the BFMC, namely National Parks and Fire and Rescue NSW.

The project assumed in the 20 year period there would be 2 large (section 44 fires). This is based on historical analysis compared to Phoenix modelling. These large fires are expected to increase annual cost of suppression to $10 million per year. This would leave 18 regular years at $5.5 million/year. Average cost for baseline suppression assumed as $5.95 million/year.

To calculate the suppression costs for the increased interface scenario, an assumption was made that baseline suppression costs wouldn't change. Due to the location of the burns on the interface large fires could still occur and require large suppression resources. This is verified by the Phoenix modelling. Annual cost for this scenario was assumed to be the same as baseline ($5.95 million/year).

In the case of the increased landscape scenario the assumption was made that there would be a reduction in fire size with this strategy. This was verified by Phoenix modelling. This scenario assumes 1 fire at $10 million and 19 years at base level at $5.5 m ($5.725 million/year).

For increased landscape and interface burning simulation the assumption was made that the result is the same (better than) as increased landscape burning, i.e. $5.725 million. This was also verified by Phoenix modelling.

Assumptions on time to benefits:

For all scenarios the project assumes that the time for maximum benefits is 5 years (fuel loads will have re-accumulated to baseline levels by this time.

Time when benefits begin for all scenarios is within a year.

Although the model has the ability to consider environmental costs, in this case they have not been considered. Future studies should endeavour to consider this cost.

8.1 NSW RFS Estimates for Prescribed Burning

8.1.1 Assumptions

Estimations based on a burn solely implemented by the NSW RFS. Costs could be greater if NPWS and or Fire and Rescue NSW participated in the prescribed burn (due to additional wage components).

Table 14 Estimate of NSW RFS Costs for implementation of a 100hectare interface burn (implemented by the NSW RFS only)

	Cost/hour/person	Number of Hours/ people	Total	Comment
Planning				
Identification	$41	3.5	143	1 person - grade 4/5
Approvals	41	9	369	1 person - grade 4/5 includes HRC BRIMS work and control line tagging etc
Prescribed Burn Plan	49	18	882	1 person - grade 6/7
Notification, consultation and scheduling	49	14	686	Estimate
Trail maintenance/repairs/control line preparation	180	24	4320	3 days excavator or dozer hire
Implementation				
Meals	18	96	3456	3 strike teams + STL - 2 meals/shifts
Fuel	150	15	2250	one tank diesel per truck 15 trucks
Aircraft	1800	6	10800	
Traffic Control (road crew)	28.5	64	1824	crew of 4 for 2 x 8hr days
Traffic Plan (moderate complexity event)	5000	1	5000	
Message boards	330	2	660	2 VMS boards for 1 week - 1 each direction
Supervision	1000	1	1000	In kind cost for staff member oversight
Volunteer cost estimate	31.15	81 people 24hours	60 555	3 strike teams plus supervision, two shifts
		TOTAL	90,945	
		Total Average $/ha	$909	

8.2 NPWS Cost Estimates Prescribed Burning

Table 6 details prescribed burning costs drawn from operating budgets from NPWS in the Hornsby Kuringai area. This data was supplied by the NPWS and should be considered in context of the following comments:

“These numbers reflect actual costs and do not include any costs for staff time or plant/equipment operating costs. The averaging process does not demonstrate the full range dollar per ha costs which can be as low as $150/ha to as high as $1000/ha. Some variables that can influence are aircraft, the day of the week, day versus night burns, as well as time of year.”

Table 15 NPWS average cost for prescribed burning (excludes staff time or plant/equipment operating costs)

year	Ha burnt	Average $/ha costs
2016-17	630	395
2015-16	1110	311
2014-15	820	146
2013-14	1077	310
2012-13	1340	212
2011-12	1166	270
Average	1024	274

Table 7 includes calculations of staff costs using the NPWS Prescribed Burn Cost Calculator V2 for a fictional 100ha landscape burn. Total cost per hectare is estimated using a combination of actual and scenario (estimated costs. It assumes that NSW RFS provides a strike team to help implement a notional 100ha burn.

Table 16 Estimate of NPWS Prescribed burning costs for a notional 100ha landscape burn.

	Cost/hour/person $	Number of Hours/ people	Total	Comment
Planning				
Identification	41	3.5	143	As per RFS estimates(scenario)
Approvals	41	9	369	As per RFS estimates(scenario)
Prescribed Burn Plan	49	18	882	As per RFS estimates(scenario)
Notification and scheduling	14	49	686	As per RFS estimates(scenario)
Trail maintenance/repairs/control line preparation				$274 per hectare (See average costs listed in table 2)
Aircraft	1800	6	10800	

Implementation				
Staff Cost Estimates per NPWS calculator			4641 2	
Volunteer cost estimate	31.15	20 people 24hours	1495 2	1 Strike team 2 shifts (scenario)
		TOTAL	7423 8	
		Total average $ha	1016	Includes $274p/ha for Trail maintenance/repairs/control line preparation

To compare NPWS cost estimates for prescribed burning with NSW RFS we have added the planning items in Table 1 (i.e. identification, approvals, prescribed burn plans, approvals and notification/scheduling).

