National Burning Project

Australasian Fire and Emergency Service
Authorities Council (AFAC) and Forest Fire
Management Group (FFMG)

Risk management and review framework for prescribed burning risks associated with fuel hazards

Report for
National Burning Project:
Sub-Project 3

September 2014

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1. INTRODUCTION

The National Burning Project (NBP) is a multi-year project jointly commissioned by the Australasian Fire and Emergency Service Authorities Council (AFAC) and Forest Fire Management Group (FFMG), with the overarching objective:

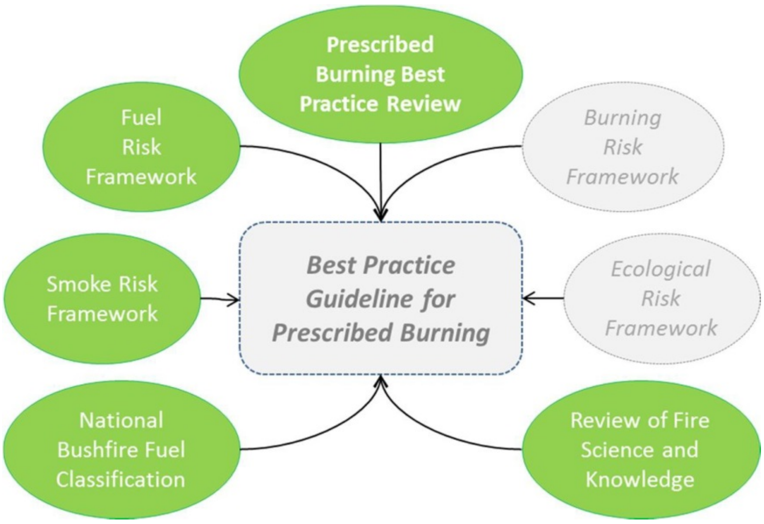
To use a national approach to reduce the bushfire risk to the Australian and New Zealand communities by the comprehensive management of prescribed burning at a landscape level that balances operational, ecological and community health risks.

A number of sub-projects (Refer to Appendix C: National Burning Project—list of sub-projects) are to be implemented under the NBP pursuant to developing national guidelines for:

- Best practice prescribed burning; and
- Ensuring greater interoperability between fire management agencies through developing common standards and approaches to prescribed burning.

The fuel hazard risk framework development sub-project is one of the projects that will contribute to compilation of national guidelines, as depicted in Figure 1 below.

Figure 1 National Burning Project—related sub-projects



1.1 Fuel hazard risk management and monitoring framework development project

Prescribed burning carries a high level of inherent risk. One important suite of risks relates to the management of hazardous fuel loads in proximity to communities and other assets.

AFAC and FFMG have engaged GHD to analyse and review existing risk frameworks for fuel hazards in each jurisdiction (each of the states and territories of Australia and New Zealand) and to develop a fuel hazard risk management and monitoring framework. Within the project brief issued by AFAC and FFMG there are two key sub-themes within the 'fuel hazard risks' theme.

The first sub-theme is:

In the event of an unplanned fire occurring, fuel hazards are a significant risk factor influencing the degree of risk to nearby communities, property and environmental values. Prescribed burning programs aim to reduce fuel hazards and therefore reduce the level of fire risk to affected communities, property and the environment.

The project brief specifically calls for a risk framework that allows for:

- An analysis of the risks;
- Setting risk reduction objectives for prescribed burning programs;
- Monitoring and measuring outcomes and changes to risk; and
- Provision of feedback and review on the fuel hazard risks.

The second sub-theme is:

Prescribed burning carries a high level of inherent risk… including managing dangerous fuel loads in close proximity to communities and other assets.

The project brief calls for the risk framework developed in this sub-project to address the fuel hazard related risks of prescribed burning (but not the burn escape, smoke, and biodiversity related risks).

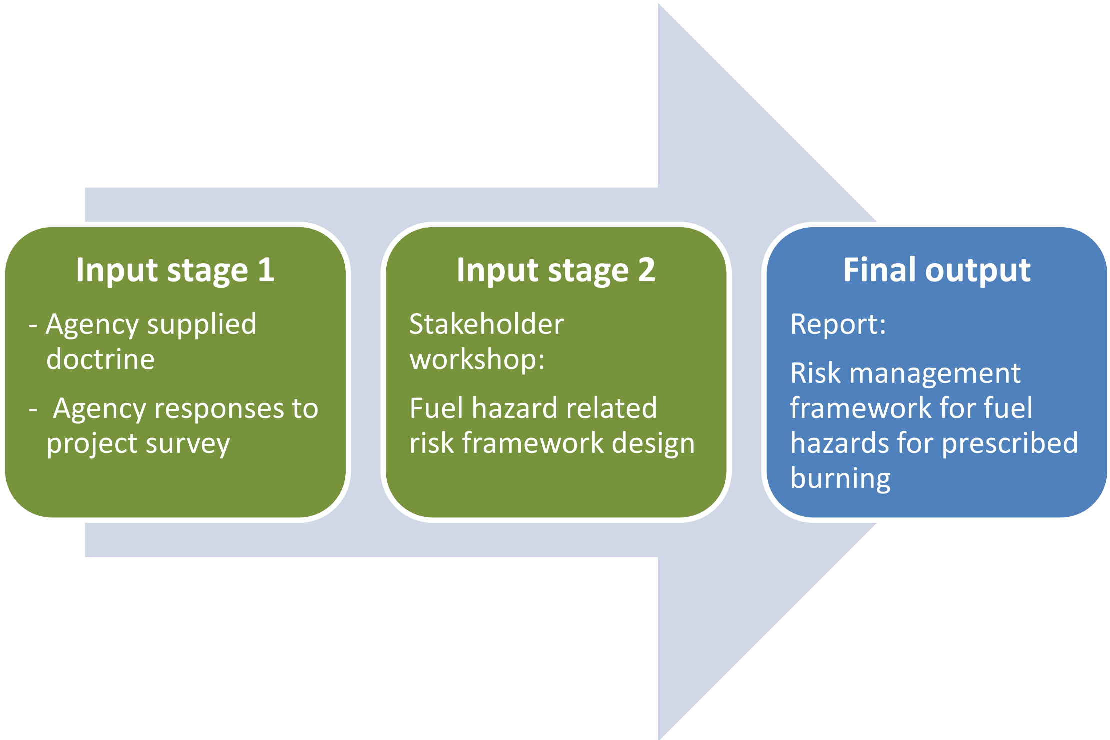
This report documents the findings and outcomes of GHD's analysis of existing fuel hazard related risk frameworks in participating jurisdictions, and recommends a national risk management and monitoring framework for fuel hazard risks.

2. METHODOLOGY

GHD devised a methodology for undertaking this project for AFAC and FFMG's consideration. The proposed project methodology was discussed at the project inception meeting, agreed, and timelines developed for its implementation.

An overview of the three stage methodology is provided in Figure 2 below:

Figure 2 Three-step project methodology



2.1 Call for agency doctrine and project survey distribution

In December 2011, GHD invited AFAC and FFMG member agencies to forward relevant doctrine relating to the management and monitoring of fuel hazard related risks, and developed a survey for agency participants to complete. To the greatest extent possible, GHD undertook web-searches to populate the survey with answers to the survey questions for each jurisdiction. This was intended to save survey participants time in completing the survey, and focus their time on validating, adding to and clarifying the information. The survey questions are identified in Appendix A.

2.2 Project workshop

On 6 March 2012, GHD facilitated a one day workshop in Melbourne to explore in more detail the issues, approaches and practices used by different agencies for the management and monitoring of fuel hazard related risks. A list of workshop participants is provided in Appendix B.

All AFAC and FFMG member agencies were invited to attend the workshop with invitations distributed through agency points of contact nominated by AFAC's project manager.

2.3 Information analysis and project report

Pursuant to the project design agreed at the inception meeting, and further canvassed during the project workshop, GHD has structured analysis of the input received from agencies and through the workshop according to the hierarchy of phases in bushfire risk management and prescribed burn planning.

These phases are:

- Fuel hazard and risk assessment at the level of ***strategic planning*** for prescribed burning (addressed in section 4 of this report);
- Fuel hazard and risk assessment at the level of ***tactical (program) planning*** for prescribed burning (addressed in section 5 of this report);
- Fuel hazard and risk assessment at the level of ***operational planning*** for prescribed burning (addressed in section 6 of this report);
- Fuel hazard and risk assessment during ***prescribed burning operations execution*** (addressed in section 7 of this report); and
- ***Post-burn monitoring and modelling*** of fuel hazards (addressed in section 8 of this report).

Section 3 of this report discusses some general concepts of fuel hazard and risk, and discusses the nature of risk management frameworks. Specific consideration is given to the subtle changes introduced with the transition from AS 4360 Risk Management to ISO 31000 Risk Management—Principles and Guidelines.

Section 9 of this report proposes a risk management and monitoring framework for fuel hazard risks.

3. FUEL HAZARD AND FIRE RISK—GENERAL CONCEPTS

In this section, some general concepts of fuel hazards and fire risk are outlined to provide a frame of reference and context for subsequent sections.

3.1 Risk management frameworks—the shift from AS/NZS 4360 to ISO 31000

In 2009 the international ISO 31000:2009 Risk Management—Principles and Guidelines usurped the AS/NZS 4360:2004 Risk Management as the primary standard on risk management in Australia and New Zealand. While ISO 31000 is founded very much on similar principles as the prior standard, there have been some subtle changes in the main points of emphasis between the two standards. Three are worth highlighting, and are listed with some commentary on the implications for developing a national risk-based framework for managing bushfire fuels:

Risks are to objectives

The glossary of terms and the structure of the ISO 31000 standard more transparently reflect that 'risk' arises not from the occurrence of an event *per se*, but from an understanding of how an event can arise and impact on an organisation and its ability to meet stated objectives. 'Risk' is defined in the standard as 'the effect of uncertainty on objectives'. Further, 'risk management' is:

A coordinated set of activities and methods… used to direct an organisation and to control the many risks that can affect its ability to achieve objectives.

Hence, while a bushfire can result in damage to critical infrastructure or other physical assets, the risk can relate to the possible effects on community-based needs and objectives brought about by the damage, rather than to the infrastructure itself. For example, effects on maintaining health & safety, providing services or maintaining the local economy. In short, articulating in a consistent way the broader objectives related to bushfire risk management and fuel hazard reduction activities and how they relate to protecting the social, environmental and economic fabric of communities threatened by bushfire, will be a central tenet of establishing a national framework for fuel hazard management.

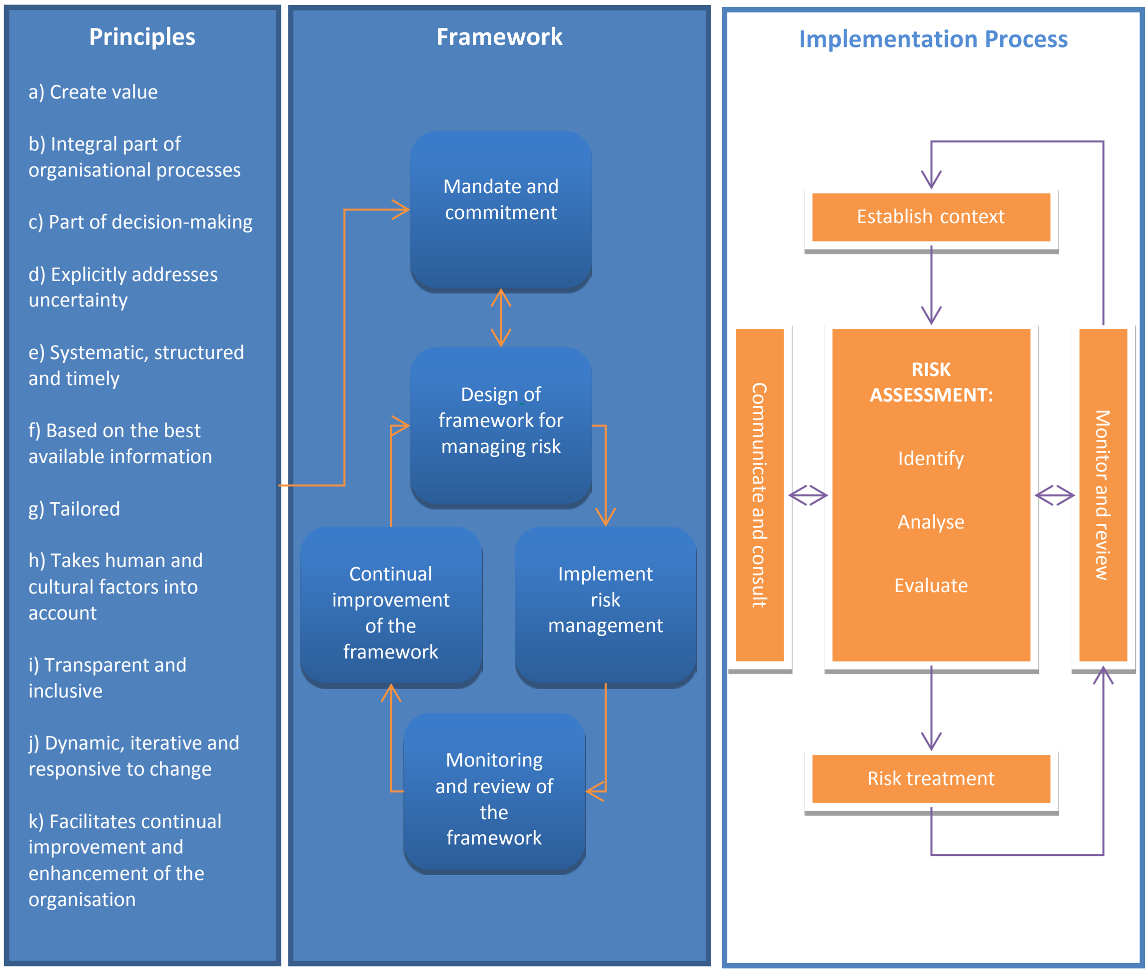
There are a variety of tools and methods available to perform risk assessments and inform management priorities.

The AS/NZS 4360 standard included strong references to the use of risk assessment 'matrices' whereby qualitative descriptors of an event's 'likelihood' and 'consequences' of occurring were used to develop a risk rating of, typically, 'low', 'high' or some similar descriptor. In the bushfire risk management context, problems can arise trying to adopt the 'matrices' as an assessment tool, due to the complex and wide range of fire behaviour variability and uncertainty that can exist and that is difficult to capture in such a way. While these types of matrices can be very useful in some situations to assist with risk assessment and recording, in recent times it has become considered—in the mainstream—to be the standard tool for undertaking risk assessment, which was never the intention of the AS/NZS 4360 standard. To address this, reference to the risk matrices have been removed from the ISO 31000 standard and an accompanying document ISO 31010:2009 Risk Assessment Techniques has been created. While the risk matrices do appear in ISO 31010 as one type of tool that may be useful in risk assessment (among a list of over 30 techniques), it is emphasised that the appropriate risk assessment and communication tools should be developed with the specific context, in this case fuel hazard and bushfire risk management, in mind.

Risk management is a process of continual review and improvement, within which risk assessment is a key activity.

The ISO 31000 generic framework for risk assessment and management is outlined below. It contains a set of principles, a risk management framework, and a risk management process, and how they inter-relate. The 'risk assessment' activities, sit within the overall risk management process. While the focus of this study is on developing a national risk assessment framework for fuel hazards management, it would be remiss to develop an approach without considering how it would be able to be conducted and subject to continual review. Particularly to the principle of verifying whether the approach is producing effective and desired risk mitigation.

Figure 3 The ISO 31000 Risk management principles, process and framework



Further discussion relating to objective setting, risk assessment considerations and the specific needs of risk assessment approaches that accommodate risk management principles for fuel hazard management activities are provided in this chapter. The concepts outlined are then used to inform the development of a recommended national framework for fuel hazard management.

