COMPLEX PRESCRIBED BURNS

PUAFIR513 DEVELOP COMPLEX PRESCRIBED BURN PLANS

PUAFIR511 CONDUCT COMPLEX PRESCRIBED BURNS

LEARNER
RESOURCE

afac

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This learner resource was originally prepared by Ross Runnalls and was reviewed by Tony Blanks. Benjamin Smith (AFAC), Jenise Blaik (Queensland Parks and Wildlife Service) and Wayne Kington (AFAC) refined the learner resource to align to best practice *National Guidelines for Prescribed Burning Operations* (AFAC 2016a) prepared by Paul de Mar and Dominic Adshead of GHD. Development of the learner resource was guided by Sandra Lunardi and Gary Featherston of AFAC.

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Figure 1: Ecological rehabilitation burning in the Wet Tropics of Queensland (Source: Queensland Parks and Wildlife Service)

Overview

This learner resource has been produced as part of the National Burning Project and has been designed to align to the National Guidelines for Prescribed Burning Operations (AFAC 2016a).

For anyone involved in prescribed burning, it is important to understand the fundamental role of fire in Australian landscapes.

> Much of the Australian landscape has evolved with fire. Fire events are a certainty and necessary for the continued survival of fire dependent species and ecosystems. Indigenous Australians understood this relationship and effectively used fire to manage landscapes for multiple purposes.
>
> National Position on Prescribed Burning (AFAC 2016b [in draft])

This has deep implications for prescribed burning. Much of the Australian landscape has the potential to be flammable, especially under worse-case-scenario weather conditions. It will burn; it is just a matter of when and how. This was reflected by the 2009 Victorian Bushfire Royal Commission (VBRC) following the tragic Black Saturday fires in 2009:

> Properly carried out, prescribed burning reduces the spread and severity of bushfire. It makes a valuable contribution to reducing the risks to communities and firefighters by complementing effective suppression and is one of the essential protective strategies associated with making it safer for people to live and work in bushfire-prone areas in the state (Teague et al. 2010).

Although prescribed burning is one of the key tools available to reduce bushfire risks, and for maintaining healthy and functional ecosystems in Australia, prescribed burning is itself an activity that contains significant inherent risks (AFAC 2016a). The safe and effective conduct of a prescribed burn requires careful and thorough planning to ensure that the agreed objectives can be safely achieved.

It is important to remember that the planning and conduct of prescribed-burning should be considered within the context of each state or territory's own legislation and codes of practice, which will need to be adhered to, and each agency will have its own protocols and procedures for developing prescribed burning plans.

Although this learner resource has been prepared mostly for government agencies involved in land and fire management; the same principles, processes and theory apply to all prescribed burning planning and implementation activities in Australia, be they conducted by government staff, industry or by private individuals.

This learner resource supports two units of competency within the Public Safety Training Package:

- PUAFIR513 *Develop complex prescribed burn plans*
- PUAFIR511 *Conduct complex prescribed burns*.

It will assist you to gain the skills and knowledge to plan and conduct a complex prescribed burn.

The prescribed burning suite of learner resources

This learner resource is part of a family of **three learner resources** covering each of the five national prescribed-burning units of competency as listed below:

- PUAFIR412 *Conduct simple prescribed burns*
- PUAFIR413 *Develop simple prescribed burn plans*
- PUAFIR511 *Conduct complex prescribed burns*
- PUAFIR513 *Develop complex prescribed burn plans*
- PUAFIR213 *Assist with prescribed burning*.

These five units-of-competency and their accompanying learner resources are orientated toward the needs of different audiences. Table 1 expresses the relationship between the units along with a description of the typical audience for each.

Table 1: Prescribed-burning learner resources and their associated units of competency

Resource	***Simple Prescribed Burns***	***Complex Prescribed Burns***
Units of competency	PUAFIR413 *Develop simple prescribed burn plans*	PUAFIR513 *Develop complex prescribed burn plans*
	PUAFIR412 *Conduct simple prescribed burns*	PUAFIR511 *Conduct complex prescribed burns*
Typical audience	Urban and rural fire personnel required to plan and/or supervise the conduct of low risk, low intensity prescribed burns.	Land management personnel and *some* rural fire personnel required to plan and/or supervise the conduct of prescribed burn operations across a range of risk and fire-intensity levels.

Resource	***Assist With Prescribed Burning***
Unit of competency	PUAFIR213 Assist With Prescribed Burning
Typical audience	All personnel required to assist under supervision in the conduct of prescribed burns.

Navigating this learner resource

The structure of this learner resource is modular. It is divided into four parts that cover the two complex prescribed-burn units of competency in the manner represented in Table 2. It is not expected that you will need to read the entire resource, but only those parts that relate to the unit of competency you are studying.

Suggested activities and learning scenarios are included throughout the learner resource, as are self-assessment questions, to assist you to monitor your progress and to support the learning process.

Table 2: How the parts of this resource relate to the complex prescribed-burning units

Part	Content	PUAFIR513 Plan	PUAFIR511 Conduct
A	Addresses the objectives of prescribed burning, and the policy and organisational environment that frame their formation.	✓	✓
B	Covers the theory underpinning operational prescribed burn planning and conduct.	✓	✓
C	Provides guidance on how to plan a complex prescribed-burn operation.	✓	✗
D	Sets out how a complex prescribed burn may be successfully conducted.	✗	✓
E	Contains self-assessment answers, a list of references, a glossary, two scenario-based review activities, and an appendix containing a list of available case studies.	✓	✓

You may have noted from Table 2 that Part E contains two scenario-based review activities:

- Review Activity 1 exercises knowledge of the process of planning a burn set out in Part C by requiring you to create a burn plan based on the template provided. After you have done this, you can check your thinking by referring to the completed burn plan set out in Review Activity 2.
- Review Activity 2 tests knowledge of the process of conducting a burn set out in Part D by requiring you to review a burn plan and construct a pre-burn briefing based on it.

Learning objectives

This learner resource was composed to meet specific learning objectives relating to the two complex prescribed burning units. These learning objectives are described below.

PUAFIR513 *Develop complex prescribed burn plans*

On completion of this unit, you should be able to:

- describe and develop burn objectives
- identify the factors to be considered in planning a prescribed burn
- develop prescribed burning plans so as to meet identified objectives through the use of a range of strategies
- gain approval for a prescribed burn plan.

PUAFIR511 *Conduct complex prescribed burns*

On completion of this unit, you should be able to:

- identify the factors to be considered when validating a prescribed burn plan, and undertake necessary consultations with appropriate internal and external stakeholders
- assess weather and fuel conditions, determine variability of fire behaviour within the burn site, and refine the objectives, prescriptions and constraints for the burn

- prepare the burn site and make it safe
- monitor weather and fuel moisture for approaching windows of opportunity, and issue required notifications to neighbours and media
- identify and prepare required resources for ignition, containment and contingencies
- gain authorisations required prior to ignition
- lead burn-day safety checks, and brief and task resources
- light, monitor and contain complex burns, adjusting lighting patterns as required
- review site safety, mop up, and secure the burn site
- undertake post-fire evaluation and reporting.

Prerequisite units

The units *PUAFIR215 Prevent injury*, *PUAFIR204B Respond to wildfire* and *PUAFIR303B Suppress wildfire* are the only nationally-specified prerequisite units for the four develop and conduct prescribed burning units. For *PUAFUR213 Assist with prescribed burning*, the only prerequisite is *PUAFIR215 Prevent injury*.

The prerequisite chain for all five prescribed-burning units is illustrated in Figure 2.