Salary (implementation costs) was estimated using the NPWS Prescribed Burn Cost Calculator V2 for a notional 100ha landscape burn.

8.3 NSW RFS Estimates for Suppression costs for a 1 in 10 Year wildfire

In deriving the annual suppression cost estimates the following information has been considered:

8.3.1 2015/16 Fire Costs:

Terrabora North (Hawkesbury) remote Hawkesbury Fire $844/ha (5326ha/$4,500,000) – could be compared to a landscape suppression effort.

Beecroft peninsula $1872 (801ha/1500000) – could be compared to interface fire. However it is likely that this fire would be much cheaper than a fire in the Hornsby district.

8.3.2 Average Fire Size

Average large fire size for the recent past 20 years in Hornsby and vicinity (Gosford, Hills, and Warringah) was approximately10 000ha. This includes the 2002 Hills complex fire, which was significantly larger than all the recent events. If the Hills complex fire is removed the average area becomes 3700ha. This figure was used in the analysis as a “large fire”.

Estimated cost for a large fire (with a section 44 declaration) perhaps $5,000,000. This equals an annual suppression cost of $10,500,000.

Annual cost of suppression per hectare ranges between $1,500 and $3,000 (i.e. 10,500,000/3,700).

8.4 Proposed methodology for APZ and Building Upgrade

Cost estimates for Building upgrades based on consultation with Council building Surveyors and anecdotal evidence:

Based on BAL result 12.5, 19, 29, 40 or flame zone assign upgrade cost per asset.

FZ = $50000

BAL40 = $30000

BAL29= $20000

BAL19 = $10000

BAL 12.5 =$5000

In assessing value upgrade work means house survives flame radiant heat and ember impacts up to 50 FFDI

Analysis utilised BAL 29 based on principle to remove properties from the “flamezone”.

8.5 APZ –Assess Each BFRMP Asset ID and determine required APZ distance to meet 19kw benchmark based on supplied slope and separation

Assign dollar figure per asset based on the following categories

10m or 200sqm= $500

20m or 400sgm = $1000

30m or 600sqm= $ 1500

Based on a assumption that the average property interface is approximately 20m wide

In assessing value – maintained APZ works mean house survives flame and radiant heat impacts up to 50 FFDI

9 Data Analysis

Phoenix was used to produce a static grid (spatial base layer of grid cells at 180m resolution) and run each scenario in Batch All Cells mode.

The FireImpact.xml output from Phoenix gives the size of each fire. This was used to calculate mean fire size and number of fires in fire size categories.

The AllCells.csv output from Phoenix provides basic fire behaviour output (intensity, ember density, flame height) for each fire within each grid cell. Post-processing was conducted to: determine which fires spread within the BFMC; calculate the average fire behaviour values per cell; and calculate the frequency of impact by intensity and ember density per cell.

Thresholds of Phoenix output values considered to result in significant impact on residential properties are intensity > 10,000 kW/m or ember density > 2.5 embers/m^2 (Tolhurst & Chong). These impact thresholds were used for all asset types.

The base static grid was joined to both the Phoenix output statistics and the asset data (address points and infrastructure lines) such that each grid cell contained the number of assets per asset category, mean fire behaviour values, and the frequency of impact.

Final calculations were performed to determine total asset loss per asset category within the BFMC under each scenario. As a 1 in 10 year FFDI weather scenario was used, the annual losses were calculated as total loss divided by 10.

Asset loss was calculated as:

Impact frequency of cell = No. times cell impacted / No. total fires within study area

Asset loss = Sum for all cells (Impact frequency of cell * No. assets in cell)

The input required for the cost-benefit analysis is the annual asset losses under the baseline scenario, and the proportional reduction in losses with each intervention compared to the baseline.

Proportional reduction in loss = 1 - (loss with intervention / loss with baseline)

For the baseline and prescribed burning interventions, loss was calculated using the impact thresholds for both intensity and ember density. For the mechanical APZ intervention, the intervention was assumed to prevent impact from flame contact or radiant heat but not embers, hence the losses from ember density only under the baseline was used as the intervention loss values. The house retro-fit intervention was assumed to prevent any loss of upgraded houses. As only houses within the BFPL buffer were considered for retro-fit, only asset impacts outside this buffer are counted under this scenario.

9.1 Results

Individual fires were modelled under the same weather conditions (very high fire danger) from a regular grid of ignition locations. While the total ignition grid (1379 ignitions) included ignition locations outside of the study area (BFMC), not all of these fires entered the study area. Only those fires that burnt within the study area are presented in the results.

Under the baseline scenario (current fire history) 628 fires affected the study area, with a mean size of 632 ha. Under the prescribed burning interventions the mean fire size, the number of fires that spread beyond 100 ha (considered to represent significant suppression effort), and the number of fires greater than 3,500 ha (considered to represent a bushfire emergency situation) was reduced. Greater reductions in fire size occurred with landscape treatment.