3.2 Risk management objectives contextualised to bushfire and prescribed burning

The National Bushfire Management Policy Statement for Forests and Rangelands (FFMG 2014) provides an agreed vision and principles for bushfire management. It also provides strategic objectives and national goals in order to achieve the vision. The relevant objectives and goals for this report are:

A - Effectively managing the land with fire

1 - Maintain appropriate fire regimes in Australia's forests and rangelands

Manage planned fire and unplanned fire (where appropriate), to reduce the risk of severe bushfires impacting on communities, and enhance the health, biodiversity and resilience of Australia's forests and rangelands. Underpinning this goal is an understanding that planned and managed fire can play a positive role in reducing the scale and magnitude of bushfires, and promote more healthy and productive forest and rangeland ecosystems……

C - Strong land, fire and emergency partnerships and capability

8 - Bushfire risk mitigation

Improve the efficiency and effectiveness of programs designed to minimise the number, spread and adverse impacts of future bushfires. This includes advocacy about the impacts that land use and settlement changes have on bushfire risk and adjacent land and bushfire management practices…..

D - Actively and adaptively managing risk

13 - Risk management

Ensure that the management of landscape fire is based on "best practice" approaches to managing fire regimes and risk. Such approaches should be based on sound scientific information and organisational and community values and learning, and allow the efficient use of resources.

Develop risk and adaptive management systems that support the assessment and reporting of landscape and local level risks, and identify cost-effective strategies for achieving outcomes (and performance measures) that reduce the impact of severe fires and promote ecosystem resilience.

In the context of maintaining community-based objectives and managing the risks to these brought on by the threat of bushfire propagation, general objectives of bushfire management might include:

- Reducing the likelihood of fires that have the potential to cause harm to social, economic and environmental values;
- Reducing the severity of fires such that harm to social, economic and environmental values is reduced; and
- Reducing the exposure and vulnerability of social, economic and environmental values that can be harmed by fires.

In relation to the first two objectives, reducing fuel hazard attributes can reduce the likelihood of harmful fires, and reduce the impact of fires that occur in conditions conducive to producing harmful fires. Thus, treating hazards is one of a suite of methods (but not the only method) of controlling risks that can affect the stated objectives. A unique aspect of considering the use of prescribed burning to reduce fuel hazards and overall risk to nearby communities is that the activity itself carries risks that can be significant in the short-term (i.e. during the activity). To optimise the overall bushfire risk management process, a key consideration in determining whether prescribed burning as a risk management option is appropriate is: will the anticipated benefits (in terms of long-term risk reduction) more than offset the short-term heightened risks during prescribed burning activity (e.g. due to ignited fire presence and possibility of escapes)? When a decision has been made to implement a prescribed burn activity, there are some activity-based objectives pursuant to minimising the potential for adverse impacts from the activity, such as:

- Containing fire spread to within the prescribed burn boundaries; and
- Attaining fire behaviour which achieves the fuel reduction, fire behaviour and environmental objectives.

Therefore, assessing fuel attributes so that weather conditions and lighting patterns suitable to achieving both objectives can be selected and applied, and determining appropriate containment strategies and resourcing requirements, will be vital.

In this report, both the bushfire protection and prescribed burning contexts of risk management are considered.

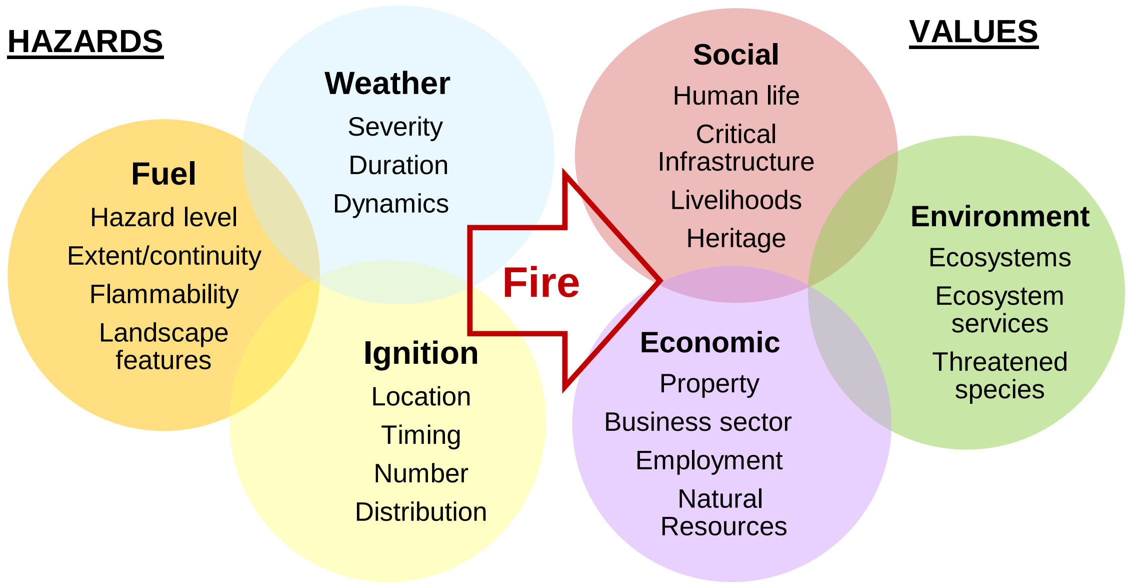
3.3 Risk assessment considerations: Inter-relationships among hazards, values and risks

Fuel hazards, on their own, do not constitute a fire risk. They have to be in a flammable state, have an ignition source, and be in a position that fire, embers or smoke emanating from the hazard can adversely impact values which are vulnerable and exposed to fire elements (flame contact, radiant heat, ember attack and smoke).

Managing the risk of impact from bushfires is different from managing the hazard associated with high fuel levels. While managing fuel hazards is an important bushfire risk management strategy, it is only one of a suite of strategies used.

All attributes of the hazards and values contribute to the degree of risk. The higher the hazard, and the higher the exposure and vulnerability of the values at risk, the higher the risk. The ‘hazard’ elements listed in Figure 4 are factors influencing the ability of a bushfire to ignite, spread and increase size and intensity, the ‘values’ listings broadly describe the things that can be at risk.

Figure 4 Fire risk arises from the intersection of hazards with values (through fire)



Commonly, 'risk' is considered as a combination of the likelihood of an event arising together with the consequences of the event. In this sense, values attributes may sometimes be equivalent to 'consequence' risk factors because they are factors influencing the severity of impacts arising from a fire. Hazard attributes may sometimes be referred to as 'likelihood' risk factors because they are factors influencing the likelihood of a fire starting and propagating. However, they are not exclusively 'likelihood' risk factors as they also influence the size, speed and intensity of the fire which has a major bearing on fire impact or consequences. Hence, the uses of the terms hazards and values to describe the primary drivers of risk achieves the same as considering 'likelihood' and 'consequence' but is more attuned to the focus on fuel and bushfire management.

3.4 Risk management considerations: Scales of assessment and prescribed burn planning phases

Risk assessment processes need to be appropriately tailored to the spatial and temporal scales being considered in planning or operations, and the resolution of outputs required. It may not be productive or efficient to conduct fine scale analysis using high resolution data if broad landscape scale outputs in broad risk categories are required. Equally, it will be sub-optimal to use coarse resolution data and analytical methods designed to deliver broad category outputs, to support decision-making which involves fine spatial and temporal scale consideration. 'Horses for courses' risk assessment processes need to be developed and applied.

The planning phases and operating scales most commonly applied in relation to assessment of bushfire risk and management of fuels are:

3.4.1 Strategic level planning at landscape scale and over decadal timeframes

At the strategic level, planning processes typically involve:

Input information

- Identification of where areas of different level of bushfire hazard are (coarse hazard resolution) and what the fire behaviour potential is for these hazards;
- How far potential impact zones (and types of impact) extend from areas of bushfire hazard;
- Identification of where values vulnerable to bushfire impact are in relation to the hazards and potential bushfire impact zones;
- Identification of ecologically appropriate fire regimes;
- Identification of features in the landscape that can be used to facilitate fuel management; and
- Identification of vegetation/fuel types that can safely, successfully, and sustainably be subject to fuel reduction treatments.

Output information

- Identification of bushfire protection objectives, and any fuel management strategies necessary to achieve these (in concert with other risk reducing strategies);
- Fire behaviour modification (and therefore fuel modification) outcome-based zones (or spatial distribution patterns) identification, with quantitative objectives; and
- Treatment regimes and fire characteristics (e.g. intensity, coverage) to achieve the fuel management and bushfire risk reduction objectives.

In relation to fuel hazards, the above-mentioned processes typically involve fuel hazard attribute inputs at the following scales:

- Vegetation type data across a landscape, coarsely grouped on the basis of fuel characteristics and taking into account the variation in rates of fuel accumulation between vegetation groups. Therefore the rate at which specific vegetation groups accumulate fuel hazard that will trigger treatment, is an important consideration in strategic planning. The overall fuel hazard profile, that is the proportion of fuel hazard in surface, near-surface, elevated and bark components, will also vary between vegetation groups. These factors need to be considered in application and timing of treatments to reduce overall fuel hazard in the landscape;

- Information about the fire behaviour characteristics associated with different vegetation types, cover extents, and different landscape positions (and derived therefrom, information about potential fire impact zones associated with fuel hazards in the landscape); and

- Information about which vegetation types can be treated with prescribed burning and which can't.

Fuel hazard and risk assessment for the strategic planning aspects of prescribed burning is discussed in detail in section 4 of this report.

3.4.2 Tactical level planning of fuel management works programs at landscape scale, over 1 to 5 year timescales

At the tactical program planning level, planning processes typically take the outputs of the strategic planning phase and develop a works program identifying the locations and extents of different work types, their objectives, proposed sequence and timing. Accordingly, in addition to the processes applied at the strategic planning level, they typically involve:

- Identification of areas of different types of fuel hazard at a resolution sufficient to determine types which can be treated with prescribed fire (and which season they should be treated in) and those types that can't be treated;

- Identification of current and predicted fuel hazard levels within tracts of hazardous vegetation; and

- Identification of spatial patterns of fuel hazard level distribution in the landscape.

In relation to fuel hazards, the above-mentioned processes typically involve fuel hazard attribute inputs at the following scales:

- Vegetation type data across a landscape, grouped on the basis of ecological attributes and fuel characteristics;

- For each vegetation type, the growth stage and fuel age distribution in the landscape—these can either be measured or more usually they are modelled or inferred from time since last fire and fuel accumulation curves; and

- Local fuel drying and wetting cycles to determine best season/timing opportunities for burning.

Note: there is a range of other data types that are very important (e.g. features suitable for use as burn boundaries, and local activity/seasonal incompatibility with burning) but these are not fuel attributes so not identified here.

Fuel hazard and risk assessment for the tactical program planning aspects of prescribed burning is discussed in detail in section 5 of this report.

3.4.3 Operational level planning for works implementation at site-specific scale—months to weeks ahead

At the operational planning level, planning processes need to 'operationalise' the planning from the broad where, what, and approximately when level undertaken at the tactical program phase, to the how, in what conditions, and with what resources and risk management measures in place. Accordingly, much more detailed information about fuel and other attributes is required at the operational planning phase, normally involving reasonably detailed site assessment.

Planning processes at the operational planning phase include a number of tasks which require detailed, fine-scale knowledge about fuel attributes:

- Assessing fuel characteristics adjacent to burn boundaries (and what potential fire behaviour they may generate) so that appropriate containment line specifications/standards can be identified for preparatory works;
- Assessing variability in fuel characteristics and condition across the burn area so that appropriate lighting stages and patterns (to achieve fuel reduction and fire behaviour prescriptions), and escape-risk management measures can be planned; and
- Assessing variability in fuel characteristics and condition in areas adjacent to the burn (and what potential fire behaviour they may generate) so that appropriate response contingency requirements can be pre-planned for scenarios of fire breaching burn boundaries.

The above processes and tasks, properly done, involve prediction of fire behaviour under the prescribed conditions, and therefore assessment of fuel attributes enabling the use of fire behaviour prediction guides/models need to be undertaken. Fire behaviour prediction for credible weather scenarios possible after completion of lighting operations, but before burn-out is complete (i.e. during the mop-up and patrol phase) should be done also.

Fuel hazard and risk assessment for the operational planning aspects of prescribed burning is discussed in detail in section 6 of this report.

3.4.4 Work method tactics during burning operations execution to take account of fine spatial scale intra-site fuel variability and weather-driven fuel condition variability

Because operational planning may be done weeks or months ahead of when a burn takes place, such things as fire behaviour predictions and nominated lighting stages and patterns are based on assumptions about fuel attributes (often averaged across whole sites or sections of sites), and weather conditions (typically the desired weather conditions). When a burn is being implemented, fuel attributes may vary significantly across a site, and moisture content may vary within the site or through the lighting period (particularly if this is over several hours or more). Therefore Operations Officers implementing burns will undertake fuel hazard and weather condition assessment on an ongoing basis throughout the burn for the purpose of devising and modifying lighting tactics (e.g. lighting direction, ignition timing, method and spacing) and crew deployment tactics. Fuel hazard (and fire behaviour) assessments undertaken during burning are among the finest scale, highest resolution assessments undertaken during the burn planning and implementation end-to-end process.

Fuel hazard and risk assessment for the burning operations execution phase of prescribed burning is discussed in detail in section 7 of this report.

3.4.5 Post-burn monitoring and modelling of fuel hazards

After a burn is complete, good practice requires assessment of whether the burn objectives have been achieved. Typically, this may involve assessment of:

- Proportion of area within the burn perimeter which is burnt, and patchiness (usually burn prescriptions have a 'treated proportion within the burn perimeter' objective expressed as a range);
- Post-burn fuel hazard rating average for the burn area (either at an 'overall hazard' level or stratified to fuel layers);
- Burn severity (intensity and impact—e.g. scorch height); and
- Whether or not non-target fuels were burnt.

Fuel hazard and risk assessment on the post-treatment context for prescribed burning is discussed in detail in section 8 of this report.

The foregoing concept of prescribed burn planning and implementation phases, and fuel hazard analysis scale/resolution dependencies have been used to structure this report and framework for managing and monitoring fuel hazard risks.

4. FUEL HAZARD AND RISK ASSESSMENT AT THE LEVEL OF STRATEGIC PLANNING FOR PRESCRIBED BURNING

A conceptual framework of what 'strategic level planning' is, in the context of how prescribed burning program requirements are identified is outlined in section 3.4.1 of this report. In this section, an overview of the strategic level planning processes undertaken in different jurisdictions is outlined, and the nature of fuel hazard consideration as part of risk assessment is indicated.

4.1 Hazard mapping for bushfire risk assessment

States and territories use similar but different methodologies for considering levels and attributes of bushfire hazards in bushfire risk assessment.

Some methodologies for hazard mapping used for strategic level planning purposes simply use broad fuel classification systems, based on those used in AS 3959 Construction of Buildings in Bushfire-prone Areas, and in some cases reduced further to a three tier classification system.

Table 1 Vegetation group—fuel hazard categorisation system (NSW)

<table>
<tr><th>AS 3959 Vegetation Classification System</th><th>Fuel Characteristics-based hazard rating</th></tr>
<tr><td>Forest</td><td rowspan="2">HIGH

[Potentially generating high intensity fire, prolific short range ember attack, and longer range spotting]</td></tr>
<tr><td>Woodland</td></tr>
<tr><td>Shrubland</td><td rowspan="3">MODERATE

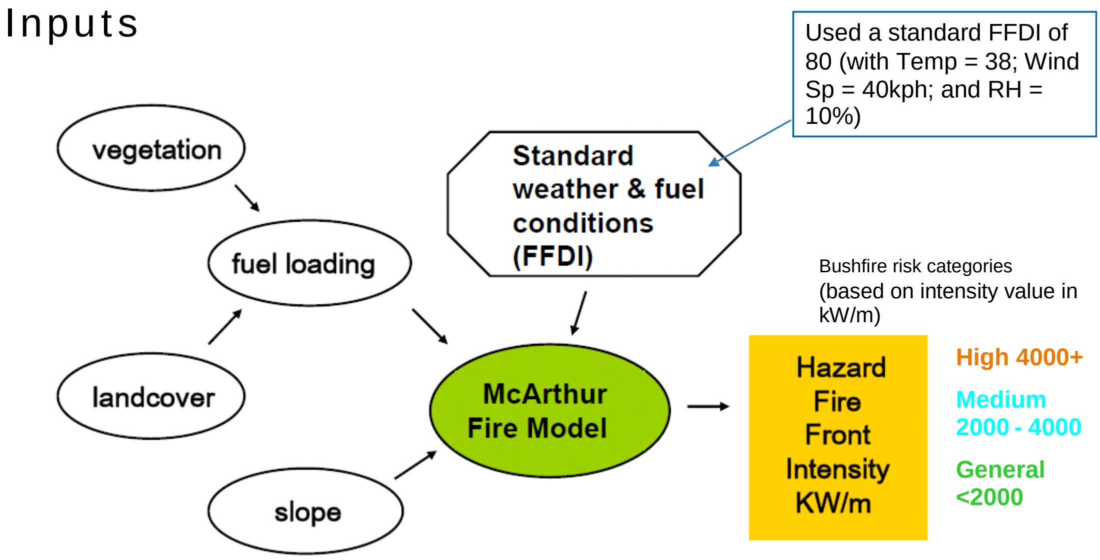
[Potentially generating moderate to high intensity fire, and short range ember attack]</td></tr>
<tr><td>Scrub</td></tr>
<tr><td>Mallee/mulga</td></tr>
<tr><td>Rainforest</td><td rowspan="2">LOW

[Potentially generating low to moderate intensity fire, and short range ember attack]</td></tr>
<tr><td>Grassland</td></tr>
</table>

Some jurisdictions combine other factors into hazard mapping including slope and aspect (e.g. Queensland).