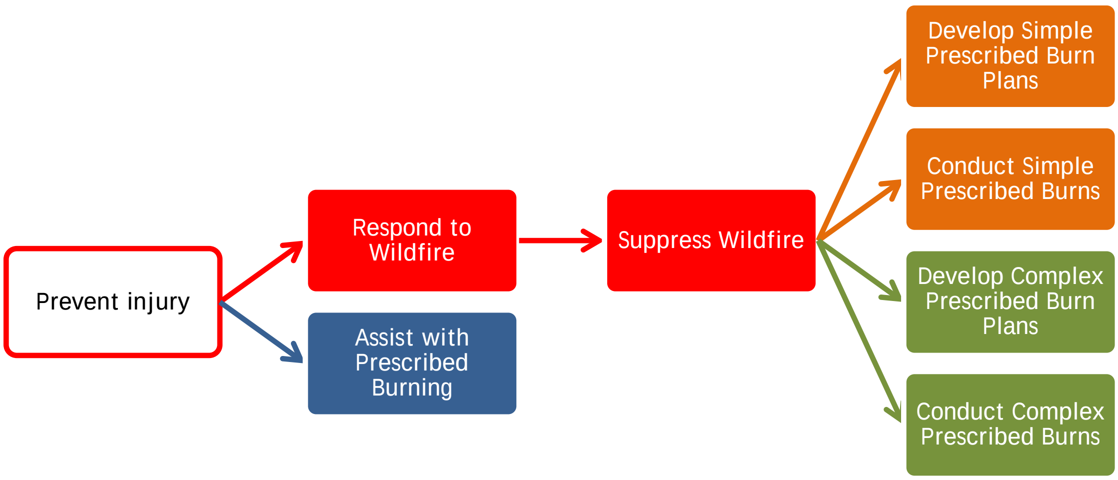


Figure 2: Prescribed burning units and their respective prerequisite units.

Please note that the specification of prerequisite units is intended to ensure that the integrity of the qualifications to which they contribute is preserved, and the failure to hold a statement of attainment for any or all prerequisite units does not preclude personnel from receiving training in prescribed burning, nor will it prevent them from finding this manual useful. It will, however, prevent students from being able to receive a statement of attainment, should they be assessed to be competent against the performance criteria associated with a particular unit. It will also prevent them from performing any role for which holding a statement of attainment in a prescribed burning unit is mandatory, until such time as a complete chain of prerequisite units has been attained and the relevant prescribed burning unit has been awarded.

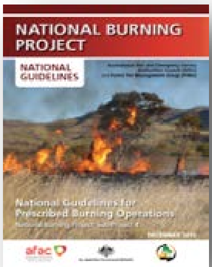
Note also that attainment of a complex prescribed burning unit will cover all the requirements to attain the respective simple unit, as follows:

- the unit *PUAFIR513 Develop complex prescribed burn plans* covers all of the requirements of *PUAFIR413 Develop simple prescribed burn plans*
- the unit *PUAFIR511 Conduct complex prescribed burns* covers all of the requirements of *PUAFIR412 Conduct simple prescribed burns*.

The National Burning Project

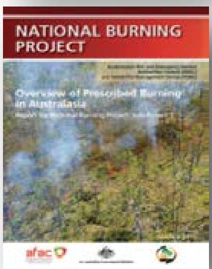
This prescribed burning learner resource form part of the suite of products produced as part of the National Burning Project. The National Burning Project is bringing together inter-related aspects of prescribed burning across Australasia to design guiding frameworks and principles for a more holistic and consistent approach to prescribed burning practices.

Students interested in further learning may be interested in the following products:



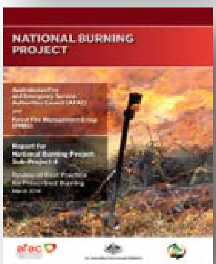
National Guidelines for Prescribed Burning Operations

Through consultation with member agencies, AFAC identified a framework of 17 principles that cover operational planning and implementation phases of prescribed burning. This framework will help align approaches while supporting planners and land managers with an interest in improving prescribed burning. This learner resource has been designed to align to this product.



Overview of Prescribed Burning in Australasia

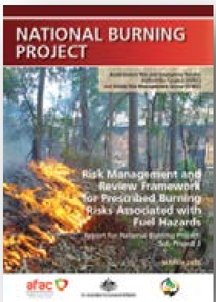
A great resource for students, this report is an introduction and overview of prescribed burning in Australasia, for those interested in the role of fire in the Australasian landscape, the origins of Australasian prescribed burning, its use as a bushfire management tool, its use for biodiversity outcomes, smoke and climate change concerns, and the evidence base that underpins the use of planned fire.

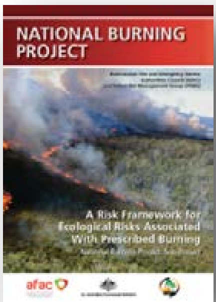


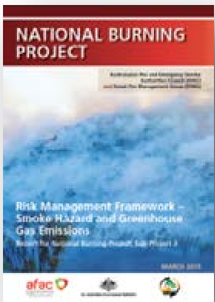
A Review of Best Practice for Prescribed Burning

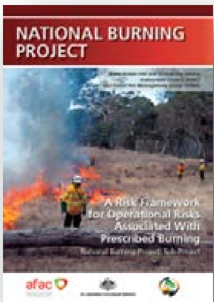
The report provides a detailed account of the prescribed burning practices that are considered to be examples of best practice. The practices north of the Tropic of Capricorn are described separately from those in southern Australia and New Zealand. The report is recommended to fire management practitioners and students of fire ecology.

In addition to the above, there are four **risk frameworks** available that consider management of risks in relation to fuel hazard, smoke and greenhouse emissions, ecology and operations.