It should be noted that the modelling does not consider additional benefits of prescribed burning such as first attack ease or fire fighter safety.

Table 17 Fire Size

	Baseline	Interface	Landscape	Combined
No. fires	628	627	627	627
No. fires >100 ha	420	407	382	376
No. fires >3,500 ha	3	2	1	1
Mean fire size (ha)	632	606	528	522

Table 18 Annual asset loss

	Urban-residential	Rural-residential	Special fire protection	Business & Industrial	Motorway	Railway	Power line
No./km assets	1.612	0.525	0.002	0.090	0.008	0.010	0.115
% of assets	0.002	0.017	0.001	0.002	0.027	0.03	0.044

All intervention scenarios gave some reduction in asset losses compared to the baseline. For prescribed burning interventions, increased interface burning resulted in a greater reduction of loss of buildings in all categories except rural-residential. Reduction of impact on infrastructure was similar for the motorway and railway, while landscape burning had a greater influence on transmission line impact. This reflects the location of these infrastructure assets in the landscape.

The reduction in losses under the mechanical APZ intervention are low as this treatment is assumed only to protect assets from intensity impact, and a greater proportion of property impacts are from embers. Ember impact also penetrates further into urban areas than the 100m buffer of BFPL considered for the retro-fit intervention.

Table 19 Proportional reduction in asset loss for each scenario compared to baseline

Scenario	Urban-residential	Rural-residential	Special fire protection	Business & Industrial	Motorway	Railway	Power line
Interface	0.60	0.15	1.00	0.74	0.44	0.35	0.16
Landscape	0.50	0.30	0.67	0.59	0.45	0.39	0.36
Combined	0.73	0.35	0.92	0.84	0.43	0.34	0.41
APZ	0.04	0.11	0.00	0.05	n/a*	n/a	n/a
House upgrade	0.66	n/a*	n/a	n/a	n/a	n/a	n/a

* Mechanical APZ treatment not applicable to infrastructure assets; Retro-fit treatment only applicable to urban-residential properties

10 Disclaimer

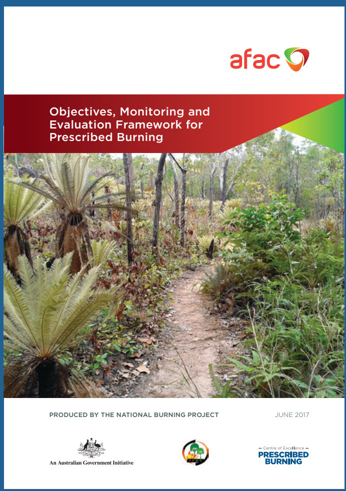
Fire behaviour modelling methodologies are an inexact science. Models and guides are often created within a limited range of conditions. Sources of error could include the models applicability to the situation, the models inherent inaccuracy, input data and knowledge, skills and experience of the analyst.

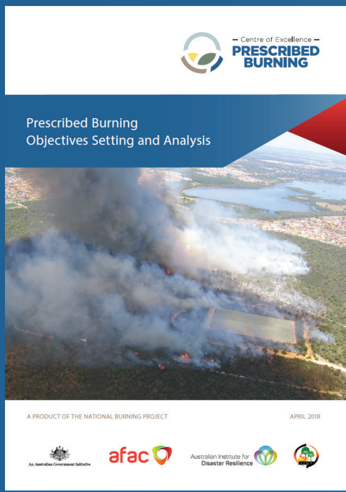
As such, maps and reports are a tool for fire managers to utilise in conjunction with other fire related intelligence. These maps and reports should not be relied upon in isolation to make operational decisions.

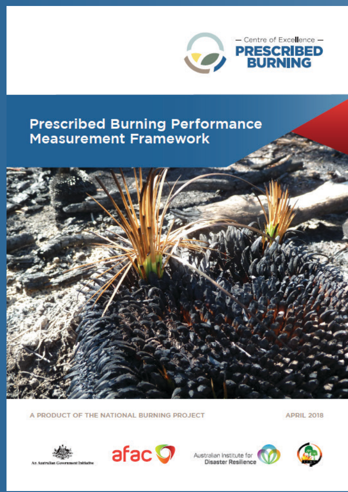
The Agency accepts no responsibility for any injury loss or damage arising from the use of this report or any errors or omissions in the information recorded on the report.

This is an experimental product. Key points for consideration:

- Results shown here represent the scenario used for fuel, weather and ignition locations. Changes to the inputs may produce very different results.
- The likelihood of such scenarios occurring has not been quantified.
- No effects of potential suppression have been included in the models.
- This work makes a number of assumptions including the accuracy of vegetation mapping and fuel load accumulation.
- This work assumes that Phoenix represents fires accurately.







Objective Setting and Analysis

Analysis of Tools and Methodologies to Balance Competing Objectives of Burning Programs

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