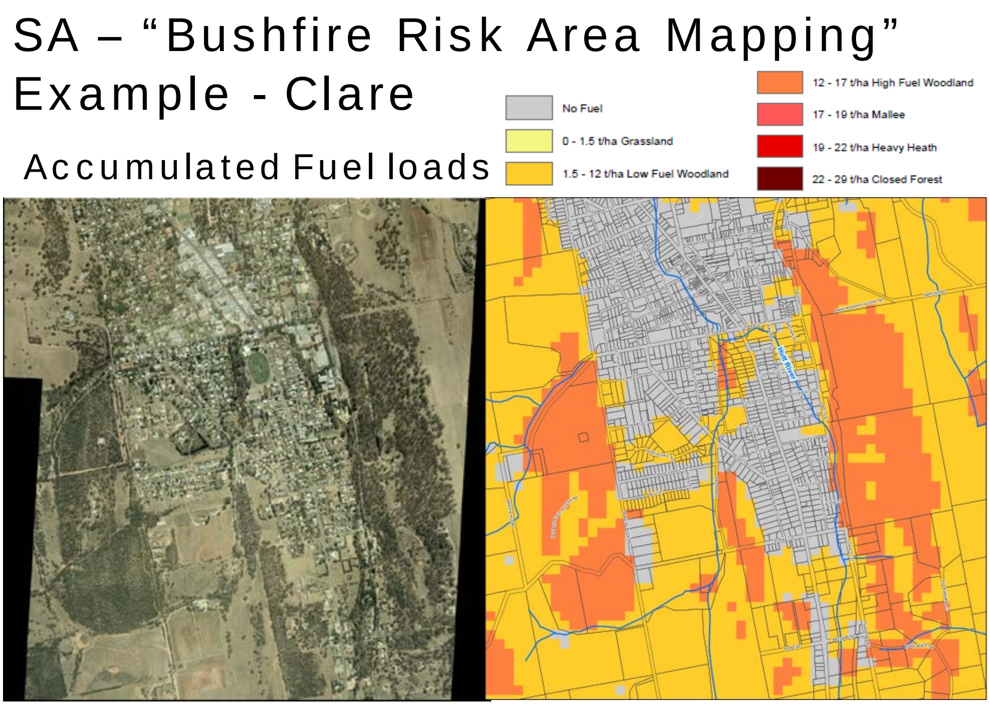
Yet other jurisdictions use standardised fuel loads for identified vegetation classifications, input these into fire behaviour models (combined with slope) to generate a fireline intensity output which is then categorised into a hazard class (e.g. SA, WA, VIC and TAS—each uses a different classification system). Figure 5 on the following page shows an example of hazard rating based on modelled fire behaviour (SA).

Figure 5 South Australian bushfire risk area mapping methodology



The SA approach uses standardised fuel load assumptions for different vegetation classes as inputs to the McArthur Forest Fire Behaviour Model. An example of how this is applied is shown at figure 6 below.

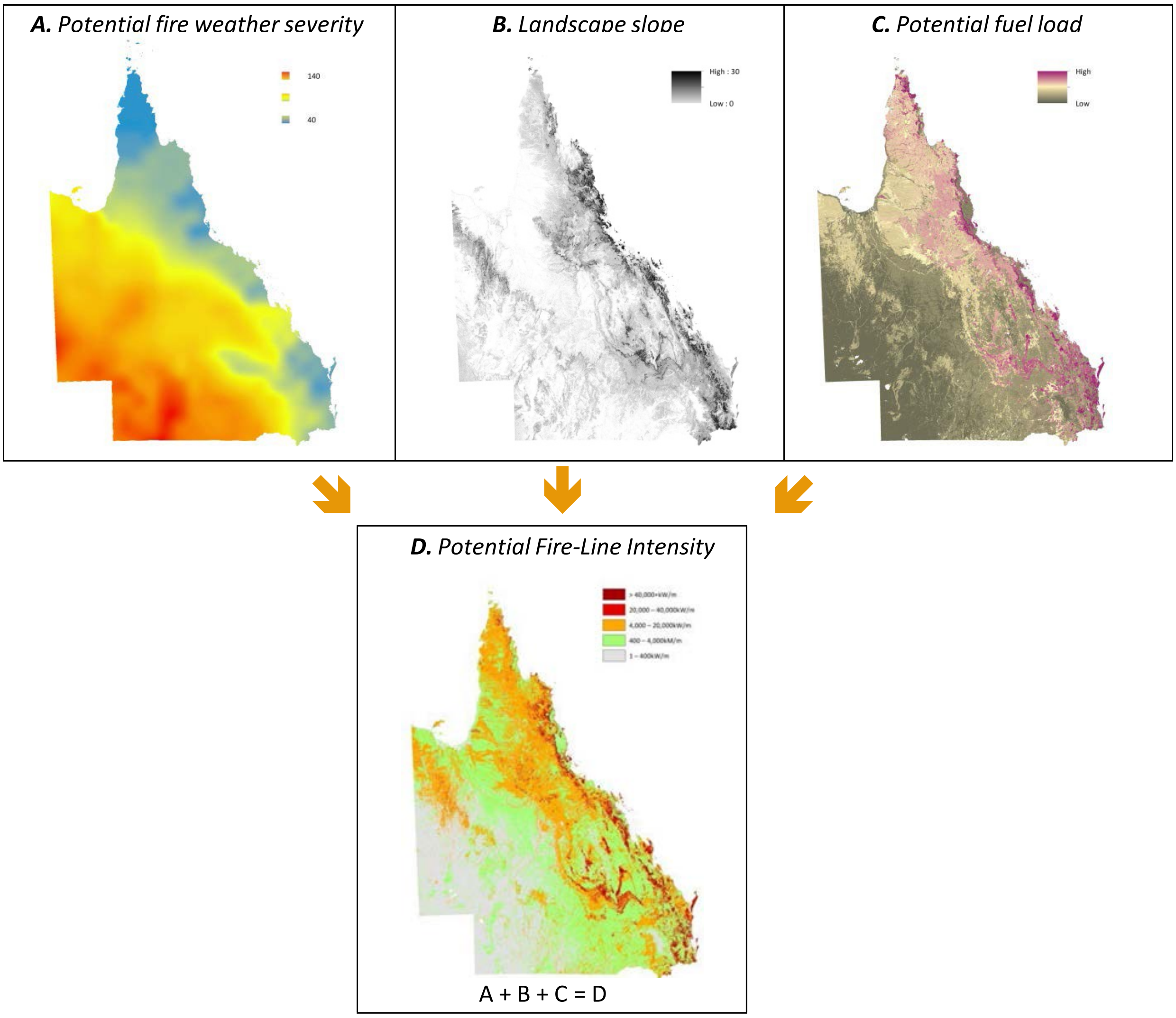
Figure 6 SA fuel load mapping methodology example



It should be noted that while the title applied to the SA mapping process in Figure 6 is Bushfire Risk Area Mapping, it is in practice a hazard mapping process. This mapping is only used to determine bushfire prone areas for development/building control purposes, and is not used for fuel management purposes.

The QLD Government with CSIRO have devised a methodology to determine state-wide Bushfire Prone Areas to support local government strategic planning and to support land management agencies planning bushfire mitigation. It is produced by combining spatial information on potential fire weather severity, landscape slope and potential fuel load to derive fire-line intensity as an indicator of the difficulty of fire suppression.

Figure 7 Queensland—potential fire-line intensity



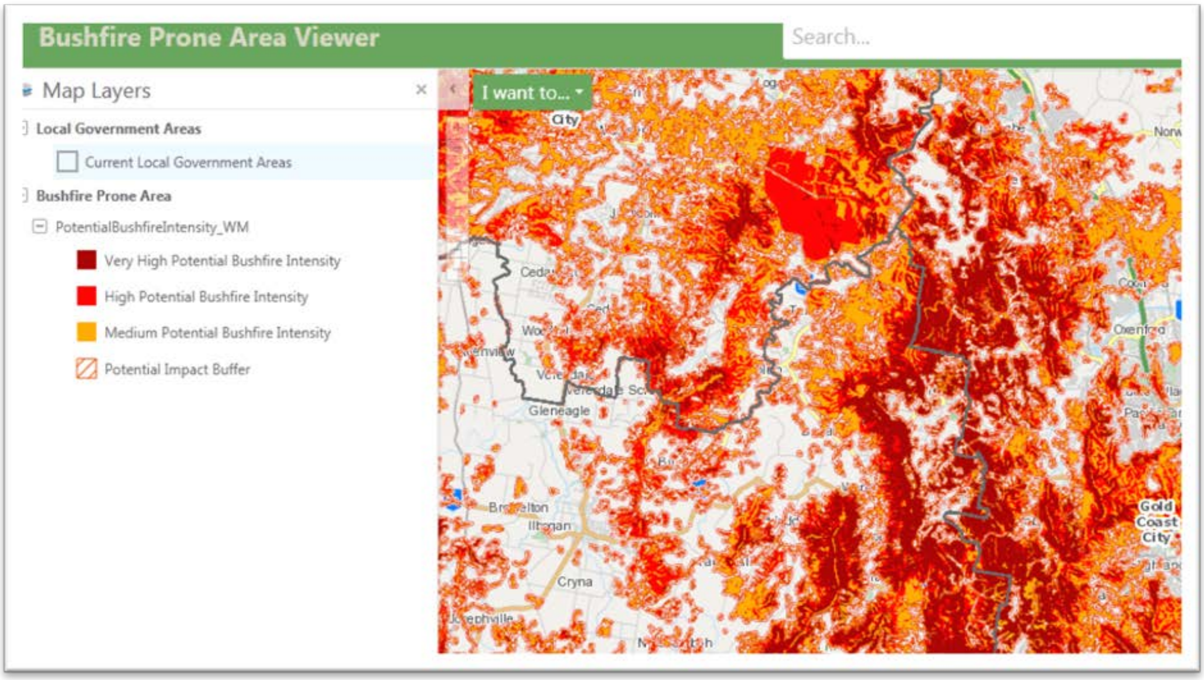
Bushfire prone mapping is then derived from the fireline intensity by removing areas that do not meet minimum thresholds (e.g. small or discontinuous areas that are unlikely to carry fire) and by adding an impacted area buffer. Bushfire prone areas are presented in three categories (shown in figure 8).

Figure 8 Queensland—potential bushfire intensity classes

Potential bushfire intensity class	Potential fire-line intensity
Very high (potential intensity)	40,000+kW/m
High (potential intensity)	20,000 – 40,000kW/m
Medium (potential intensity)	4,000 – 20,000kW/m

The result is broad-scale bushfire prone area mapping (see Figure 9 below) made available to the public, local governments and land management agencies via the internet.

Figure 9 Sample—Bushfire Prone Areas—Gold Coast



The coarse hazard mapping approaches highlighted in this section, and other approaches like them, when used in conjunction with values mapping, can be used to identify where hazards and values intersect and on what scale, and therefore indicate the general locations prescribed burning for strategic protection purposes might be considered as one of a suite of risk reduction strategies.

4.2 Bushfire spread simulation for strategic planning

At the more innovative, emerging end of spatial risk assessment has been the use of bushfire spread models to simulate bushfire growth, spread and potential impact. Such modelling enables the potential consequences of bushfires starting in different locations and under different weather conditions to be assessed. Further, the impact of different hazard reduction treatments can also be assessed in terms of how these modify pre-treatment modelled bushfire spread and impacts.

The jurisdiction where bushfire simulation is being used systematically as a component of bushfire risk assessment is in Victoria. The implementing agency, the Department of Environment and Primary Industries (DEPI), is using the Phoenix Rapidfire simulator to simulate bushfire development, spread and impact.

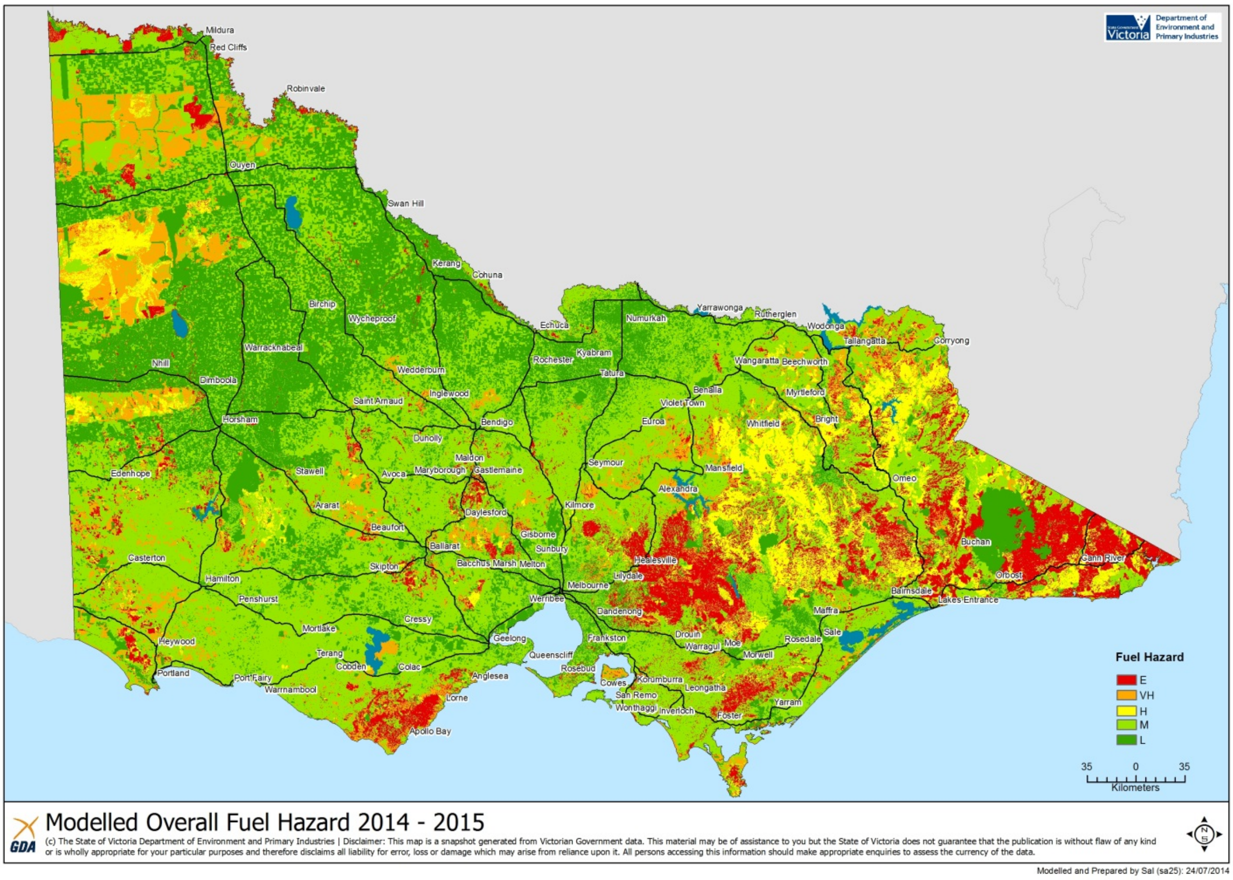
To run, the bushfire behaviour models in Phoenix require:

- Spatial data for vegetation types/classifications covering whole landscapes (not just on at-risk sites or particular land tenures);

- Spatial data for fire history (location/extent, date burnt, fuel reduction effect of fire), both planned and unplanned covering whole landscapes, going back at least 5 years and preferably longer;
- Fuel accumulation curves quantifying fuel characteristics (presently total fine fuel quantity) at different post-fire age classes for all vegetation types;
- Digital elevation model;
- Weather scenario for the period of the fire run (inputs for drought factor, temperature, relative humidity, wind direction and speed);
- Values-at-risk data (e.g. address point locations for property, forestry and agricultural asset types and locations, and other values including threatened ecological communities/species locations and heritage assets); and
- Trained Fire Behaviour Analysts (completed National Fire Behaviour Analyst course) and proficient at running the Phoenix Rapidfire simulator.