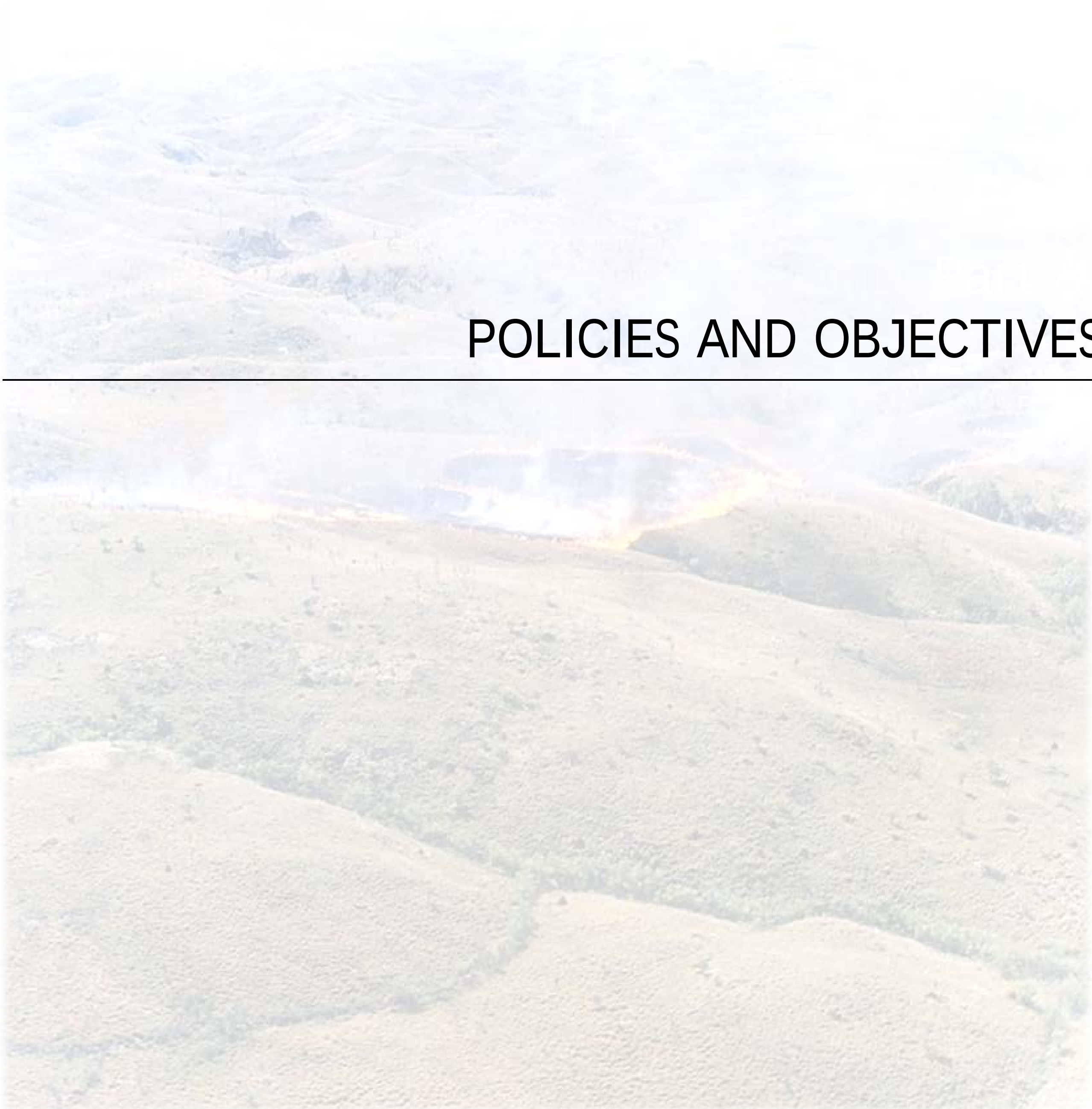


All products are available from **www.afac.com.au/initiative/burning**.

Part

A

POLICIES AND OBJECTIVES



Section

1

Prescribed burning and its policy and organisational environments

This section covers the policy, principles and organisational environments that guide prescribed burning.

Prescribed burn(ing) is defined as:

> the controlled application of fire under specified environmental conditions to a predetermined area, and at a time, intensity, and rate of spread required to attain planned resource-management objectives (AFAC 2012, p. 24).

The terms 'prescribed burn' and 'planned burn' are very close in meaning and can be used interchangeably. However, in this learner resource, the term 'prescribed burn' will be used preferentially.

Other key terms used in this learner resource include:

- **Prescribed-burn plan (or just 'burn plan')** — an approved plan that incorporates the specifications and conditions under which the prescribed burn operation is to be conducted (AFAC 2012, p. 4). The burn plan has various names in different organisations. Examples include the Ops Plan (SA) and Burn Proposal (QLD). In some jurisdictions the burn plan may be accompanied by a separate environmental assessment, ignition plan, consultation plan, traffic control plan etc. and may include separate work orders (for road works etc.). For the purposes of this document, all of these separate plans that relate to the implementation of a prescribed burn will be collectively called the 'burn plan'.
- **Burn manager** — the person in charge of conducting the burn. In different agencies, different terms are used, such as the Burn Officer in Charge or Operations Officer.
- **Simple prescribed burn** — a prescribed burn characterised by low risk, low intensity, small area, low potential impact on assets, completion in one shift and minimal variation of fuel and terrain.
- **Complex prescribed burn** — a prescribed burn characterised by moderate to high risk, a range of fire intensities, medium to large areas, significant potential impacts on assets and may involve a variety of fuels and terrain. The burn operation may involve a large number of resources requiring the establishment of a formal management and support structure. It may

require several separate ignitions (ground and/or aerial), possibly over several days. It may have a number of high value assets requiring complex protection actions.

- **Bushfire (or Wildfire)** — an unplanned vegetation fire. A generic term which includes grass fires, forest fires and scrub fires both with and without a suppression objective.

The definition of simple and complex prescribed burns may vary between states and some agencies have rating systems that facilitate more objective and multi-factored assessments of burn complexity. Learners should access the tools or definitions relevant to their area.

A full list of terms and definitions used are contained in the Glossary at the back of this resource.

Principles and purpose of prescribed burning

Prescribed burning may be used for fuel-hazard reduction to reduce the severity and impact of bushfires, to regulate environments that have adapted to the periodic influence of fire, to control introduced species in native bush and grasslands, to encourage grazing opportunities and to regulate and clear land cultivated for timber. Yet, despite the diversity of purposes for burning, the underlying principles governing the use of controlled fire remain the same.

Principles of burn management

Land management agencies will normally have an approach to the use of prescribed burning which aspires to the principles below. These principles tend to be reflected in agency procedures and doctrine and were drawn together to form the National Position on Prescribed Burning (AFAC 2016b [in draft]).

1. Protection of life is the highest consideration.
2. Landscape health is linked to fire and fire management.
3. Prescribed burning is a risk management tool to mitigate bushfire.
4. Engagement with community and business stakeholders is important.
5. Prescribed burns should have one or more explicit measurable outcomes.
6. Informed knowledge of fire in the landscape is important.
7. Capability development is important.
8. Traditional owner use of fire in the landscape should be acknowledged.
9. An integrated approach is required across land tenures.
10. Prescribed burning is carried out under legislative, policy and planning requirements.

Refer to the National Position on Prescribed Burning for a discussion on each principle.

Applications of prescribed burning

Prescribed burns can be undertaken to achieve the following broad objectives:

- reduction of fine fuel loads in key areas to reduce the intensity of, and difficulty of suppressing, a subsequent bushfire
- the modification of other fuel properties (e.g. bark fuels, elevated shrub fuels) in key areas to reduce the likelihood of dangerous fire behaviour in a subsequent bushfire (e.g. spotting, flame height)

- removal of debris and creation of desirable seed-bed conditions following timber-harvesting operations
- control of target species invading vegetation communities (e.g. pines invading native forests or heathlands from adjoining plantations, or woody weeds invading native grasslands)
- maintenance or restoration of ecosystems, habitats or species populations
- promoting the greatest possible diversity of habitats and representation of successional stages of vegetation (maintaining a landscape in various stages of recovery from fire creates a diversity of different habitats)
- for production purposes, such to encourage pasture or for protection of silvicultural assets.

Other more specialised management objectives can be achieved by the planned use of fire, such as the manipulation of plant-community composition to achieve biodiversity-conservation outcomes. Each of these different objectives will require different burning conditions, which must be identified and prescribed in advance.

Activity 1.1

Identify all the common applications for prescribed fire for the type of burning that you undertake.

Policy considerations

In most jurisdictions in Australia there are both legal obligations to undertake prescribed burning to control bushfires or bushfire risk, and legal restrictions for how and when prescribed burning can be undertaken.

Legal obligations

Most agencies managing public land have a statutory (legal) obligation to manage the land with respect to:

- **fire protection** issues (reduction in the impact of bushfires on life and property)
- **environmental** issues (maintain the resilience of natural ecosystems).

Also, in most parts of Australia, private property owners and the managers of public land have a statutory requirement to minimise fire hazards on their land.

Meeting fire protection requirements will include, amongst many other things, modification of fuel hazard or fuel structure over broad or localised areas to reduce the impact of unplanned bushfires. The well planned and soundly managed use of fire offers one of the few practical tools to achieve such modification.

Management of ecology will also involve consideration of fire. The composition and structure of ecosystems can be altered by the exclusion of fire, or by the planned or unplanned application of fire. Thus the planned application (or exclusion) of fire can be used as a tool to maintain or deliberately alter ecosystems.

In some situations, a statutory requirement to protect rare or endangered flora or fauna may require the planned application or exclusion of fire (e.g. an Action Statement under Victoria's Flora and Fauna Guarantee Act).

Legal restrictions

Any prescribed burn carries with it some risk that fire behaviour will:

- damage assets or environmental values within the planned area
- escape planned boundaries, and damage assets or environmental values beyond the planned area.