Victoria has invested heavily in preparing and validating spatial data to run Phoenix, in particular developing a vegetation-fuel classification system with time-since-fire fuel quantity data. Based on fuel accumulation data for vegetation types, overall fuel hazard can be modelled for current or future years.

Figure 10 Modelled Overall Fuel Hazard—Victoria 2014 – 2015



Some other States are interested in using the Phoenix Rapidfire bushfire simulator however they do not currently have suitable spatial datasets necessary to run the fire behaviour model upon which the simulator runs. Over the past two years the NSW Rural Fire Service has initiated projects which will establish the data necessary to run the Phoenix Rapidfire model. These include spatial capture of fire history for NSW extending back a minimum of five years, but longer where data is available; and classifying NSW vegetation types on the basis of their fuel characteristics and deriving fuel accumulation curves for each. The RFS has commenced putting staff through the National Fire Behaviour Analyst course. GHD understands the aggregate cost of these projects has exceeded $1 million.

The WA Land Information Authority (Landgate), The WA Department of Fire and Emergency Service (DFES) and University of Western Australia have developed Aurora as a national prediction, detection, simulation and early warning system. Aurora shows real-time fire spread predictions via the web using hotspot and weather data feeds and is supported by vegetation, fuel and topographical data. Although developed as a national system, it is only currently used by DFES.

Presently there is no national fuel classification system in place, although AFAC and FFMG have engaged CSIRO to develop a national fuel classification system over the next two years. The outputs of a national fuel classification system should be suitable to use in fire behaviour modelling.

Simulators have been developed overseas; however, these operate using either the Rothermel fire behaviour model designed for vegetation types in the US (e.g. FARSITE and GeoFogo), or Canadian fire spread models based on Canadian vegetation types (e.g. Prometheus). Due to Australian vegetation types being significantly different from north American vegetation types, and north American fuel classification systems not being relevant for Australian vegetation types, those models are not used extensively in Australia. However, the Prometheus system is used in Tasmania and New Zealand.

4.3 Objectives-based fuel management zoning

From the foregoing consideration of where fuel hazards are, their fire behaviour potential and their proximity to values-at-risk; the strategic planning phase for prescribed burning involves deciding where programs of prescribed burning will be undertaken, and what the fuel reduction objectives of intended treatments will be. In a number of jurisdictions, a fuel management 'zoning' system is described (e.g. NSW, QLD, VIC, ACT, TAS, SA) with different fuel management objectives assigned to each zone. By contrast in WA, the landscape is not apportioned to fixed fuel management zones, rather, strategic plans identify spatially-explicit objectives for how far a bushfire should be able to spread before running into a fuel reduced area, and then tactical plans identify how burns should be distributed in the landscape to meet the stated objective.

In well-designed zoning strategies, the location, effective dimensions, and desirable fuel characteristics (and indicative treatment regimes) of a zone should be objectives-based.

Typically, jurisdictions which use a fuel management zoning have adopted an approach generally consistent with the fuel management zoning approach outlined in the COAG National Inquiry on Bushfire Mitigation and Management (Ellis *et al.* 2004). The COAG Inquiry report stated:

This Council of Australian Governments Inquiry supports the adoption by all states and territories of a system for classifying fuel management zones across the landscape—not solely within individual land *tenures. The zone category would direct the nature and priorities for risk-management action.* COAG Report (p 124).

The COAG Inquiry report provided an example of a fuel management zoning system comprised of:

- ***Asset protection zone***—this is typically the rural-urban interface, where regular fuel reduction should be undertaken in the vicinity of specific assets;
- ***Strategic fuel management zone***—this aims to provide areas of reduced fuel in strategic areas, to reduce the speed and intensity of bushfires and reduce the potential for spot-fire development;
- ***Land management zone***—the primary purpose here is to meet the objectives of the relevant land manager, which can be planned fire for fuel reduction, biodiversity conservation or forest regeneration; and
- Fire-sensitive areas such as rainforests or pine plantations will usually require fire exclusion and can be identified as assets requiring protection from fire, or allocated to a fire-exclusion zone.

Figure 11 DEPI Victoria's Code for Bushfire Management on public land

Asset Protection Zone (APZ)

126. Using intensive fuel treatment, the Asset Protection Zone (APZ) aims to provide the highest level of localised protection to human life and property and key community assets. The goal of fuel treatment is to reduce radiant heat and ember attack in the event of a bushfire. Fuel treatment will be carried out in the APZ through a combination of planned burning and other methods such as mowing, slashing or vegetation removal.

127. Achieving the objectives of this zone may have negative impacts. Where this is likely, the Department will seek to moderate the negative impact as far as practicable.

Bushfire Moderation Zone (BMZ)

128. This zone aims to reduce the speed and intensity of bushfires. This zone complements the APZ in that the use of planned burning in the BMZ is designed to protect nearby assets, particularly from ember spotting during a bushfire.

129. Where practicable, the BMZ will aim to achieve ecological outcomes by seeking to manage for ecologically desirable fire regimes, provided bushfire protection objectives can still be met. This may include using other fuel management methods.

Landscape Management Zone (LMZ)

130. Within this zone, planned burning will be used for three broad aims:

- bushfire protection outcomes by reducing the overall fuel and bushfire hazard in the landscape
- ecological resilience through appropriate fire regimes
- management of the land for particular values including forest regeneration and protection of water catchments at a landscape level.

Other fuel reduction methods will be used within this zone as appropriate.

Planned Burning Exclusion Zone (PBEZ)

131. This zone excludes the use of planned burning primarily in areas intolerant to fire.

The extract above is from DEPI Victoria's Code for Bushfire Management on Public Land and describes the fuel management zoning system used, and the general purpose of each zone.

Like most other fuel management zoning systems used in Australia, zone objectives are stated in general or relative terms (e.g. reduce speed and intensity of fire). More specific objectives relating to target fuel characteristics and zone dimensions are usually detailed for Asset Protection Zones, but are usually not specified or are very general for other zones. Due to not being defined in objectives or planning guidance, the matter of what proportion of a landscape to treat with each zone, what dimensions particular zone types should have (and why), and what level of fuel reduction should be targeted within the zone thus remain vague and open to polarised debate. A more detailed discussion of strategic planning issues and considerations is contained in the report: National Burning Project—Review of Best Practice for Prescribed Burning (AFAC 2014).

4.4 Section summary

At the strategic planning level, only relatively coarse resolution fuel hazard data is required to enable identification, in broad hazard categories, of the general locations where hazards intersect with values to be protected. Australian jurisdictions are using a range of different spatial methodologies to generate hazard or fuel risk maps. No two jurisdictions have the same methodology, and within some jurisdictions, agency approaches differ.

Higher resolution and finer scaled consideration of fuel hazard attributes is enabling the use of bushfire simulation technology which has the advantage that scenarios can be examined for a range of weather and future fuel distribution scenarios. These high-tech approaches are data and resource intensive; however, for those in a position to apply the necessary resources, such approaches enable future-casting of bushfire scenarios under a range of different management strategies, and enable options effectiveness evaluation.

The common ground across jurisdictions is that fuel hazard assessment processes at the strategic planning scale have broad category outputs, typically on a 3 to 5 point scale. Accordingly, there is some potential for standardising approaches across two or more jurisdictions if the will exists to do so.

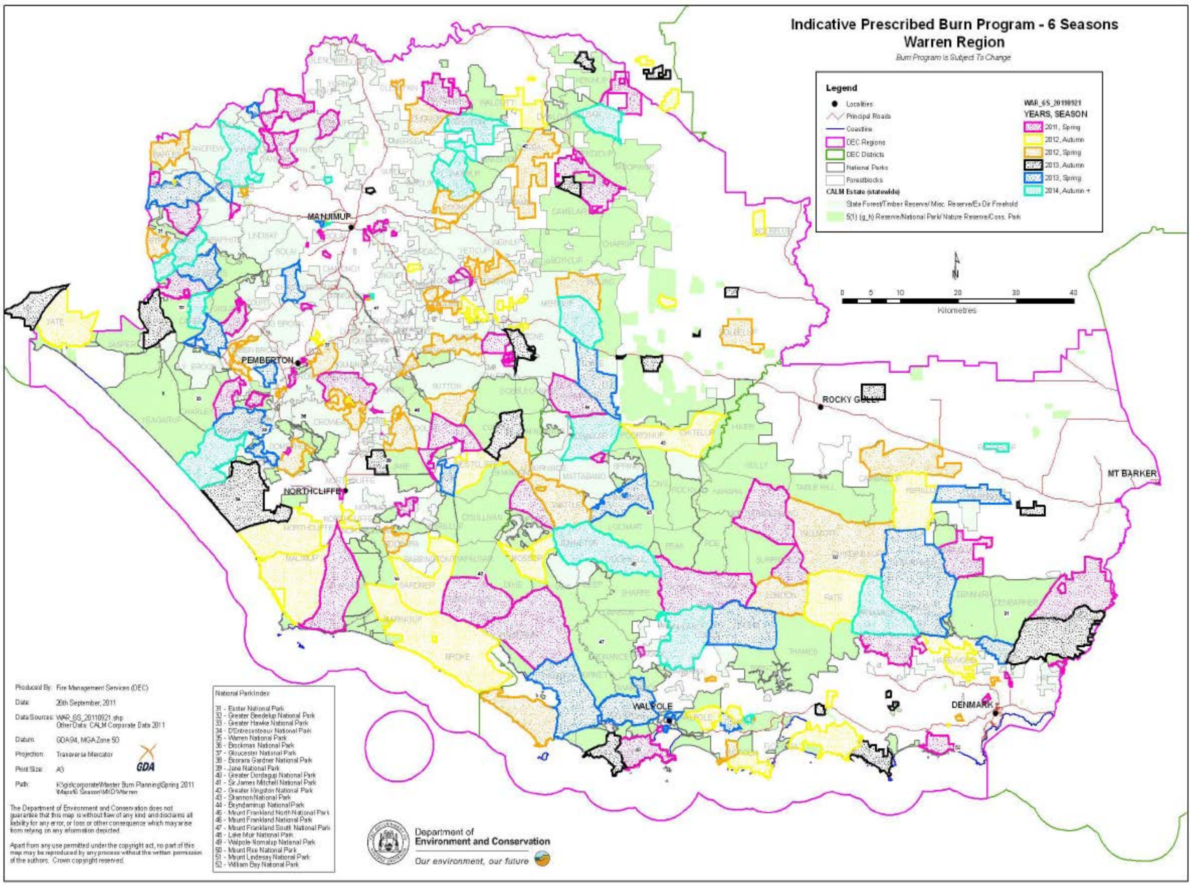
5. FUEL HAZARD AND RISK ASSESSMENT AT THE LEVEL OF TACTICAL (PROGRAM) PLANNING FOR PRESCRIBED BURNING

At the tactical program planning level, planning processes typically take the outputs of the strategic planning phase and develop a works program identifying the locations and extents of different work types, their objectives, proposed sequence and timing.

5.1 Tactical (program) planning outputs and time horizons

The outputs of tactical program level planning are typically maps and/or tabulated work-lists showing where and when works are planned to be undertaken. Examples of works programs extending over a three year period include Victoria (DEPI's Fire Operations Plans) and WA (DPAW's Master Burn Plan). These plans are reviewed annually in the case of DEPI, and six-monthly in the case of DPAW.

Figure 12 Example of a Prescribed Burn Program (DPAW WA, Warren Region)



In Figure 12 above, the three year, six-season indicative burn plan for DPAW's Warren Region is shown. Prescribed burns are proposed for each autumn and spring over a three year period. Burns are distributed across the public land estate, not just close to built assets.

The Department of Defence has a tactical works planning cycle for its lands, extending over five years, with a five year review period unless brought-forward by the occurrence of bushfires significantly affecting the planned future works program.

Some jurisdictions undertake tactical planning at a one year ahead time scale only (e.g. NSW, NT). QLD undertakes tactical planning at a one to three year timeframe.

5.2 Fuel hazard attributes considered in tactical (program) planning

In terms of fuel hazard attributes, the main fuel factors considered in the tactical planning phase are:

- Vegetation type/group; and
- Time since last fire.

Spatial data for these attributes are usually held by land and fire management agencies. The latter is used as an indicator of fuel hazard level, and is used in conjunction with the former for considering fire regime requirements.

Fuel hazard attributes are not the sole driver of tactical planning processes. A key driver of tactical planning is the availability and quality of roads and trails in the landscape from which prescribed burns can be lit and controlled. The availability of trails to work from provides a major constraint to where burns can be placed, and what dimensions and orientation burn areas can have.

Some agencies undertake 'open-ended' or unbounded burning where natural features (low fuel, previous burns or high moisture areas) in the landscape are used to contain burns, or impending weather will limit fire spread and extinguish the burn.

5.3 Intuitively considered fuel hazard attributes

There are however other fuel attributes which are often taken into account by prescribed burn program planners at the tactical planning stage. These are considered on a more 'intuitive' basis by local fire planners rather than on a structured quantitative or semi-quantitative basis. They include:

The landscape position and dimensions of the fuel hazard

Agencies use historical and intuitive knowledge of how fires spread through landscapes as an input to determining prescribed burn location and dimensions. For example, north to west facing slopes may be targeted on the basis that very high intensity fire runs can occur in such locations due to the alignment of up-sloping ground with adverse fire weather direction. Such landscape locations are also known to generate long distance spotting. The convection column from high intensity fires running up hill can weaken when fire reaches the top of a slope, resulting in fire brands falling out of the column and coming to ground whilst still alight.

Large landscape areas with poor access for fire suppression, where bushfires can grow to a significant size, making large runs with the onset of adverse fire weather, may be targeted for unbounded burning treatments (e.g. ridge system burning) to break up the continuity of heavy fuel accumulations.

The proximity of recently burnt areas and other low fuel areas in the landscape:

Tactical program planning is rarely, if ever, random. A significant factor influencing tactical program planning is the location of areas recently burnt by bushfires or other prescribed burns. Agencies typically look for opportunities to link low-fuel areas in the landscape to provide contiguous fuel-reduced areas, particularly across potential fire-paths, so that unplanned bushfire spread may be slowed when it reaches these areas, and thereby reduced in extent and intensity. Recently burnt areas also provide areas in the landscape to assist prescribed burn control. For example, prescribed burns may be lit in conditions such that they spread toward recently burnt ground. This practice is commonly used in unbounded burning undertaken in tropical and semi-arid Australia, but is also practiced in southern States.

The long-distance spotting potential of the vegetation:

The spotting propensity of vegetation can also be a factor taken into account when planning prescribed burns. In well-conceived prescribed burns, planners will give consideration to what spotting distances are typically associated with different fuel hazard types, and plan the depth of the burns accordingly where containment feature choices allow. Known high spotting propensity problem-fuels may be selected for burning when conditions are not conducive to spotting.

5.4 Fuel hazard attributes and burn timing

Tactical (program) plans often identify an intended season for burning. The selection of season for burning may be driven by seasonal rainfall cycles, fuel drying and wetting cycles and humidity cycles.

In northern NSW, early spring burning is commonly practiced following the typically low winter rainfall period and frost curing of grasses. In autumn, vegetation types with grassy fuels may be difficult or impossible to burn due to being green following the summer peak rainfall period and prolific growth period extending into autumn.

In southern Queensland, cool and drying conditions in winter allow prescribed burns to be undertaken readily. Spring tends to be a period of increasing fire danger as humidity drops and strong westerly winds emerge. Summer is often too wet, but runs of fine weather in summer and autumn allow prescribed burning supported by good soil moisture.

In northern Australia, burn timing is driven by the monsoon cycle. Smaller scale, lower intensity burns can be achieved early in the dry season once grass fuels have dried out sufficiently to carry fire after the wet season. Larger scale, higher intensity fires are likely to occur later in the dry season.

In southern Australia, both spring and autumn burning are practiced, largely driven by the wetting and drying cycles of particular vegetation types and when they can be burnt at low intensity.

For example, some vegetation types may be difficult to burn on a drying cycle because they are at first too wet, and by the time they are dry enough to sustain fire spread, it may be too close to fire danger periods to contemplate burning. One example is Karri burning in south-west WA. The winter rainfall peak may leave heavy fuel accumulations in Karri forest too wet to burn in early spring. By the time the fuel has dried sufficiently to sustain fire spread, it may be too close to summer when west coast troughs have become established as part of the late spring to early autumn weather pattern and adverse weather can be expected. Mid-autumn may be preferable as fuels have been dry over summer, have started to increase in moisture due to shortening day length and cooler night conditions, and the risk of adverse fire weather after burning has greatly diminished.

Some burns may require two-stage (or multiple-stage) burning. For example, north to west aspects may be in a condition suitable for low intensity burning in early spring, however, more sheltered aspects may be too moist to burn when the more exposed aspects will burn, and will therefore need burning at a later time when they have dried out sufficiently to carry fire.

Therefore, burn timing is routinely proposed on the basis of typical seasonal climate cycles, according to rising and falling fuel moisture trends in the locality. While a season of burning can be nominated, program delivery management must have a high degree of flexibility to account for variability in seasonal drying patterns across the landscape. Some parts of a geographic area may be too wet or too dry to burn at the nominally planned time, and therefore flexibility to deploy resources to areas where burning conditions are favourable will be required. In practice, nominal seasonal work plans and schedules are merely a basis for planning, with change a necessity driven by local and seasonal climate variability.

5.5 High-flexibility tactical planning in northern Australia

The most flexible approach to tactical planning and extensive use of open-ended and unbounded burning occurs in tropical Australia. Tactical planning is undertaken as an ongoing process throughout the fire season. Firstly, the distribution of fire scars from the previous fire season is assessed using satellite imagery, followed by the planning of where to commence planned burning based on:

- The location of fuels that are sufficiently dry to carry fire;
- The location of fire scars that can be used to limit fire spread, and to which prescribed burns can be linked;
- The location of not-yet-flammable fuel areas that can be used to limit fire spread;
- How prolific or otherwise seasonal vegetation growth has been;
- The ability to use areas of flammable fuel to push fire into less flammable areas;
- The ability to create early season fire scars as boundaries to support later season fires;
- Seasonally prevailing wind direction; and
- Ground access, control opportunities and limitations.

It is common practice for burning to be undertaken in older fuels (in the grass dominated landscapes of the Top End, fuels older than two years may be considered old fuels) with burning undertaken such that prescribed burns run into previously burnt areas. As the early dry season progresses, new fire scars are continually monitored using satellite imagery—updated daily on the Northern Australia Fire Information (NAFI) network website—with prescribed burns progressively planned opportunistically to link burnt areas to provide burnt buffers in the landscape which may serve to restrict the spread of late dry season fires which burn at higher intensity and would otherwise burn much larger areas. The highly tactical burn planning approach which must be completed in relatively short timeframes (2 to 3 months) across very large areas necessitates extensive use of open-ended and unbounded burning using aerial ignition. The annual grass fuel recovery cycle, high fire frequency environment, large landscape scale and limited access and resources demands the high-flexibility open-ended burning approach. Data from NAFI, as well as committed and competent people are important aspects in supporting this complex and dynamic regime.

5.6 Section summary

The key aspects of managing risk at the tactical program phase of the prescribed burn planning process are:

- In relation to landscape level bushfire risk - selecting locations for prescribed burning that will optimise risk reduction benefits; and
- In relation to prescribed burning risk—taking into account the recent fire history and current landscape condition, determining the most appropriate vegetation types and fuel characteristics, landscape position and burning conditions (seasonal timing) for minimising the risks associated with burning operations.

There are a range of fuel hazard attributes considered by program planners. These are a mix of commonly available spatial data layers (e.g. vegetation type and fire history/fuel age), and intuitive local operational knowledge based considerations including how fires develop and spread in the landscape, the spotting potential of particular fuel hazard types and terrain features, and locations where there are poor prospects of controlling fires.

Burn timing is driven by local knowledge of grass curing and forest fuel drying and wetting cycles, how fuel hazard types respond to these, and regional cycles of adverse weather occurrence.

Optimised tactical program planning takes account of all these factors.

The intuitive factors considered may be undocumented, being ‘local knowledge’ that is maintained in an organisation on a geographic management area basis, passed on by on-the-job oral history basis.

There is common ground among jurisdictions in that spatial data on vegetation types and fire history is routinely collected, although not to any standard specification.

Note: there is a range of other data types that are very important (e.g. features suitable for use as burn boundaries, and local activity/seasonal incompatibility with burning) but these are not fuel attributes so not identified here.

6. FUEL HAZARD AND RISK ASSESSMENT AT THE LEVEL OF OPERATIONAL PLANNING FOR PRESCRIBED BURNING

Once a prescribed burn has passed through the nomination and approval process at the tactical program level, it passes in to the operational planning phase. At the operational planning level, planning processes are undertaken to 'operationalise' the planning from the broad where, what, and approximately when level undertaken at the tactical program phase, to the how, in what conditions, and with what resources and risk management measures in place. Accordingly, much more detailed information about fuel and other attributes is required at the operational planning phase, normally involving reasonably detailed site assessment.

6.1 Components of an operational burn plan

The vast majority of Australian and New Zealand fire and land management agencies which undertake prescribed burning have a planning template. No two jurisdictions use the same operational planning template, and in many jurisdictions, templates are developed at the agency level. However, there are a number of common planning elements between jurisdictions, including:

- Burn identification (name and/or number), agency and management area/unit details;
- Brief description of the burn area (including area, vegetation types/condition, when last burnt, and terrain features) and fuels (using agency system for classifying and rating/quantifying fuel hazard levels);
- Purpose(s) of the burn (e.g. property protection, ecological etc.);
- Burn objectives and/or success criteria;
- Burn prescriptions (these usually cover weather and fuel moisture parameters for the burn, and may extend to desired fire behaviour parameters);
- Environmental prescriptions/conditions;
- Pre-burn preparations to be undertaken;
- A map showing areas to be burnt, exclusion areas, containment lines, water points, terrain, identification of values and risks within and adjacent to the burn, resource organisation and allocation, escape routes and safety zones, public safety control points (e.g. no public access areas, traffic management points), safety hazard locations etc.;
- Risk assessment for the burn;
- Resource requirements for the burn;
- Notification requirements (e.g., neighbours, stakeholders and public);
- A lighting strategy for edge and core ignition (some plans may specify standards for these);
- Organisation and communication arrangements during the burn;
- Pre-determined suppression strategies in the event of spotovers or escapes;

- Operations and safety briefings and checklists;
- Relevant agency endorsements and authorisations;
- Record keeping and reporting requirements; and
- Post-burn monitoring requirements.

As can be seen, there are many matters to be addressed, with fuel hazard risk aspects only a small, but very important component.

6.2 Consideration of fuel hazard attributes in operational planning

Planning processes at the operational planning phase include a number of tasks which require detailed, fine-scale knowledge about fuel attributes. These operational planning tasks include:

- Assessing fuel characteristics adjacent to burn boundaries (and what potential fire behaviour they may generate) so that appropriate containment line specifications/standards can be identified for preparatory works;
- Assessing variability in fuel characteristics and condition across the burn area so that appropriate lighting stages and patterns (to achieve fuel reduction and fire behaviour prescriptions), and escape-risk management measures can be planned; and
- Assessing variability in fuel characteristics and condition in areas adjacent to the burn (and what potential fire behaviour they may generate) so that appropriate response contingency requirements can be pre-planned for scenarios of fire breaching burn boundaries.

In relation to point two, an interesting recent case is the Margaret River fire in WA which was an escaped prescribed burn. The lesson learnt here was that in practice, some planned burn blocks will not be able to be burnt using one ignition event because the different fuel types require different burning conditions to sustain fire spread. In such situations, a multi-stage burning strategy needs careful consideration, with attention given to predicting what vegetation types will burn under what conditions, and then planning the various burn stages in an order that enables fire risk to be managed, and in particular, to specifically identify residual risks to be managed in between burning stages.

The above points, properly done, involve prediction of fire behaviour under the prescribed conditions. Therefore assessment of fuel attributes enabling the use of fire behaviour prediction guides/models need to be undertaken. Further, fire behaviour prediction for credible weather scenarios possible after completion of lighting operations, but before burn-out is complete (i.e. during the mop-up and patrol phase) should be undertaken.

Australian land and fire management agencies have relatively few prescribed fire behaviour prediction guides available to them. The main forest fire behaviour models in use in south-eastern Australia (McArthur Mk 5 Forest Fire Behaviour Meter, and VESTA Dry Eucalypt Forest Fire Behaviour Guide) are for established lines of fires burning in summer conditions and have relatively poor resolution at the low end of the FDI scale at which most prescribed burning is undertaken.

In many coastal and higher rainfall zone heath types, there are no fire behaviour models currently in operational usage. Operationally used heath models are principally for mallee-heath in semi-arid zones.

Grass fire behaviour meters (for northern tropical Australia, and southern Australia) are widely used.

McArthur's Leaflet 80 for prescribed burning in dry Eucalypt forests is no longer in widespread use—but is used to a limited degree in NSW and ACT.

In Queensland, Leaflet 80 has been adapted as part of a collection of tools presented in the field guide How to Assess if Your Burn is Ready to Go. The guide presents tabulated fire behaviour predictions for different forest fuel types/structures, together with guidance on assessing weather patterns, drying times, fuel moisture, fuel hazard and fire severity. It is designed to support assessment of predicted fire behaviour and severity against stated prescribed burn objectives emerging from the development of ecological Planned Burn Guidelines for each of the 13 terrestrial bioregions of Queensland.

Western Australia makes systematic use of prescribed fire behaviour predictions using the Red Book, which provides tabulated fire behaviour prediction for a range of forest fuel types/structures occurring in south-western Australia. It is however forest-focussed and does not specifically provide for fire behaviour prediction in heath and shrubland vegetation types.

Ideally, to support operational planning for prescribed burning, fuel assessment outputs should provide the input requirements for fire behaviour models. Table 2 on the following page identifies the fuel hazard assessment approaches/procedures currently used in conjunction with prescribed burning.

Table 2 Fuel assessment systems used in Australia and New Zealand

Jurisdiction	Fuel Hazard Assessment Systems used	Comments
Australia Wide	Field Guide—Fuel Assessment and Fire Behaviour Prediction in Dry Eucalypt Forest	Commonly referred to as the 'VESTA fuel assessment guide' • 6 category scale for Surface Fuel; Near Surface Fuel; Elevated Fuel; • 5 category scale for Bark Fuel; • Provides fuel 'ratings', 'hazard scores', and t/ha range for each category; • No 'Overall' or total fuel categories; and • Not linked to any fire behaviour prediction model designed for application for prescribed burning.
Queensland	Field Guide—How to Assess if Your Burn is Ready to Go, and CSIRO Grassland Fire Danger Meter (in Northern Queensland)	The field guide includes estimates of: • Fuel drying times and fuel moisture; • Fuel load estimates derived from surface fuel estimates combined with three tiers of elevated fuel load estimates. Outputs as total fuel load (t/ha) for use in Leaflet 80 adapted tables; • Consideration of Victorian Overall Fuel Hazard guide (as an additional consideration after fire behaviour and severity is estimated).
NSW	Uses Victorian Overall Fuel Hazard Guide (for RFS Hazard Complaints System)	NSW not using VESTA fire behaviour guide—still using McArthur Mk 5, therefore fuel assessment outputs are predominantly in total fuel load (t/ha). Makes some use of McArthur Leaflet 80 for prescribed fire behaviour prediction in Dry Eucalypt Forests - uses fuel quantity in t/ha.
Victoria	DSE Overall Fuel Hazard Assessment Guide 4th edition 2010	Commonly referred to as the Victorian Overall Fuel Hazard Guide • 5 category scale for Surface Fuel; Near Surface Fuel; Elevated Fuel; • 5 category scale for Bark Fuel in 3 bark-type categories; • Provides fuel hazard 'rating'; • Provides a conversion table for converting VIC Fuel Hazard Rating to VESTA 'hazard score'; • Provides a conversion table for converting VIC Fuel Hazard Rating to fuel load (t/ha range) for each layer; • Contains a look-up table system for aggregating surface and near-surface fuel layers into a combined rating; and • Contains a look-up table system for aggregating all fuel layer layers into an 'Overall Fuel Hazard Rating'. Not linked to any fire behaviour prediction model designed for application for prescribed burning
ACT	Uses Victorian Overall Fuel Hazard Guide.	See notes above for Victoria.

Tasmania	A range of methodologies used including Mount AB (1972), Marsden-Smedley and Catchpole (1995) and elements of VIC OFHG and VESTA fuel assessment guide.	Fire behaviour prediction not routinely undertaken for prescribed burning. Forestry Tasmania fuel assessment outputs are total fine fuel weight (t/ha). Parks and Wildlife Service using VIC OFHG. Marsden-Smedley and Catchpole model for buttongrass moorland and Canadian pine plantation models are sometimes used.
South Australia	DENR Overall Fuel Hazard Guide for South Australia 2nd edition 2011	Very similar to, and based upon, the Victorian Overall Fuel Hazard Guide. Surface and Near-surface fuels are combined. Using CSIRO mallee-heath burning guide for prescribed burning in semi-arid heathlands.
Western Australia	DEC WA use 'Forest Fire Behaviour Tables for WA'—known as the Red Book. DFES use a range of 'Visual Fuel Load Guides' specific to bioregions in WA.	Features of the fuel assessment approach incorporated in the Red Book are: • Uses surface litter depth to calculate a litter weight in t/ha (using a relationship table); • Uses a scrub fuel weight calculation methodology using combinations of 'scrub height' and 'scrub density rating' for a range of specified 'scrub structural types'. Available scrub fuel is differentiated between low intensity prescribed burns, moderate intensity bushfires, and high intensity bushfires; and • Adjusts 'available scrub fuel loading' on the basis of a scrub flammability rating. Features of FESA's fuel assessment methodology are: • Adopts the Red Book surface litter weight calculation methodology; • Uses a field photo guide to determine 'scrub fuel' quantity; and • Overall fuel load is the combination of litter and scrub fuel quantities.
Northern Territory	Kimberly Grasslands Field Curing Guide for use with CSIRO's Fire Spread Meter for Northern Australia	Fuel characteristics semi-arid and arid vegetation types are mostly considered on the basis of time or cumulative rainfall since the last fire to identify thresholds at which fire spread will be maintained.
New Zealand	SCION Manual for predicting fire behaviour in New Zealand Fuels	Fuel load assessment section provides look-up tables for estimating 'available fuel load' in different vegetation types under different conditions including: • Pine plantations of different ages; • Indigenous forest types; • Ungrazed and grazed pasture grasslands; • Crop stubble; • Tussock grasslands; and • Scrublands (Gorse; Manuka/Kanuka; Heathlands/Wetlands; and scrub hardwoods).

6.3 Reference to fuel assessment outputs in operational plans

As discussed in section 6.1 operational plan content varies between jurisdictions, and in some cases between agencies within a jurisdiction. However, reference in operational plans to fuel hazard assessments is reasonably consistent between jurisdictions. The following references to fuel hazard assessments are usually made:

- Pre-treatment fuel quantity or 'hazard level' is documented, typically averaged across the whole prescribed burn area or averaged for each major vegetation group within a prescribed burn area;
- Quantitative or semi-quantitative fuel reduction objectives are established for the burn (e.g. reduce average fuel weight across the burn area from X t/ha to Y t/ha, or reduce the overall fuel hazard rating for the burn area from Very High to Moderate);
- Based on the fuel assessment and the weather prescriptions for the burn, expected fire behaviour within the burn area may be documented;
- Based on weather prescriptions for the burn, and fuel assessment in areas adjacent to the burn, expected fire behaviour in areas to which the burn could escape may be documented;
- Fuel assessments will inform risk assessments undertaken for the burn;
- Lighting methods and patterns will be devised based on fuel assessments as a key input;
- Choice of containment line (if not pre-determined at the tactical program planning stage) may be based on fuel assessments as a key input;
- Levels and types of resourcing for lighting and control of the burn will be devised based on fuel assessments as a key input; and
- Levels and types of resourcing for ongoing mop-up and patrol of the burn beyond the ignition days will be devised based on fuel assessments as a key input.