Inevitable by-products of the burn, such as smoke, may also under some circumstances generate a substantial hazard or public nuisance.

To reduce these risks and impacts, some restrictions are commonly placed on the use of prescribed fire at certain times of the year, or under certain environmental conditions.

The laws and regulations governing prescribed burning vary from state to state, and local councils may exercise power to ban burning on certain days within their municipalities. It is important that you make yourself aware of the legislative and regulatory requirements relevant to the location in which a prescribed burn is to occur.

Burning during periods leading up to high fire danger may also require enhanced safety precautions, such as:

- all perimeters comprise mineral-earth control lines
- burns are brought out to control lines on the day of lighting
- the maximum possible area of fuels within the control lines must be burnt.

Smoke is increasingly being seen as a public nuisance when atmospheric conditions limit its dispersal, particularly near urban areas, or when major public outdoor events are planned.

Smoke from prescribed burning can be a hazard due to reduced visibility on public roads, around airfields and airports, or in any other situation in which good visibility is required.

In addition, smoke is a health hazard for susceptible individuals, particularly the very young and the elderly, and people with pulmonary or other respiratory diseases, such as those subject to asthma.

Smoke can also have agricultural impacts, such as the effects of smoke on grapes.

Some agencies now have procedures whereby prescribed burning in defined regions is limited or prohibited if atmospheric conditions may lead to significant pollution. Such procedures may rely on daily consultation with other agencies, such as state environment protection authorities.

Activity 1.2

Identify seasonal or other environmental restrictions that may apply to prescribed burning in your area. Contrast these with those restrictions of a similar nature imposed on prescribed burning by another land management agency or fire service in your state or territory (if applicable).

Figure 3: Asset protection burning using low intensity fire (Source: Bushfire CRC)

Organisational environment

Each organisation undertaking prescribed burning will have its own doctrine, comprising industry-wide codes of practice and organisationally specific policies and procedures, governing the use of fire. This allows for regional differences and tailored approaches. However, there are underlying commonalities that can be identified.

Codes of practice

Where principles, standards and guidelines have been established to govern the work of fire- and land-management agencies, these are often published as codes of practice. Like the codes of practice for other industries, these codes of practice are intended as benchmarks necessary to the maintenance of public confidence.

These codes may cover a general domain of responsibility, such as fire management on public land, or relate to a more restricted area of activity to which an agency has responsibility, such as the South Australian Country Fire Service's Code of Practice for Broad Acre Burning.

Organisational doctrine

While a code of practice sets out standards for a profession or industry as a whole, it has become increasingly common for large government organisations, including fire and emergency services and land management agencies, to publish authorised documents providing instruction in its activities. Each organisation conducting prescribed burning will have its own area of doctrine regarding burn operations, elements of which it will have in common with other organisations at a state or national level. Demonstrated familiarity with your agency's prescribed-burn doctrine is usually a prerequisite for endorsement to plan or supervise prescribed-burn activities.

Increasingly, organisations utilise IT systems to guide and assist staff in planning and reporting on prescribed burns, and it is important to familiarise yourself with such systems where they exist. Often these systems integrate geographical information system (GIS) mapping facilities to assist in decision making and planning. The importance of recording the history of fires (both planned and unplanned) is being increasingly recognised, as this is helpful in suppression planning, fire-management research, as well as prescribed-burn planning.

Authorisations required

The conduct of a prescribed burn is not an operation to be entered into lightly. It is essential that any such burn is managed by suitably skilled personnel with proper authorisation.

Private land

On private lands, any prescribed burn must only be undertaken with the express authority of the landowner or manager. Fire brigades, for example, who may undertake fuel reduction burns on private property, need to ensure that the proper authorisation of the landowner or occupier has been obtained.

Where seasonal fire restrictions are in force, any prescribed burn on private land may proceed only if authorised by the agency managing those restrictions (for example, by issue of a burning permit).

Public land

On public land, each agency responsible for its management normally has specific authorisation procedures to light or maintain fire on that land. This authority will extend to other employees who, by direction, are involved in prescribed burning operations.

In some circumstances, agency staff may also be required to obtain 'burning permits' before undertaking prescribed burning operations on public land.

For all burns, be they on private or public land, a vital part of the authorisation process is a need to notify other interested persons formally of the intention to burn. In most states there are statutory requirements for the formal notification of neighbours within a set period before the commencement of the burn.

Figure 4: Ignition while extinguishing the backing fire along a non-mineral earth break (Source: Department of Environment, Water and Natural Resources, SA)

Activity 1.3

Identify personnel in your immediate location who are authorised to undertake prescribed burn planning and how such authorisations are obtained.

Are burning permits required to be obtained by personnel in your agency? To whom must applications be made? Are they required all year round or during specific times? If so, when?

Who must receive notifications of intention to burn in your area? What are the requirements which exist in your location, regarding notifications to other persons of the intention to burn?

Section 1 summary

- Prescribed burning is the controlled application of fire under specified environmental conditions to a predetermined area, and at a time, intensity, and rate of spread required to attain planned resource-management objectives.
- A simple prescribed burn is a low risk, low intensity burn, conducted over a small area with minimal variation of fuel and terrain, has low potential impact on assets, and which can be completed in one shift.
- A complex prescribed burn is a moderate to high risk burn, which may be of low or high intensity, may be conducted over medium to large areas, may incorporate a variety of fuels and terrain types, and may have significant potential impact on assets.
- In most parts of Australia, private property owners and managers of public land have a statutory requirement to ensure fire hazards are minimised on their land.
- The laws and regulations governing prescribed burning vary between jurisdictions, so it is important that you make yourself aware of the legislative and regulatory requirements relevant to the location in which a prescribed burn is to occur.
- It is essential that any prescribed burn is managed by suitably skilled personnel with proper authorisation:
  - On **private** lands, any prescribed burn must only be undertaken with the express authority of the landowner or manager.
  - On **public** land, each agency responsible for its management normally has specific authorisation procedures to light or maintain fire on that land.
- Most organisations have their own procedural doctrine relating to prescribed burning which may consist of standard operating procedures, guidelines, policies and templates. It is important to follow your agency’s standards.
- For all burns, be they on private or public land, a vital part of the authorisation process is a need to formally notify other interested persons of the intention to burn.

Self-assessment questions

1. Fuel modification is one of the applications of prescribed burning. Explain how it can assist subsequent bushfire suppression operations?
2. In relation to fire hazards, what is the general statutory requirement for land owners or managers in most parts of Australia?
3. What is the key factor that distinguishes a simple prescribed burn from a complex prescribed burn?
4. For what different types of purposes and applications are prescribed burns used?
5. What factors may restrict the use of prescribed burning at particular times of the year?

Section

2

Overview of the burn-planning process

The fire-management planning process extends from broad-level considerations down to detailed site-by-site planning and implementation, and can be divided into four stages:

- strategic planning
- program planning
- operational planning
- burn implementation.

This learner resource provides detailed guidance on the **operational planning** stage (which is covered in Part C) and the **burn implementation** stage (covered in Part D), however, it is worthwhile understanding the end-to-end process.

It should also be noted that different organisations have different terms for the stages discussed below, and sometimes combine stages into a single process. For example, in northern Australia, the program-planning and operational-planning stages are usually combined into a highly dynamic rolling program of burns. This is a necessary approach driven by high vegetation growth rates, high fire frequency, and a need to dynamically review and respond to changing conditions.

Strategic planning

A strategic fire plan should provide a long-term, landscape-level planning approach, providing aims and objectives for the fire management of a geographical area, identifying values and assessing fuel hazards to determine management strategies. Most strategic fire plans utilise a zoning system to set broad objectives and prioritise areas for prescribed burning; others use risk-based modelling, or a combination of both. While the focus is often on managing life and property risk, planning for land-management objectives, including biodiversity-conservation issues, often forms a significant part of strategic planning.