6.4 Fuel assessments as a component of burn risk assessment

Australian and New Zealand land and fire managers apply widely varying approaches to 'risk assessment' for burning operations. Some undertake structured, semi-quantitative risk assessment processes using programmed spreadsheet tools (e.g. Tasmania, Victoria and South Australia), some of which incorporate fire behaviour model formulas. Other jurisdictions have more qualitative approaches to risk assessment, focussed principally on documenting the nature of identified risks, and the controls to be applied in managing them. Risk assessments are broader than fuel hazard related risks alone, but generally do incorporate fuel hazard related risks. Fuel hazard related risks are focussed on key areas including:

- Risk of fire causing harm to firefighters and their equipment;
- Risk of fire causing damage to non-relocatable values within or immediately adjacent to the burn;
- Risk of fire escaping burn boundaries and impacting values outside the designated burn boundary; and
- Risk of fire behaviour exceeding desired parameters within the designated burn area and therefore compromising burn objectives.

Example of fuel hazard consideration within risk assessment tools

On this and the following two pages, some re-created screen-grabs showing the fuel hazard risk related components of the SA Department of Environment, Water and Natural Resources' (DEWNR) Burning Risk Assessment Tool (BRAT) are shown. It is important to identify that the BRAT is not an end in itself. Its introduction and use in DEWNR is as much about inculcating risk assessment into burning practice and communicating risk as it is about assessing the risk of a particular burn.

Figure 13 Input screen for fuel hazard attributes (sample selection)

SOUTH AUSTRALIAN PRESCRIBED BURN RISK ASSESSMENT TOOL		
	Burn Name and Number	
	Name of person completing form	
	Date of form completion	
Risk Factors - Likelihood. What is being burnt?		
BURN OBJECTIVES		
Main objective for performing the planned burn		Fuel management: landscape management zones
VEGETATION TYPE		
Vegetation type	Inside burning unit	Eucalypt heathy forest
	Outside or adjacent to unit	Grassy woodland
FUEL CHARACTERISTICS, FUEL - HAZARD RATING AND TIME SINCE FIRE		
Time since fire	Age (years): inside burning unit	25+ years
	Age (years): outside or adjacent to unit	25+ years
Fuel hazard: inside burning unit Note: in coastal mallee and heathland, non-eucalypt woodland and heathland, and woody weed vegetation type include values for elevated fuel height	Surface hazard	Extreme
	Surface depth (mm)	35 to <50 mm
	Near-surface hazard	Very high
	Near-surface depth (cm)	51 to 100 cm
	Elevated hazard	Extreme
	Elevated fuel height (m)	1 to 2 m
	Bark hazard	Extreme
Fuel hazard: adjacent to burning unit	Surface hazard	Extreme
	Surface depth (mm)	35 to <50 mm
Note: in costal mallee and heathland,	Near-surface hazard	Very high
non eucalypt woodland and heathland,	Near-surface depth (cm)	51 to 100 cm
and woody weed vegetation type include	Elevated hazard	Extreme
values for elevated fuel height	Elevated fuel height (m)	1 to 2 m
	Bark hazard	Extreme

Note: the input screen also requires input of weather parameters for the burn and 3 days following. These are used in conjunction with the fuel hazard attributes to generate fire behaviour predictions.

An example of the weather parameter inputs for the SA BRAT are shown on the following page.

Figure 14 Input screen for weather parameters (sample selection)

Risk Factors - Likelihood. What are the appropriate conditions to burn under? ***WEATHER PARAMETERS, FUEL MOISTURE AND FIRE DANGER RATING***		
During the burn	Wind speed in the open at 10 m (km/h)	15
	Relative humidity (%)	50
	Temperature (°C)	22
	Days since rain	7
	Amount of last rain event (mm)	5
	Month of burn	Nov
Fuel Moisture	Fine fuel moisture (meter) - internal	11 to 15%
	Fine fuel moisture (meter) - external	11 to 15%
Atmospheric instability - Haines Index	Day of burn	L - 4
	Maximum over preceding 2 days	L - 4
Fire behaviour potential: **Eucalypt heathy forest and woodland ONLY**	Maximum FDI next day	6 to 12
	Maximum FDI over following 3 days	6 to 12
DF: Eucalypt heathy forest and woodland ONLY	Drought Factor: day of burn	8
Grassland curing: Grasslands/ grassy woodlands	Curing (%)	70
Fire behaviour potential: **For all other prescription vegetation types** Conditions required for the next day of the burn and the following 3 days after the burn	Maximum average wind speed next day	15
	Maximum average wind speed over following 3 days	15
	Minimum relative humidity next day (%)	50
	Minimum relative humidity over following 3 days (%)	40
	Maximum temperature next day (°C)	20
	Maximum temperature over following 3 days (°C)	22
Overnight fire risk: **Required for ALL prescription vegetation types** Expected overnight conditions for the night of the burn and the following3 nights after the burn	Minimum overnight wind speed in the open at 10 m (km/h)	8
	Minimum wind speed over following 3 nights at 10 m (km/h)	10
	Maximum overnight relative humidity (%)	73
	Maximum relative humidity over following 3 nights (%)	86
	Minumum overnight temperature (°C)	12
	Minumum temperature over following 3 nights (°C)	8
	Rain and/or dewfall overnight following burn day (mm)	0
	Rain and/or dewfall over following 3 nights (mm)	0

Based on the fuel and weather attribute input data, the SA BRAT generates fire behaviour predictions and risk assessment outputs. It should be noted that a range of factors are considered beyond the fuel hazard related factors extracted in the samples shown here.

Figure 15 Output screen samples:

RISK FACTORS: PERFORMING THE PLANNED BURN		*Category*	*% of rating*
Fuel hazard	Inside block	Extreme	30.0
	Adjacent to block	Low	2.3
Weather	Fire behaviour potential: day of the burn	Low	1.0
	Fire behaviour potential: next day	Low	0.5
	Fire behaviour potential: following 3 days	Low	0.3
	Stability: day of the burn	Low	0.5
	Stability: max over preceding 2 days	Low	0.3
	Fuel moisture	Low	1.0
Site factors	Inside block	Moderate	1.8
	Adjacent to block	Low	0.4
	Boundary factors	High	5.0
Ignition strategy	Lighting pattern, technique and duration	Low	0.9
Resources	Personnel and equipment	High	4.1
	Standby resources	Moderate	1.1
Preparation works completed prior to burn ignition		Low	0.0
	BURN OVERALL RISK RATING	**Moderate**	**49.0**
RISK FACTORS: OVERNIGHT FIRE RISK		*Category*	*% of rating*
Overnight fire risk	Night following day of ignition	Moderate	50.0
	Following 3 nights after day of ignition	High	75.0

In the South Australian Burning Risk Assessment Tool, of all risk factors, the greatest weighting is given to fuel hazard within and adjacent to the burn block, with weather attributes given the next greatest weighting. In the above example, fuel hazard factors within the burn block have contributed 30 out of the 49 points scored for risk factors involved in performing the burn.

6.5 Section Summary

At the operational planning phase, fuel hazard assessment is undertaken firstly to confirm that the proposed burn needs to go ahead (i.e. that fuel hazard levels predicted to exist on the basis of time-since-fire desk-top assessment are actually evident in the field). However, the main purpose of fuel assessment at the operational planning stage is for use in estimating what fire behaviour can be expected under the prescriptions to be applied; and therefore what risks may arise for achieving the burn objectives, firefighter and public safety protection, maintaining burn security, and protecting values-at-risk within or in proximity to the burn. Fire behaviour predictions are in many cases intuitive from the prior operational experience of operational planners due to the paucity of prescribed fire behaviour prediction models suited to prescribed burning conditions, currently available in Australia.

Consideration of burn escape risks, what lighting patterns to use, whether control lines are adequate for the burn, what firefighter, public safety measures and asset protection measures are prudent all ultimately depend on what fire behaviour is predicted (which requires quantitative fuel assessment).

At the operational planning stage, fuel assessment mostly considers ‘fuel averages’ (both for quantity/arrangement, and fuel moisture) either across a burn site, or across major vegetation groups within a site. Therefore there is a risk of not accurately planning for the full range of fire behaviour scenarios. WA is an exception, where each strata and vegetation type is considered separately in operational planning with different fuel potentially targeted at different times and seasonal conditions.

There is some common ground among jurisdictions in approaches to fuel assessment at the operational planning stage. Jurisdictions which assess fuel characteristics in strata, are generally using a common fuel stratification process (surface; near-surface; elevated; and bark fuels) and although there may be output category differences, conversion tables are provided to enable conversion between output categories. Jurisdictions which do not use the aforementioned fuel stratification system mostly use a total fine fuel quantum in tonnes per hectare.

In terms of how fuel hazard assessments are being used for risk assessment, a wide range of approaches are being used. Some jurisdictions are using structured, systematic processes using programmed spreadsheets, while others are using less structured, more subjective risk identification processes which rely on the experience of practitioners.

While the recently emergent programmed spreadsheet Burning Risk Assessment Tool innovations have considerable value, they have inherent and acknowledged limitations in that they typically have as their fuel hazard inputs ‘averaged’ for a burn site. Fuel quantity, structure and moisture content will have significant variation across a burn site (particularly for larger burns in variable terrain with a variety of vegetation types) and therefore consideration of the site variability is largely left to the burning operations execution stage.

7. FUEL HAZARD AND RISK ASSESSMENT DURING PRESCRIBED BURNING OPERATIONS EXECUTION

The finest scale and most comprehensive risk assessment and control actions occur at the burning operations execution phase. This fact is not always well appreciated as the risk assessment processes involved are mostly undocumented mental assessments. The mental risk assessment processes applied at the burning operations execution phase are absolutely crucial to achieving the burn objectives and risk control outcomes planned earlier in the prescribed burn planning process. The risk assessment actions applied address the fine spatial and temporal scale changes in fuel hazards, which occur across a burn area and throughout a burning period, that are not usually assessed at the higher levels of planning.

7.1 Fuel hazard risk assessment actions undertaken at burning operations

Listed below are some examples of fuel hazard risk assessment actions which are frequently undertaken at burning operations:

- Assessing the full length of burn containment lines to identify specific areas where adjacent fuel hazards may pose risks to burn security (e.g. patches of heavy fuel, roadside windrows, long-unburnt stringybark trees, hollow trees, problem vegetation types in which fire behaviour can suddenly escalate, heavy fuels in gullies sloping up to containment lines etc.);
- Considering how fire behaviour will change as it moves from one vegetation type to another, and how this will affect burn security and objectives;
- Considering how fire behaviour will change on different slopes and aspects, and how this will affect burn security and objectives;
- Considering how diurnal fuel moisture cycles will affect fire behaviour, including variation in drying rates on different aspects;
- Considering how changes in wind direction and/or speed may change during the day and how this will affect fire behaviour and burn security;
- Considering how different lighting methods, patterns and spacing will affect fire behaviour in different fuel types and topographic positions, and how these will affect burn security and objectives;
- In marginal conditions (e.g. bordering on too moist or too dry) considering where and when to start burning operations to take best advantage of diurnal fuel moisture cycles (or deciding not to burn);
- When fire behaviour is sub-optimal to meet burn objectives, considering how to increase or decrease fire behaviour whilst maintaining burn security; and
- Considering what fire behaviour will occur if fire escapes across boundaries in different locations and what suppression resources are appropriate to contain any escapes.

Burn supervisors and crew members are making frequent assessments (mostly mental and undocumented) of these fuel hazard risk factors throughout a burn, and making decisions to amend lighting patterns and sequences and alter resource deployment arrangements at the burn to maintain burn crew and public safety, burn security, and to ensure burning objectives are met. These assessments require detailed understanding of how fuel attributes, weather variables and lighting patterns interact to affect fire behaviour.

To provide the basic requisite knowledge, agencies provide training in prescribed burning to national competency standards. These competency standards are generic and not specific to any particular vegetation types, terrain types or weather pattern types. Prescribed burning training may or may not cover methodologies for fire behaviour prediction. If taught, predictive models may not cover the full range of vegetation types occurring locally and in some cases may not be readily applicable to prescribed burning conditions (e.g. be models for predicting bushfire behaviour of established line fires in summer conditions). The general paucity of prescribed fire behaviour guides available for use by land and fire management agencies (especially under prescribed burn conditions) means that reliance on the practical operational knowledge and skills of burning operations supervisors is a particularly critical dependency.

As has been discussed in previous sections, there is a wide range of complexity and risk factor variability between prescribed burns. Generic training cannot attempt to cover the full range of complexity levels and risk factor variability. Therefore agencies adopt different approaches to classifying burns into different fuel type, complexity or risk classes. Some have established trigger requirements (mostly based on demonstrated experience in different hazard types/complexity levels) for supervising burning operations according to fuel type/complexity classification.

7.2 Section summary

At the burning operations execution phase, important risk assessment processes and control action decisions are made, mostly being undocumented mental assessments. The risk assessment actions applied address the fine spatial and temporal scale changes in fuel hazard risks that occur across a burn area and throughout a burning period, that are not usually assessed at the higher levels of planning. These are often made in high operational tempo conditions and require those making risk assessments and determining control actions to have detailed understanding of how fuel attributes, weather variables and lighting patterns interact to affect fire behaviour.

While generic ‘plan and conduct prescribed burn’ training may cover the general fundamentals of burning operations and associated risk factors to be considered, the detail of landscape feature and hazard- specific risk factors may not be covered (particularly the range of vegetation types/conditions occurring within a jurisdiction). Competency in such matters is accumulated through on-the-job experience and mentoring by experienced practitioners. Therefore agencies select personnel for key operational roles based in part on the type, range and depth of operational experience held by personnel available to them. The fuel hazard risk assessment activities that take place during burning operations constitute the final level of risk assessment and control actions taken during the prescribed burning process. It is the level at which the detail of inherent variability in fuel hazard attributes within a burn area is addressed. It is the ‘last line of risk control’ for picking up any errors or omissions in previous levels of risk assessment. Accordingly, a rigorous approach to ensuring that those personnel supervising the execution of burning operations have knowledge, skills, experience and attitudes appropriate to the complexity and risk of the burning operations is vital.

8. POST-BURN MONITORING AND MODELLING OF FUEL HAZARDS

After burning operations are completed, there are two main types of fuel hazard assessment undertaken.

8.1 Post-burn extent and effectiveness assessment

A short time after burning operations are complete, and in many cases during the final stages of burning operations mop-up, it is usual for a 'post-burn assessment record' to be completed. These typically record a mix of quantitative and qualitative information about the results of the burn relative to the burn objectives. Information recorded typically includes:

- Total area 'treated' (usually based on the area within the perimeter of the burn);
- Extent and location of any additional 'unplanned' area (or non-target areas) burnt;
- Proportion of treatment area burnt (burnt ground within the burn perimeter)—often this is a coarse estimate expressed as a percentage of the total area, and is usually a rough visual estimation viewed only from burn boundaries if only ground crews are present, or overhead visual assessment from a helicopter or fixed wing aircraft if aerial ignition is used. Use of transects through the burn area to conduct more detailed assessment of burnt and unburnt patch proportions is rarely used operationally, and is mainly restricted to research applications. In Australia's tropics and rangelands, satellite imagery is routinely used to record burn scars (fire extent);
- Average 'fuel load' or 'overall hazard rating' remaining after the burn (typically expressed as an average across the burnt proportion of the site);
- Some assessments may include an intensity category assessment and/or area affected by crown scorch;
- Assessment of whether or not the burn met its objectives (usually in terms of proportion of area treated and quantity of fuel reduced); and
- Whether or not any follow-up works are required to complete the burn.

The fuel hazard attributes quantitatively assessed in post-burn assessments are typically at a coarse resolution and include:

- Overall fuel hazard category for the burnt areas—usually an average across the burnt area (in some cases with fuel hazard level for each fuel strata also recorded) and/or;
- Total fine fuel load remaining in tonnes per hectare—usually an average across the burnt area; and
- Percent burn coverage.

On the following page is an extract (Post Burn Assessment page) from the NSW NPWS Prescribed Burn Plan Template.

Figure 16 NSW NPWS Post Burn Assessment template

Post Burn Assessment

Completed by Prescribed Burn Planner

Area Information		
Gross area burnt	ha	
Estimated burn coverage	%	
Estimated post burn fuel load	t/ha Score: ☐ Low ☐ Mod ☐ High ☐ V. High ☐ Extreme	
Estimated crown scorch	%	
Operational Performance		
		Comment (if no, why?)
Burn contained within planned boundaries?	☐ Yes ☐ No	
Fuel reduction objective met?	☐ Yes ☐ No	
Environmental requirements met?	☐ Yes ☐ No	
Remedial Action		
Prompt: Describe any remedial action required		
Remedial Action Completed	Date:	

Report prepared by:		
	Name	Signature & date

8.2 Fuel hazard accumulation monitoring

After an area has been burnt, various approaches are taken to monitoring fuel accumulation on the site for consideration of when the site may next require burning.

Time-since-last-fire is a commonly used indicator of fuel load recovery based on fuel accumulation curves for the vegetation type/group being considered.

In grasslands and heathlands where the full depth of the vegetation structure burns, burnt areas can be discerned from satellite imagery and the year of detection can be recorded. In short fire cycle environments satellite imagery is acquired and interpreted more frequently allowing monthly identification of new fire scars in the landscape. This is appropriate for the tropics where grass fuel recovery timeframes are short. Satellite imagery is also used for fire scar mapping on open grassy woodlands where the open tree canopy does not interfere with visual detection of ground fuels. Figure 17 below shows fire scars occurring in Arnhem Land in 2011, with green, blue coloured areas being early dry season fires, and yellow, orange and pink being late dry season fires.

Figure 17 2011 fire scar map for Arnhem Land NT

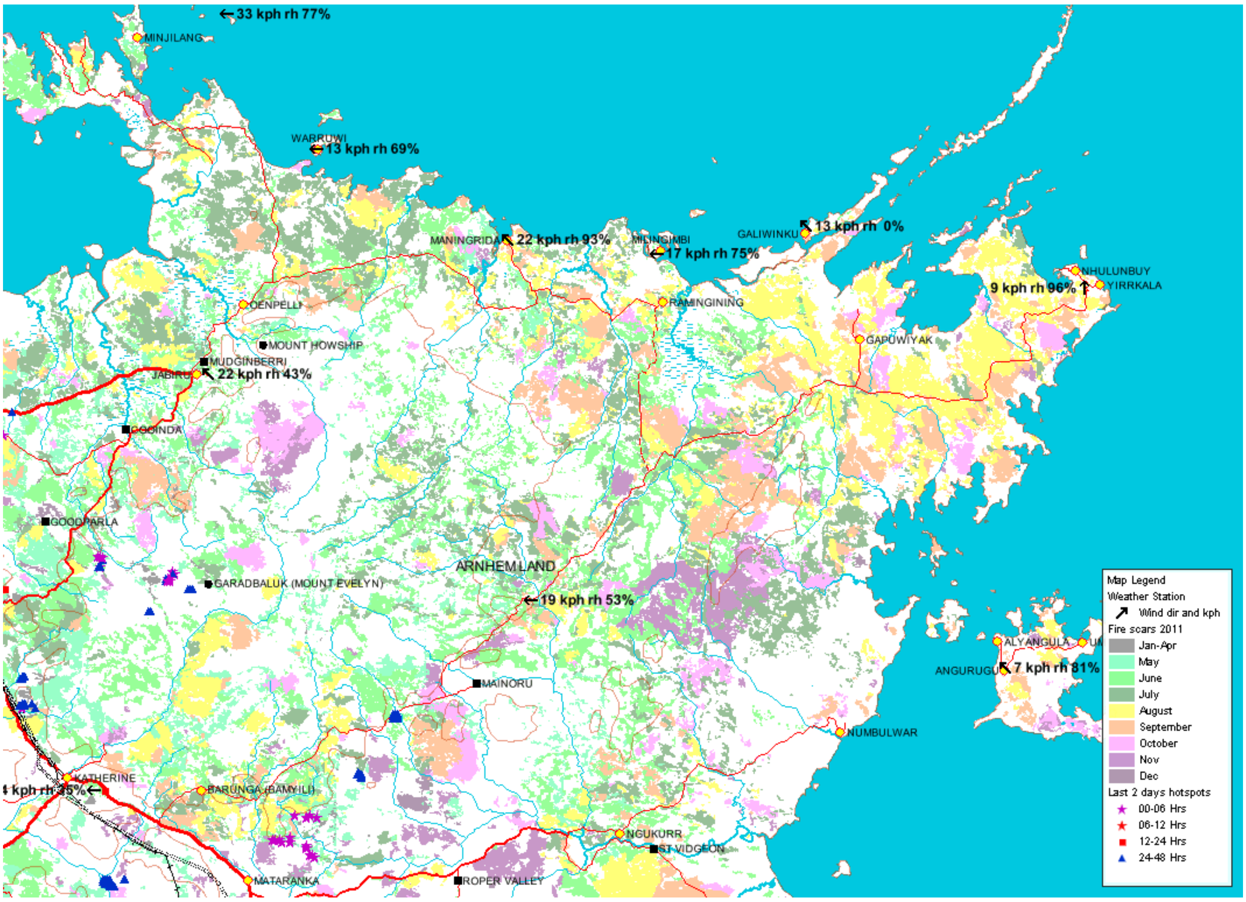


Figure 17 above is sourced from the North Australian Fire Information (NAFI) website which is extensively used by fire and land management agencies across the Top End.

Use of satellite imagery for detecting prescribed burns in forests and tall scrubs is more problematic and not operationally feasible with current technologies. Overstorey and understorey canopies obscure fuels in the surface and near-surface fuel strata where burning takes place so they are not observed by the satellite. Live vegetation in the upper understorey and overstorey canopy are not normally burnt in low intensity prescribed burns and therefore burnt surface fuels are too difficult to detect due to being masked by the reflectance from the live canopy fuels.

Therefore for most forest areas, fire history recorded in spatial databases is used. Fuel hazard levels are estimated from fuel load/years since fire relationship curves (commonly known as fuel accumulation curves).

Examples of fuel accumulation curves for surface and near surface fuels in dry eucalypt forests are shown in Figure 18 below. Curves similar to these, developed for specific forest types, are used by land management agencies and the NSW Rural Fire Service.

Figure 18 Fuel accumulation curves for surface and near surface fuels in dry eucalypt forests

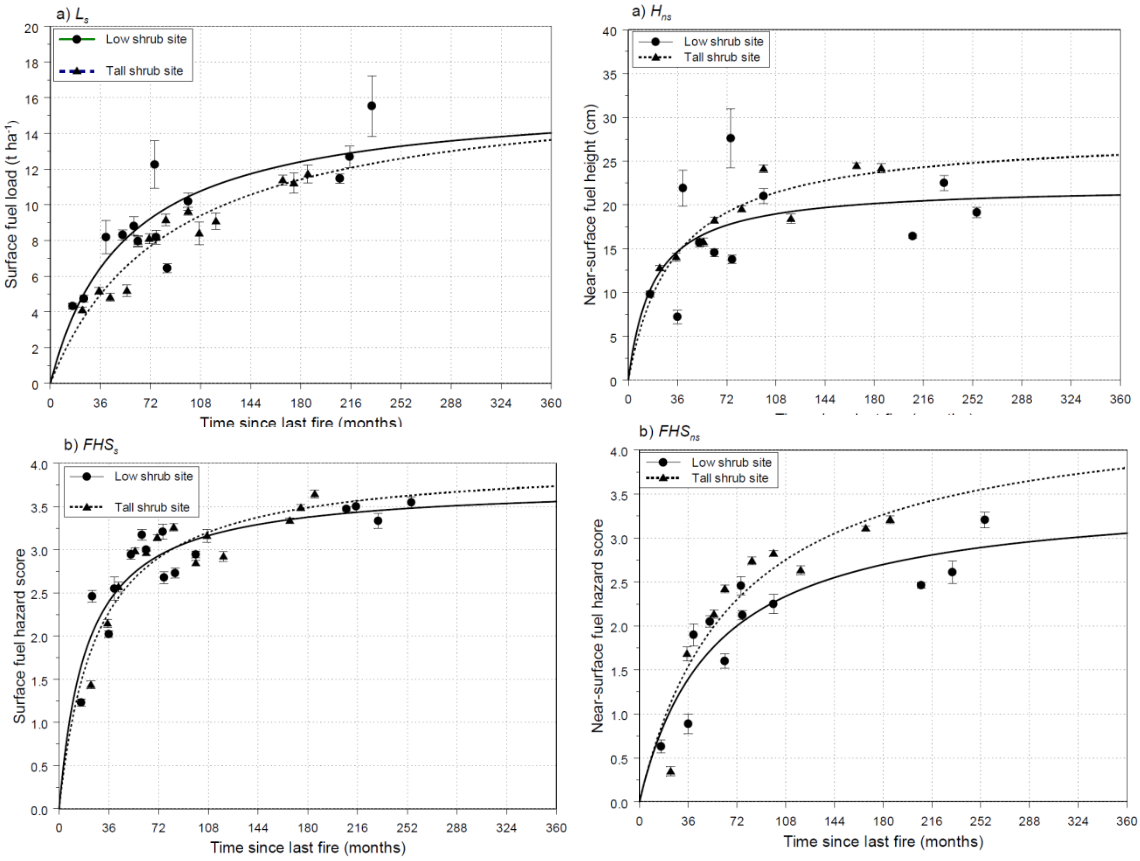


Figure 18 above is sourced from Project Vesta research in dry open jarrah forests in south-west WA.

8.3 Section Summary

Post-burn assessment and monitoring is typically undertaken to evaluate the success of burning operations and to model fuel conditions after the burn.

It is usual for post-burn assessments to be conducted a short time after the burn or at the final stages of burning operations. These typically assess the area treated, proportion of treatment area burnt, residual fuel (as tonnes per hectare and/or overall fuel hazard rating) and if the burn met objectives.

Ongoing consideration of fuel conditions after a fire is common. Time since last fire is often used as an indicator of fuel recovery. Satellite imagery is useful to determine fire scars for vegetation types where the entire structure burns, such as in grasslands and healthlands. It is extensively used in Northern Australia where grass fuel recovery timeframes are short and monthly identification of fire scars helps build a landscape assessment of fuel recovery.

In forest types where the canopy obscures burnt fuels, the usefulness of satellite technology to identify fire scars is very limited and therefore fire history is recorded by field or aerial assessment. In common use are fuel accumulation curves for specific forest types, that in combination with fire history data, indicate fuel accumulation based on time since last fire.

9. A NATIONAL FRAMEWORK FOR FUEL HAZARD RISK MANAGEMENT

From the analysis in the preceding sections, a framework for considering fuel hazard related risks for prescribed burning has been developed. The framework is depicted on the following pages.

The framework identifies the following:

- The prescribed burn planning and operations sequence from strategic planning through to burning operations execution;
- The general purpose and context for fuel hazard risk assessment at each stage of the prescribed burn planning and operations process;
- Fuel hazard risk factors for consideration at each stage of the prescribed burn planning and operations process, noting that these get progressively finer in resolution as the phases of planning and operations progress; and
- Monitoring and review requirements relevant to each phase.

The value of the framework is chiefly:

- To set out and define the key phases of the prescribed burn planning and implementation process;
- To identify the purpose and scale of risk assessment at each phase; and
- Identify the key fuel hazard attributes for assessment.

It is a high-level, non-prescriptive framework (as national frameworks should be). It can be readily adopted in Australian and New Zealand jurisdictions, providing for improved alignment of approaches whilst still accommodating locally developed methodologies tailored to the different statutory and policy frameworks, institutional arrangements and agency capabilities, and operating environments in each jurisdiction.

Knowledge and systems exchange between jurisdictions, as has been conducted to various extents in the past, can promote practice improvement in different parts of the framework, particularly if considered as part of structured review and improvement processes.

Key national-level systems and tools are identified below. These could facilitate improved alignment of planning approaches and practices.

- Development of a national fuel group classification system (on the basis of fuel characteristics);
- Development of a national fuel attributes classification and assessment system; and
- Development of national fire behaviour predictive models for major fuel groups (aligned to the national fuel classification systems identified above) and designed specifically for prescribed burning conditions (lower end of the FDI scale; for spot and short line ignitions).

Once other prescribed burning risk management frameworks have been developed (AFAC/FFMG projects for smoke and carbon emissions risk; burn escape, safety and damage risk; ecosystem services and biodiversity risks); it may be possible to develop national, but locally customisable tools for prescribed burning risk assessment.

Figure 19 Fuel hazard risk management framework outline

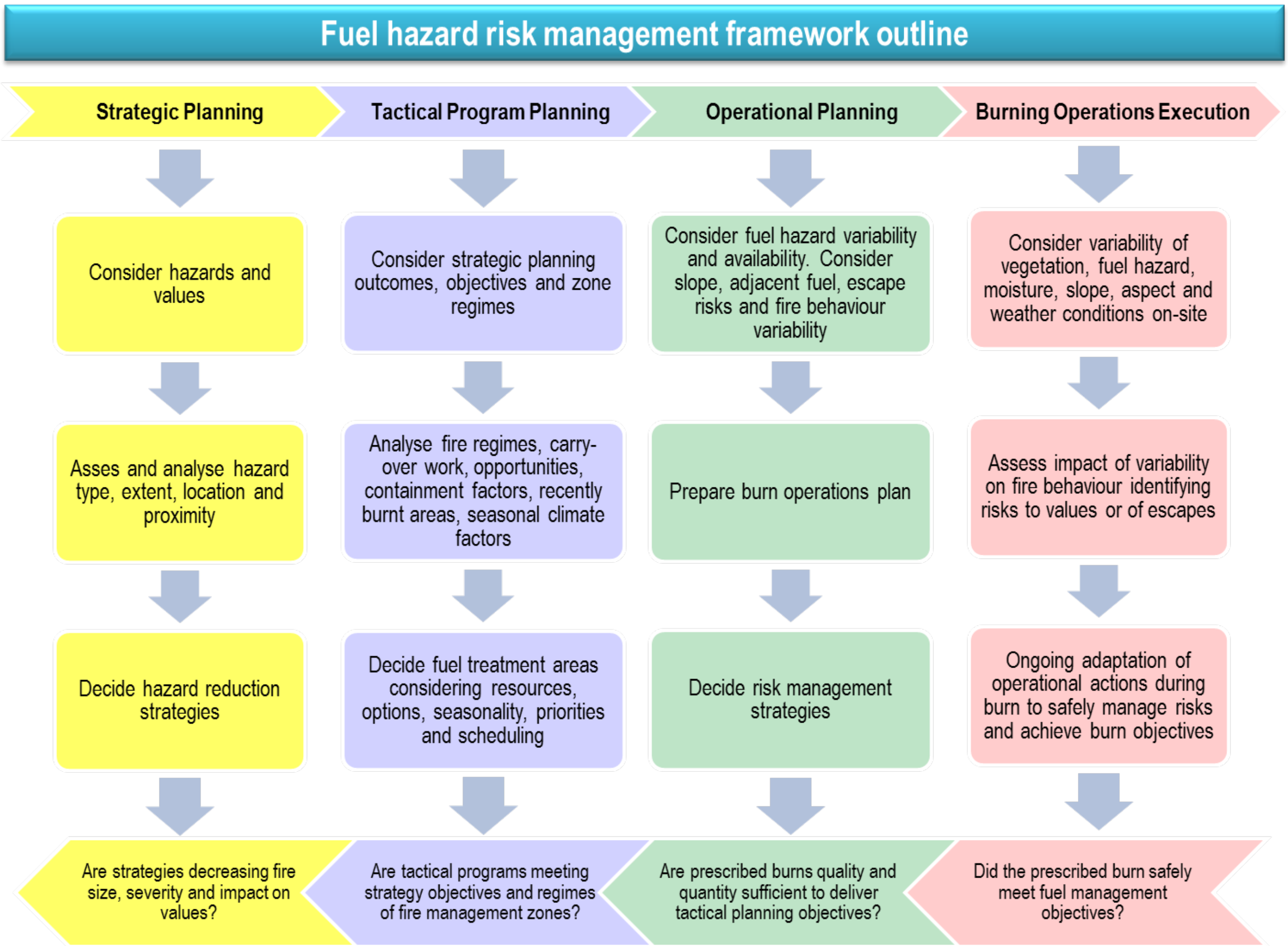


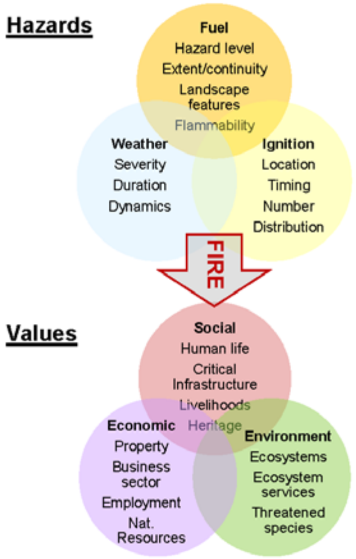
Figure 20 Fuel hazard risk management framework for prescribed burning (over page)

Fuel hazard risk management framework for prescribed burning

Communicate and consult

STRATEGIC PLANNING → **TACTICAL PROGRAM PLANNING** → **OPERATIONAL PLANNING** → **BURNING OPERATIONS EXECUTION**

STRATEGIC PLANNING



ASSESS & ANALYSE BUSHFIRE RISKS

Identify how bushfires can develop and spread through fuel hazards in the landscape, and determine their potential impact zones (intersection with assets/values).