Program planning

Program plans prioritise the delivery of strategic planning outcomes, usually in the form of annual or multi-year work programs. Program plans are often presented in map and/or spreadsheet form, detailing the work schedule based on competing management priorities, resources and seasonal conditions. They often include a spatial representation of areas nominated to burn (burn nominations) and sometimes basic skeletal information about the site and burn objectives (often automatically generated by GIS).

Operational planning

The operational-planning process develops burn plans for each area scheduled for treatment in the annual burning program. The burn plans should ensure safety requirements are met, include measurable objectives (or success criteria), prescriptions that will assist in achieving fire behaviour consistent with the objectives, identify ignitions strategies consistent with achieving the objectives, identify resourcing and notification requirements and include a range of risk management actions to manage impacts on values. A burn plan may consist of one or more documents that typically include:

- a statement of burn objectives
- a description of the area, including fuels
- a description of the values including environmental (specific species of concern, fire sensitive ecosystems etc.), cultural (Aboriginal or European artefacts and places) and built assets/infrastructure (residences, sheds, schools, transmission lines, major roads, etc.)
- a map suitable to assist in undertaking the burn
- prescriptions or limits for fuel and forecast weather conditions
- ignition patterns and techniques
- measures for protection of assets and other values
- resourcing requirements (for ignition, mop up and patrol)
- health and safety issues (for burn personnel and the public)
- contingency planning
- risk assessment
- notifications
- post-burn evaluation requirements
- guidance on implementation.

In Part C, the process of developing a burn plan is addressed in detail.

Burn implementation

Implementing a burn plan may start weeks or even months prior to the day of the burn, and requires interpreting the burn plan to validate its location, boundary, objectives, prescriptions and resource requirements, and undertaking preparatory works to ensure control lines, safety zones and access routes are ready.

It also requires monitoring the weather and fuel-moisture conditions for windows of opportunity, confirming resource requirements and availability, conducting the burn, and modifying planned activities on the day if conditions require it.

Implementation of the burn plan is addressed in Part D of this learner resource.

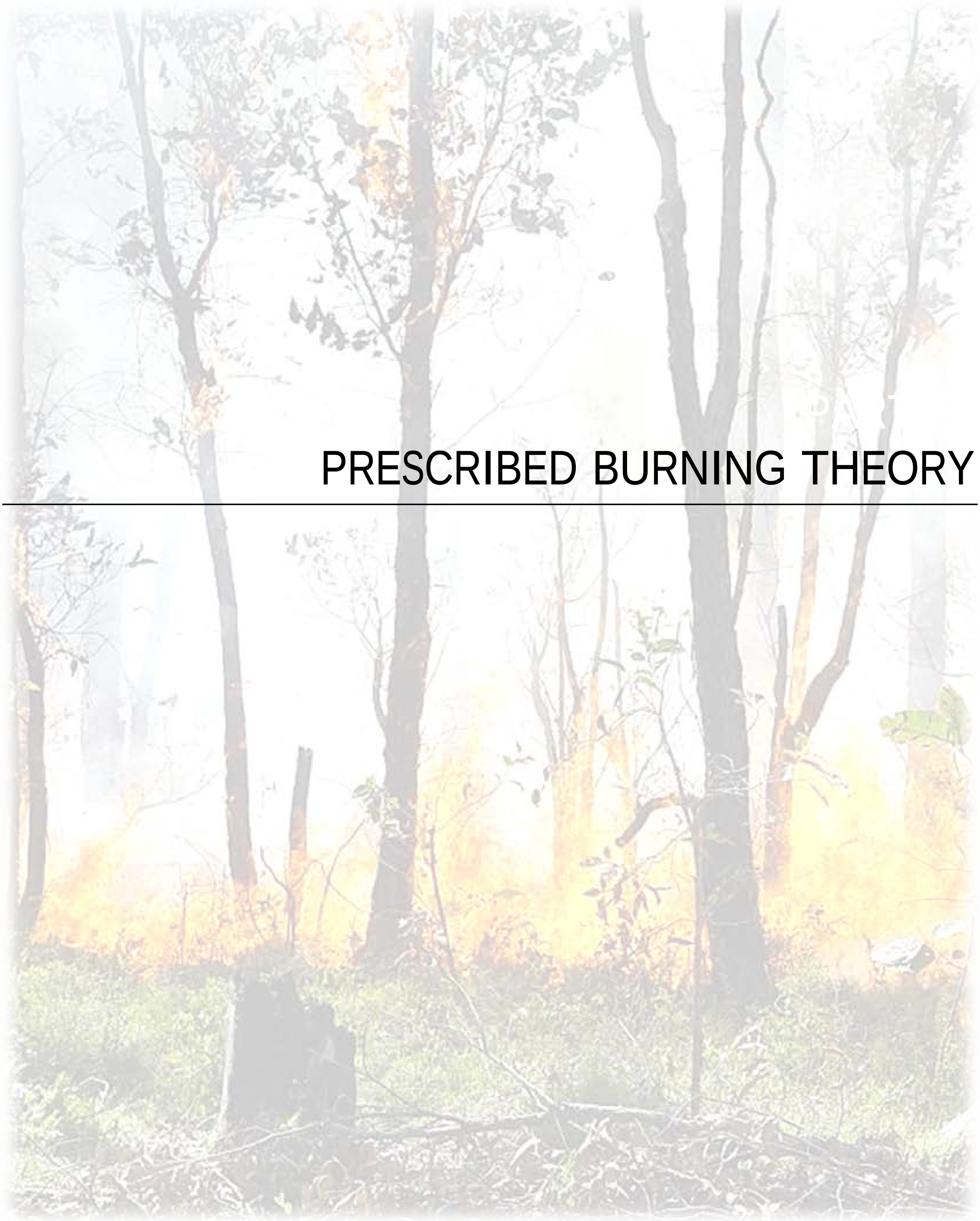
Section 2 summary

- The fire-management planning process occurs at four levels:
  - strategic planning
  - program planning
  - operational planning
  - burn implementation.
- The **operational planning** process usually results in the development of burn plans for each area scheduled for treatment in the annual burn program.
- A complex burn plan should provide the key elements required for the burn manager to safely and effectively conduct a complex planned burn operation, including:
  - a statement of burn objectives
  - a description of the area, including fuels
  - a description of the values including environmental (specific species of concern, fire sensitive ecosystems etc.), cultural (Aboriginal or European artefacts and places) and built assets/infrastructure (residences, sheds, schools, transmission lines, major roads etc.)
  - a map suitable to assist in undertaking the burn
  - prescriptions or limits for fuel and forecast weather conditions
  - ignition patterns and techniques
  - measures for protection of assets and other values
  - resourcing requirements (for ignition, mop up and patrol)
  - health and safety issues (for burn personnel and the public)
  - contingency planning
  - risk assessment
  - notifications
  - post-burn evaluation requirements
  - guidance on implementation.
- Implementing the burn plan requires:
  - advance preparations, including
    - interpretation of the burn plan to validate its location, boundary, objectives, prescriptions, and resource requirements
    - undertaking preparatory works on control lines, safety zones and access routes
  - monitoring the weather and fuel moisture conditions for windows of opportunity
  - confirming resource requirements and availability
  - conducting the burn
  - modifying planned activities on the day if conditions require it.

Self-assessment questions

1. Which stage or level of planning provides a long-term, landscape-level planning approach, providing aims and objectives for the fire management of a geographical area?
2. What is the main purpose of operational planning?
3. What are the key elements in a complex prescribed-burn plan?