Fuel hazard risk factors for consideration:

- Hazard type (fire behaviour potential)
- Hazard extent (fire size and impact area potential)
- Hazard topographic location (fire beh' escalation pot'l)
- Hazard proximity to fire-vulnerable values (impact pot'l)

DECIDE STRATEGIES

Determine bushfire behaviour modification objectives.

Hazard reduction strategy elements for consideration:

- Which fuel hazard types to fuel-reduce
- Treatment types, objectives and dimensions
- Re-treatment regimes or trigger conditions
- How much of the landscape to treat
- How to arrange treatments/zones in the landscape to maximise risk reduction benefits and optimise trade-offs

Identify residual risk and how hazard reduction will work with other bushfire risk reduction strategies.

TACTICAL PROGRAM PLANNING

PLAN HAZARD TREATMENT PROGRAMS

Tactical planning is undertaken to organise the delivery of strategic planning outcomes. The fuel hazard related outputs of strategic planning may be such things as designation of fuel management zones, with different fuel reduction objectives, treatment area dimensions and fire-return cycles attaching to each. Alternatively, outputs may be expressed as desired fuel age distribution patterns in the landscape (e.g. a bushfire should not be able to run more than X km before running into an area with a fuel age of Y or less). However strategic planning outputs are expressed, tactical planning of fuel hazard reduction programs is aimed at giving effect to the strategic plans.

ANALYSE OPTIONS AND REQUIREMENTS

Strategic inputs for analysis:

- Strategic planning implementation requirements and desired fire regimes
- Works carrying over from previous planning periods
- Risk reduction enhancement opportunities offered by recent fuel hazard-reducing events including wildfires
- Availability of man-made and natural features to facilitate burn containment
- Values-conflicts requiring consideration

Fuel hazard risk factors for consideration:

- Areas recently burnt by bushfires
- Areas recently treated by hazard reduction
- Areas in designated burning zones approaching (or beyond) treatment trigger thresholds
- Current seasonal climate effect on fuel hazard distribution and condition

DECIDE FUEL TREATMENT AREAS, PRIORITIES AND WORK SCHEDULES

Based on available options , priorities, resources and seasonal conditions, decide the works quantum and schedule to be implemented over the planning cycle.

Outputs need to be specified to a level of detail appropriate to allow efficient operational planning to be undertaken.

OPERATIONAL PLANNING

PREPARE BURN OPERATIONS PLANS

Operational Burn Plans are prepared for each burn nominated in the tactical level program. These identify, among other things:

- Burn objectives (including post-treatment fuel outcome specifications)
- Burn prescriptions (ideally these should include fire behaviour prescriptions not just weather parameter prescriptions)
- Conditions to avoid (e.g. particular wind directions)
- Burning ops preparatory requirements
- Resource requirements and organisation
- Notification requirements
- Operating instructions (including lighting sequence and patterns; burn inclusion and exclusion areas, and site-specific risk management measures for the burn)

To achieve burn objectives, comply with prescriptions and identify resources and risk management requirements, consideration of what fire behaviour will occur during burning is essential and necessitates consideration of fuel hazard factors.

Fuel hazard risk factors for consideration:

- Fuel (vegetation) type and variability within the burn area
- Fuel quantity or hazard level variability within the burn area
- Anticipated fuel availability (as determined by moisture content) within the burn area
- How slope and lighting patterns will affect fire behaviour in the different fuels
- Locations where fuel factors pose elevated risks of fire breaching burn boundaries or damaging assets in or adjacent to the burn
- Fuel characteristics to allow fire behaviour prediction in fuels adjacent to the burn area

BURNING RISK ASSESSMENTS

A range of risk factors are assessed including those posed by fuel hazards. Typically, they identify whole-of-burn-area scale risk levels using site fuel 'averages'. They are mostly used for the purpose of triggering different levels of burn review, authorisation and supervision practice, and contingency planning requirements.

BURNING OPERATIONS EXECUTION

RISK ASSESSMENT DURING BURNING OPERATIONS

Burn supervisors and crew members make frequent assessments (mostly mental and undocumented) of fuel hazard risk factors throughout a burn, making decisions to amend lighting patterns and alter resource deployment arrangements to maintain burn crew and public safety, burn security, and to ensure burning objectives are met. Fuel hazard risk assessment actions undertaken include:

- Assessing burn containment lines to identify specific areas where adjacent fuel hazards may pose risks to burn security (e.g. patches of heavy fuel; roadside windrows; long-unburnt stringybark trees; hollow trees, vegetation types in which fire behaviour can suddenly escalate; heavy fuels in gullies sloping up to containment lines etc.)
- Considering how fire will behave as it moves between vegetation types and how this will affect burn security and objectives
- Considering how fire behaviour will change on different slopes and aspects, and how this will affect burn security and objectives
- Considering how diurnal fuel moisture cycles will affect fire behaviour, including variation in drying rates on different aspects
- Considering how changes in wind direction and/or speed may change during the day and how this will affect fire behaviour and burn security
- Considering how different lighting methods, patterns and spacing will affect fire behaviour in different fuel types and topographic positions, and how these will affect burn security and objectives
- In marginal conditions (e.g. bordering on too moist or too dry) considering where best to start burning operations to take best advantage of diurnal fuel moisture cycles (or deciding not to burn)
- When fire behaviour is sub-optimal to meet burn objectives, considering how to increase or decrease fire behaviour whilst maintaining burn security
- Considering what fire behaviour will occur if fire escapes across boundaries in different locations and what suppression resources are appropriate to contain any escapes

OUTCOME LEVEL MONITORING (long-term) — **ACTIVITY LEVEL MONITORING AND REVIEW**

- Are fuel management strategies decreasing fire size, severity and impact? Are social, economic and environmental loss/damage rates reduced? Periodic review of strategies.
- Assess extent to which the tactical program is sufficient to achieve fuel management zone/distribution specifications. Periodically review tactical planning practices.
- Assess whether the volume and quality of burning operations is sufficient to deliver the tactical program. Periodically review planning practices and delivery model.
- Assess burn outcomes against objectives, prescriptions and risk control specifications. Record outcomes. Periodically review operating practices.

ACKNOWLEDGEMENTS

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The report was prepared by Paul de Mar and Dominic Adshead of GHD for AFAC, AGD and FFMG. The report was edited by Wayne Kington.

The content in part was generated at a workshop attended by member agency staff and key stakeholders (refer to Appendix B: Workshop Attendees List). Their contributions at the workshops are acknowledged. Other valuable contributions were received from other agency staff so thanks also goes to them.

The National Burning Project Steering Committee has worked consistently to ensure the project attracted funding, stayed on track and achieved desired outcomes. Their contributions are also acknowledged.

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Appendix A

Project Survey Questions

Fuel hazard and fire risk assessment and monitoring

Through the project survey GHD sought information from AFAC/FFMG participating agencies regarding:

- How they classify or categorise different fuel hazard types, states and conditions within their jurisdictions;
- How agencies assign fuel hazard values or levels to different fuel hazard classes/states in their jurisdictions;
- What methodologies and systems they use to monitor and record changes in fuel hazard (states and condition) over time;
- How they use fuel hazard attributes and values in bushfire risk assessment and operational applications, including:
    - How is the type of fuel hazard (e.g. vegetation type/class) used in fire risk assessment?
    - How is the extent or size of a fuel hazard used in fire risk assessment?
    - How is the state of the fuel hazard (e.g. age class/growth stage) used in fire risk assessment?
    - How is the condition of the fuel hazard (e.g. fuel moisture content) used to assess fire risk?
    - How are key fuel attributes (e.g. spotting potential, difficulty of suppression) used in fire risk assessment?
    - What methodologies are used to determine how fuel hazard proximity to assets alters fire risk?
    - How are changes in fuel attributes as a result of fuel hazard reduction treatments assessed and recorded (e.g. whole area or proportion of area treated, how the reduction of fuel is quantified)?
    - How are changes in the level of fire risk to assets recorded/reported in relation to fuel reduction treatments?;
- What fuel hazard data/information limitations (availability, quality, currency etc.) affect the ability of jurisdictions/agencies to use fuel hazard information in risk assessment and operational applications?;
- What fuel hazard management zoning systems (and associated fuel management objectives) do agencies use as a management framework for devising planned burning and other fuel treatment programs?; and
- Are there any minimum or optimum threshold values that jurisdictions set as being requirements for a fuel hazard reduction to be effective in reducing risk and how are these assessed (e.g. size of burn, proportion of area fuel reduced, degree of fuel reduction/modification)?

Appendix B

Workshop Attendees List

Risk management framework: fuel hazard risks sub-project workshop

Tuesday 6 March 2012—AFAC, 340 Albert Street East Melbourne

Craige Brown, Melbourne Water;
Miguel Cruz, CSIRO;
Tony Corrigan, ACT Emergency Services Agency;
Tim McGuffog, Forestry Corporation of NSW;
Mike Wouters, Department of Environment, Water and Natural Resources, SA;
Gary Featherston, AFAC;
Simon Heemstra, Rural Fire Service, NSW;
Justin Cook, Forestry SA;
Chris Hodder, Parks Victoria;
Phillip Timpano, Department of Environment and Primary Industries, VIC;
Jim Gould, CSIRO;
Mick Meyer, CSIRO;
Bruno Greimel, QLD Fire and Rescue Services; and
Eddie Staier, Parks and Wildlife Service, TAS.

Appendix C

National Burning Project—List of Sub Projects

The objective of the National Burning Project is to use a national approach to reduce the bushfire risk to Australian and New Zealand communities by the comprehensive management of prescribed burning at a landscape level that balances the operational, ecological and community health risks. The project will produce a series of outputs through sub-projects that together form a framework. The framework will endure long after the project and future projects will be required to add further elements to, update and refresh the framework. There are elements of the framework that are outside the scope of this project and will be delivered separately by the project partners. The current scope of the framework and the component sub-projects are listed in the table below.

#	Short Title	Long Title	Status as at December 2013
1	**Review Fire Science and Knowledge**	Prepare and publish a review of the fire science, operational experience and indigenous knowledge at a national level for all fire bioregions.	Completed
2	**Analysis of Objectives**	Report on an analysis of the tools and methodologies available to balance competing objectives of burning programs and matching these to user's needs.	Unfunded Unplanned
3	**Risk and Monitoring Framework**	Design a management and review framework to manage the major prescribed burning risks. Four risks are currently planned: • Fuel Hazard • Smoke and CO_2 emissions • Ecological • Operational (safety)	Risks 1 and 2 completed. Risks 3 and 4 unfunded.
4	**Best Practice Guideline for Prescribed Burning**	A review of the end to end processes, practices and systems of prescribed burning jurisdictions, land managers and across a range of burning objectives.	This review report completed. Operational practice guideline underway. Strategic practice guideline planned.
5	**National Bushfire Fuel Classification**	Develop a best practice guide for the classification of bushfire fuels	Underway
6	**National Position on Prescribe Burning**	A nationally agreed position is developed and communicated that outlines the principles for the use of prescribed burning.	Planned
7	**Prescribed Burning Competencies**	Define agreed standards for the tasks associated with the planning and conduct of prescribed burns.	Completed
8	**Develop Training Materials**	Develop training materials for prescribed burning for national application.	Underway
9	**Prescribed Burning Training Delivery**	Investigate the options for national training delivery and mutual recognition frameworks.	Unfunded Unplanned
10	**Resource Optimisation**	Develop processes for the sharing of resource between prescribed burning programs.	Unfunded Unplanned
11	**Performance Measures**	Develop performance measures for prescribed burning and design a reporting framework.	Unfunded Unplanned
12	**National Tool Box**	Provide a set of tools that support prescribed burning activities	Unfunded Unplanned

Appendix D

National Burning Project—List of Publications

The National Burning Project will progressively publish a comprehensive library of reports from the sub-project results. The list of planned publications is provided below:

Title	Description	Date of Report	Date of Publish	Authors	Contri-butors
Review of Best Practice for Prescribed Burning	A report to scope the development of a best practice guide for prescribed burning by reviewing current practices across Australia.	December 2013	March 2014	de Mar P, Adshead D	AFAC, FFMG, AGD, GHD
Risk Management Framework—Fuel Hazards		30-Apr-12	September 2014	de Mar P, Adshead D	AFAC, FFMG, AGD, GHD
Risk Management Framework—Smoke Hazards		1-Jul-12	October 2014	de Mar P, Adshead D	AFAC, FFMG, AGD, GHD
Scope and Framework for an Australian Fuel Classification		30-Jun-11	November 2014	Hollis J, Gould J, Cruz M and Doherty M	AFAC, FFMG, AGD, CSIRO
Australian Bushfire Fuel Classification—Scope and Objective.		31-Aug-12	November 2014	Gould J, and Cruz M	AFAC, FFMG, AGD, CSIRO
Australian Bushfire Fuel Classification—Glossary		31-Aug-12	November 2014	Gould J, and Cruz M	AFAC, FFMG, AGD, CSIRO
Australian Bushfire Fuel Classification—Assessment Methodology		31-Aug-12	November 2014	Gould J, and Cruz M	AFAC, FFMG, AGD, CSIRO
Overview of prescribed burning in Australasia.	A review of the science and practice of prescribed burning written to provide background to practitioners and information to interested members of the public.	30-Jun-12	November 2014	Poynter M	AFAC, FFMG, AGD, CSIRO (reviewer)
Australian Bushfire Fuel Classification—Case Study Report		2013	February 2014	Gould J, and Cruz M	AFAC, FFMG, CSIRO
National Position on Prescribed Burning		2013	2015		AFAC, FFMG
Prescribed Burning Competencies		2013	2015		AFAC, FFMG

Title	Description	Date of Report	Date of Publish	Authors	Contri-butors
Prescribed Burning Training Material—Assist with Prescribed Burn		2014	2015		AFAC, FFMG, BCRC
Prescribed Burning Training Material—Plan Simple Burn		2014			AFAC, FFMG, BCRC
Prescribed Burning Training Material—Plan Complex Burn		2014			AFAC, FFMG, BCRC
Prescribed Burning Training Material—Conduct Simple Burn		2014			AFAC, FFMG, BCRC
Prescribed Burning Training Material—Conduct Complex Burn		2014			AFAC, FFMG, BCRC
Best Practice Guide for Operational Prescribed Burning					
Best Practice Guide for Strategic Prescribed Burning					
Australian Bushfire Fuel Classification—Business Case					
Australian Bushfire Fuel Classification—Implementation					
Review of Prescribed Burn Training					
Report on the options for resource sharing in prescribed burning					
Performance Monitoring and Reporting for Prescribed Burning					

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