Part B



PRESCRIBED BURNING THEORY

Section

3

Objectives

Prescribed burning is the controlled application of fire under specified environmental conditions and within defined boundaries, to achieve planned management objectives. These objectives are developed in response to fire management issues, which can be grouped into four broad classes:

- protection
- broad-area risk mitigation
- ecological management
- land management.

Most areas will have some form of strategic-planning document, and often these documents zone areas for protection, mitigation, ecological or land-management purposes. These plans are the best place to begin to get a sense of the type of objectives required. GIS mapping tools that contain asset, infrastructure, ecological, species and cultural-heritage information will also help determine the objectives required. Ultimately, a field visit would be needed to validate and refine objectives further.

While risk forms the key distinction between simple and complex burns (with simple prescribed burns being characterised as low risk, low intensity and small area), simple burns are likely to have only one or, at most, two operational objectives, typically with an aim of value or asset protection. Complex prescribed burns, on the other hand, will generally have more than one operational objective, and these may combine value or asset protection and risk mitigation purposes with ecological and/or land management objectives within a single burn operation.

Example operational objectives that can be used or modified for a burn plan are provided under the sections below. Prescribed burn objectives must be:

- clear and succinct, so that they are understood by everyone at the prescribed burn
- unambiguous, in order to avoid confusion about what the priorities are
- measurable, so that they are relevant and can be monitored.

Some organisations divide objectives into management objectives that are broad (e.g. ‘protect private property’) and success criteria that are measurable (e.g. ‘at least 80% of the area is burnt’). In this document, the term measurable objective has the same meaning as success criteria.

For protection

The aim of fire management for protecting lives, values and assets is to reduce the intensity of a potential bushfire, primarily through the modification of both fuel load and fuel arrangement in areas close to property or other assets/values that are vulnerable to unplanned fire. Values in this context may include property, infrastructure, economic resources, cultural places and certain fire sensitive natural values. Examples of objectives include:

- reducing the overall fuel hazard to below moderate over 90% of the target area
- reducing fuel load to less than five tonnes per hectare over 90% of the target area
- burning 90—100% of understorey fuels in the target area.

Such intensive fuel management, however, may compromise some environmental values.

It should be noted that burning is not necessarily the only or best method to undertake fuel management for protection issues. Slashing, mowing or other forms of mechanically treating fuel are often undertaken in preference to burning in certain situations.

Urban—rural interface areas present further issues, which are covered in greater detail in Section 7.

For broad-area risk mitigation

Apart from intensive fuel management for life and asset protection, strategic plans also identify broader areas of vegetated land where prescribed burning can (over areas of sufficient width and continuity):

- provide barriers to the spread of bushfire (by reducing its rate of spread, intensity and potential for spot-fire development)
- create areas to assist in making fire suppression safer and more effective.

These burning zones may be orientated across typical bushfire-spread paths in large blocks of forested/vegetated land (usually public land), and may be located and spaced in a way that minimises the area able to be burnt under strong winds. Ideally the width of the treated strip(s) should be considerably greater than the spotting distance of a bushfire under conditions in which fire suppression might reasonably be attempted.

Prescribed burns for broad-area mitigation or bushfire risk-reduction objectives will generally be of low intensity. Planning would usually also aim to reduce fuel load or fuel hazard over a broader area, but often to a lesser degree than asset/property protection burns. Examples of objectives include:

- reducing the overall fuel hazard to below moderate over 70% of the target area
- reducing fuel load to less than five tonnes per hectare over 70% of the target area.

Note: In bushfire-mitigation areas, burning often aims to achieve ecological or environmental objectives simultaneously. Therefore, it may also be desirable to state an ecological-management objective (see below).

For ecological management

For millennia, fire has played an important role in shaping Australian environments, ecosystems and biota, including through indigenous burning practices and through natural causes, such as lightning strikes. As a result, many ecosystems are adapted to regular introduction of fire, while others are not. Also, the type, interval and frequency of fire applied are important factors in success. The use of prescribed fire can protect environmental values by reducing the likelihood of a high-intensity fire unduly impacting the area, or nearby areas. Prescribed burns can also impact environmental values (such as sensitive ecosystems, soils, water-catchment values), or cause weed spread via vehicles, equipment or disturbance. These issues require consideration, and sometimes their own objectives, if they are to be managed effectively.

Objectives for ecological- or environmental-management outcomes may be quite diverse, and depend on the ecosystems, species populations, issues and species involved. Most areas will have some form of strategic planning document which will provide broad guidance to those preparing operational plans, however it is recommended you consult with local experts for assistance in tailoring objectives. With some exceptions, burns of this type will generally be of low intensity, and will aim to create a mosaic of burnt and unburnt patches.

Some generic objectives may include achievement of:

- a 30—60% spatial mosaic of burnt patches in the target area
- less than 10% of the canopy scorched
- more than 90% of clumping-grass bases remain as stubble
- more than 90% of fallen logs (with a diameter ≥ 10 cm) retained
- stimulation of native seed bank germination over 50% of the burn area
- zero soil erosion within the prescribed burn area.

Introductory fire-ecology principles are covered in Section 8.

For land management

Fire is often used for other land-management purposes, such as for silviculture, weed management, re-vegetation, grazing or other forms of agricultural production. In such cases the objectives will be specific to the resource being managed. Example objectives may include:

- stimulating regrowth of grasses over >90% of the target area
- reducing slashing trash by 90%
- remove 90% of understorey vegetation and lay an ash bed prior to planting
- reducing the abundance of woody weeds (e.g. lantana) by 75%.

Activity 3.1

Develop appropriate objectives for a proposed burn in your locality. State what type of burn it is (protection, mitigation, ecological or land management) and remember that strategic planning documents or fire management zones (where available) will guide you. It may be desirable to use more than one objective, or to adjust the target percentages based on the situation.

Section 3 summary

- Objectives are developed in response to fire management issues which can be broadly classified under the following categories:
  - protection
  - mitigation
  - ecological management
  - land management.
- Prescribed burn objectives must be:
  - clear and succinct, so that they are understood by everyone at the prescribed burn
  - unambiguous, in order to avoid confusion about what the priorities are
  - measurable, so that they are relevant and can be monitored.
- Fire management for life and asset/value **protection** aims to reduce the intensity of a potential bushfire, primarily through the modification of both fuel load and fuel arrangement, in areas close to assets/values or property
- Fire **mitigation** objectives provide barriers to the spread of bushfire, by reducing its rate of spread, intensity and potential for spot-fire development, and create areas to assist in making fire suppression safer and more effective.
- **Ecological** burns will generally be of low intensity and will aim to create a mosaic of burnt and unburnt patches. It is recommended to consult with local experts for assistance in tailoring objectives.
- Fire for other **land management** purposes (such as for silviculture, weed management, grazing or other agricultural production), may aim to stimulate regrowth of grasses, reduce slash after cutting, or reduce woody weed.

Self-assessment questions

1. Give an example of an operational objective for an ecological prescribed burn.
2. Give an example of an operational objective for a protection prescribed burn.
3. Give an example of an operational objective for a mitigation prescribed burn.
4. Give an example of an operational objective for a land-management prescribed burn.

Figure 5: Burning along an ecotone (Source: DPAW, WA)

Section

4

Risk

Risk management is an integral part of any sound management system, and agencies are increasingly requiring an assessment of the risk level of burns and burn plans as part of the approval process. This assists when resourcing and scheduling burns, and also helps planning and operations personnel appreciate and focus on critical risk treatments. Be aware of your agency's risk-management systems and procedures.

ISO 31000:2009 Risk Management — Principles and Guidelines, is the international standard for risk management. It defines risk as 'the effect of uncertainty on objectives', meaning that risk cannot be clearly identified unless the objectives to which it relates are clearly defined. In the context of ISO 31000:2009, these objectives are an expression of underlying community or ecological needs or values. These objectives — such as 'protection of life and property', 'protection of the community' or 'protection of biodiversity values' — are echoed in strategic- or policy-level documents and the measurable objectives of individual burn plans should reflect these higher-level needs and values.

Figure 6: Prescribed burning is one of the strategies to reduce bushfire risk (Source: Office of Bushfire Risk Management WA)

Risk can be considered in terms of its dimensions. The dimensions of risk are the topics under which risk can be considered, such as burn security, crew safety, public safety, and the environment. Table 3 provides examples.

Table 3: Risk dimensions against phases of prescribed burning

Risk dimension	Strategic planning phase	Program planning phase	Operational planning phase	Implementation phase
Burn objectives	Strategies and fire management zones	Program Plan targets, risk landscapes or performance measures	Measurable objectives, burn prescriptions and ignition strategies	Validating burn plans, effective briefings, post-burn assessments and closing adaptive management loops.
Burn containment	Systems, procedures, standards	Scheduling of burn and works	Planning suitable boundaries, resources and contingencies	Assessing control lines, adjusting ignition patterns, monitoring conditions
Crew safety	Systems, procedures, standards, training	Allocation of resources	Burn complexity matched to crews/burn manager, contingencies	Briefings, equipment, command structure, debriefs
Public safety	Regulation, policies and procedures	Burn area selection	Prescriptions, specific risk controls, contingencies	Notifications and resources to manage public and traffic
Environmental	Knowledge, systems, strategies	Prioritisation trade-offs, fire intervals and seasons	Prescriptions, specific risk controls	Ignition strategies, specific risk controls, evaluation

Within each dimension of risk, the degree of risk can be reduced by adding risk-control measures into layers of protection that back each other up, leading to a reinforced risk-management system.

Each layer of risk control is imperfect and may have flaws (or 'holes'). Therefore, by having several layers of risk control, the chance of these 'holes' lining up and causing a loss, accident or incident is minimised. This is referred to as the Swiss Cheese Model of risk control (see Figure 7).

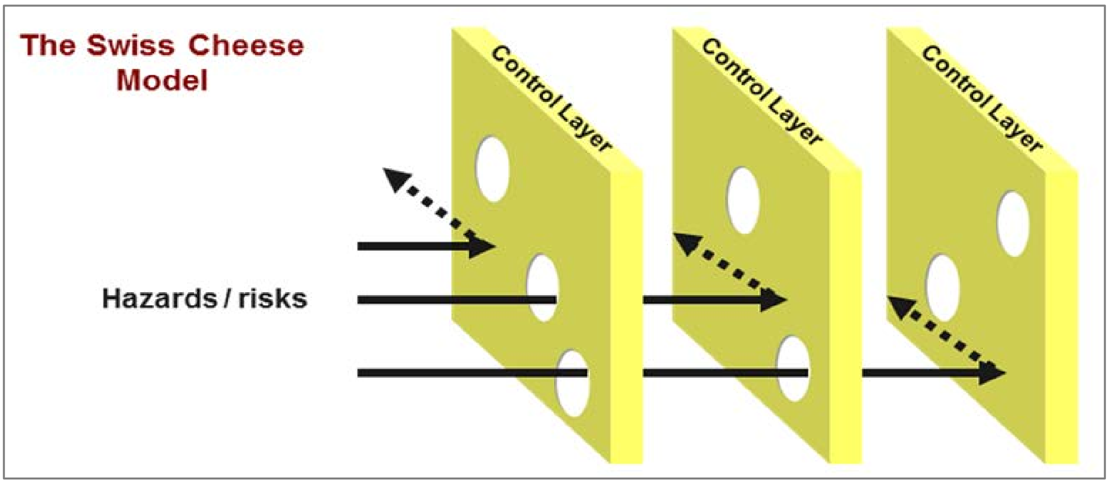


Figure 7: Swiss Cheese Model of Risk Management (Reason 1990)

Figure 8 is an example of one particular dimension of prescribed-burn risk, with its control measures wrapped like layers of an onion, and reflecting the conceptual approach captured within the Swiss Cheese Model.

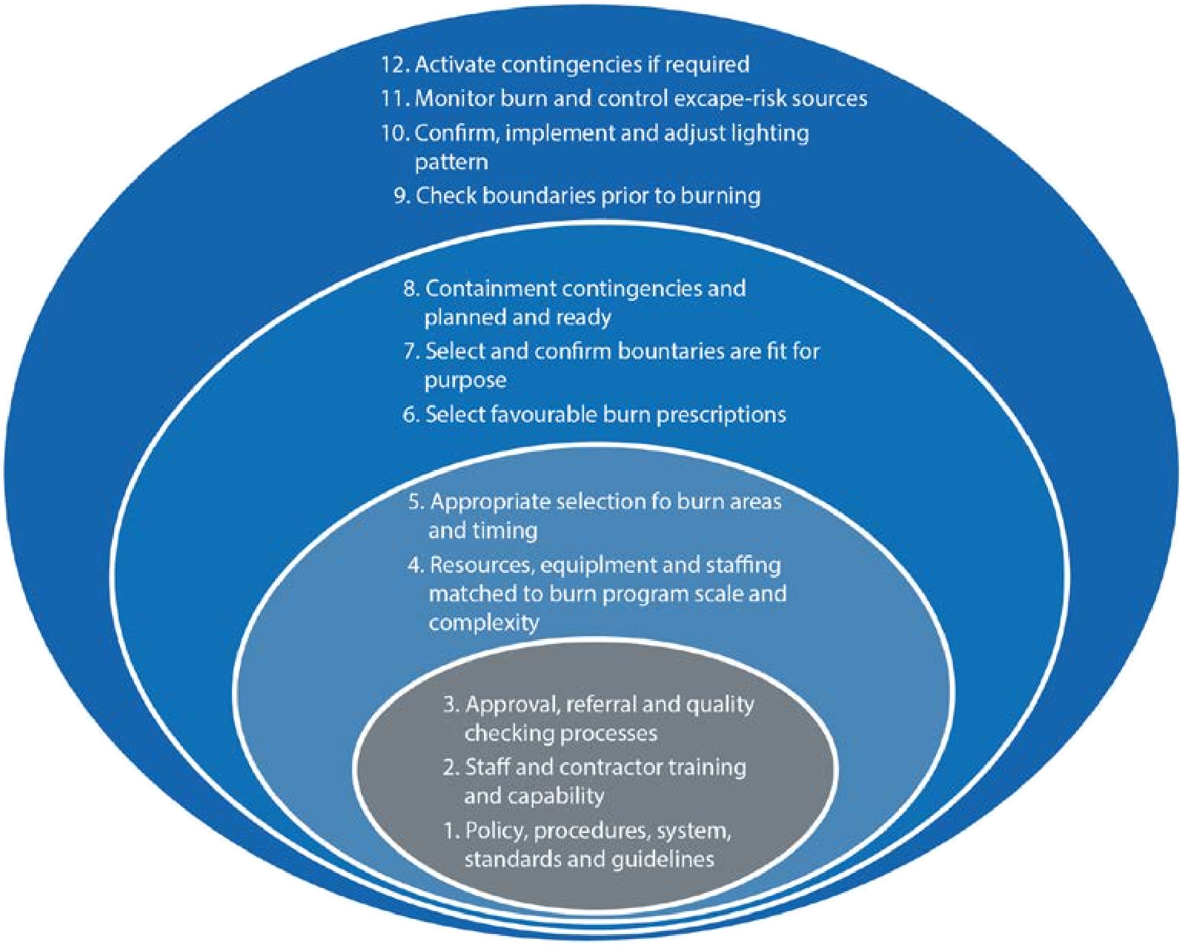


Figure 8: Burn containment risk-control measures (AFAC 2016c)

Risk can also be thought of as either static or dynamic. Static risk is constant or tends to be consistent in nature over a given timeframe, whereas dynamic risk arises from causes that are open to change, and which may vary in likelihood and/or potential consequence over a given timeframe. For example, static risks may include a dead stag on the edge of the burn which might catch alight, whereas a dynamic risk may include the impact of actions taken or other occurrences during conduct of the burn (for example, an unforecasted wind change that occurs after the burn has commenced). The burn manager needs to be continually reassessing risk as the burn and associated works progress.

For more information on risk controls for prescribed burning, including risk-control layer diagrams for a range of risk-control dimensions, refer to *A Risk Framework for Operational Risks Associated with Prescribed Burning* (AFAC 2016c).

The process of managing risks occurs in stages (see Table 4).

Table 4: Risk-management stages

Identify	**1. Values are identified.** Setting measurable objectives that reflect strategic-planning information helps to align prescribed burning to broad agency-level or community-level values, such as protection of life, property and biodiversity. Beyond this, each burn plan identifies at-risk values, fire-containment risks, and safety issues that may require attention at or near the burn site.
Assess	**2. Risks to identified values are assessed to determine if they require mitigation.** Managing risks inherent within prescribed burning requires that planners and practitioners understand that hazards, considered in isolation, do not constitute a fire risk, but need to be in a flammable state, have an ignition source, and be located in sufficient proximity to objects of value. Hence, in a prescribed burn context, risk should be understood as arising from the intersection of hazards with values, such that the overall degree of risk is a product of the combined attributes of all the hazards, plus the combined attributes of all potentially affected values (see Figure 10).
Treat	**3. Those risks requiring mitigation are treated to eliminate or reduce the risk level** Planning and taking action to safely meet the objectives of the burn (i.e. selecting or adjusting ignition strategies, prescriptions, constraints, or other aspects of the burn's implementation), while at the same time planning and taking action to mitigate risks to vulnerable values
Monitor	**4. Risk-treatments are monitored to ensure their effectiveness** Monitoring the progress of the burn, and adjusting ignition and mitigation strategies, as required, to safely meet objectives and protect values.
Review	**5. The success of the risk-management process is reviewed with a view to its improvement** Post-burn evaluation and reporting on the outcomes of the burn, including the success (or failure) in meeting objectives and the reporting of any incidents.

The following sub-sections will examine each element of the risk management cycle in more detail.

Identifying risks

The overarching risk considerations at the strategic- and program-planning levels relate to mitigating the risk of bushfire and avoiding poor land-management or ecological outcomes. Prescribed burning is a risk treatment that reduces fuel hazard in order to reduce the risks associated with severe bushfire. Used effectively, it can also promote the health, biodiversity and resilience of Australia's forests and rangelands. However, prescribed burning is a risk treatment that involves significant, inherent, short-term risks that require identification during the planning of an individual burn. These include risks to:

- life, property and infrastructure
- cultural heritage values
- amenity values, e.g. recreation areas
- utilities (power and telephone lines, water-supply structures, communications towers)
- land use, e.g. timber production, grazing, bee-keeping
- biodiversity values, e.g. fire-sensitive ecosystems.

These are usually identified through reviewing strategic information, GIS outputs, previous burn reports, and by making field visits.

Other risk types that increasingly require consideration include:

- political risks, in recognition of the need to maintain political support for prescribed burning
- reputational risks to the organisation undertaking prescribed burning, regarding perceptions of its ability to undertake safe and effective prescribed-burn operations.

Figure 9: Assessing fuels (Source: Department of Environment, Water and Natural Resources, SA)

Assessing risks

Managing risks inherent within prescribed burning requires that planners and practitioners understand that hazards, considered in isolation, do not constitute a fire risk, but need to be in a flammable state, have an ignition source, and be located in sufficient proximity to objects of value. Hence, in a prescribed burn context, risk should be understood as arising from the intersection of hazards with values, such that the overall degree of risk is a product of the combined attributes of all the hazards, *plus* the combined attributes of all potentially affected values (see Figure 10).

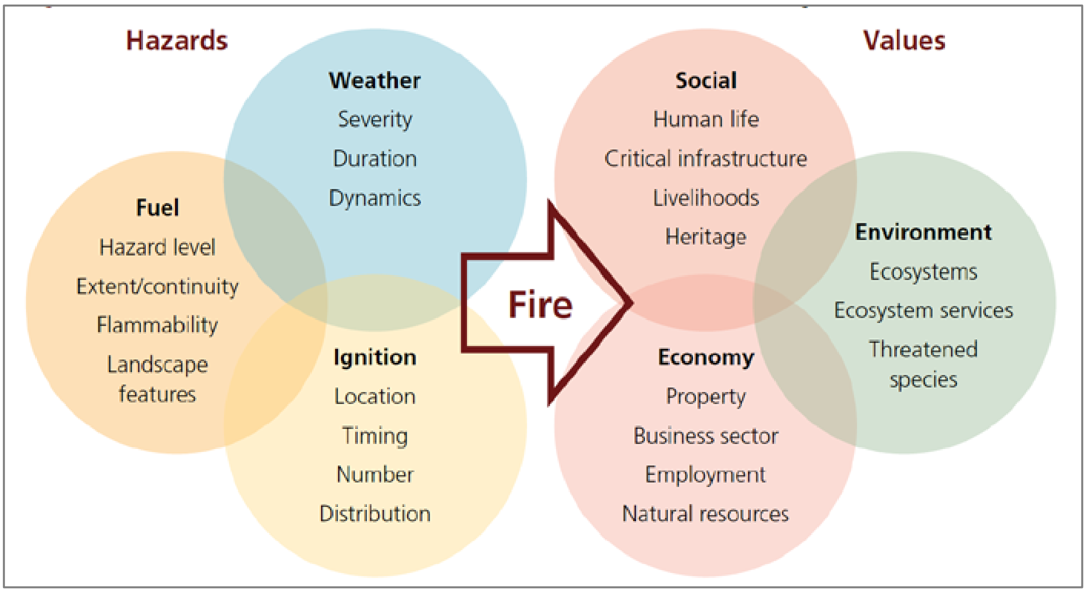


Figure 10: Fire risk arises from the intersection of hazards with values through fire (AFAC 2015, p.13)

Treating risks

Monitoring the weather and matching a particular site to an appropriate window of opportunity, understanding the site's topography, and the fuel types, quantities, mixtures and variations in distribution present, selecting the right time of day to start ignition, and choosing the ignition pattern and spacing that will yield the desired fire behaviour are all essential to managing the risks associated with prescribed burning; and most risks are addressed in this way.

However, putting in place measures to ensure the fire doesn't escape (such as constructing fire control lines and having additional and specialised resources on standby) and planning for contingencies in the event control is lost (including the selection of safety zones, escape routes, fall-back control lines, crew and public safety arrangements and having additional resources on standby) constitute important additional risk-mitigation measures.

Specific mitigation strategies may be necessary to protect values at risk on the site, where these values are not already sufficiently addressed by the above strategies. Examples may include assets, utilities or areas of fire-sensitive vegetation. Often these strategies involve construction of temporary control lines, burning away from these areas, specifying particular wind directions, using particular ignition strategies or staging burning so that these areas are burnt in suitably milder conditions.

Monitoring risks

Monitoring risks as the burn proceeds is essential to allow the burn manager to adjust ignition patterns to the variability of the site and to changing weather conditions. Monitoring of risks is achieved by monitoring the following:

Weather	forecasts and onsite temperature, wind and humidity
Fuel moisture content	essential in order to understand available fuel
Fuel variability at the site	unexpected variations in fuel
Predicted fire behaviour	both for conditions during the burn and in the hours that follow
Resource allocation	needs to be monitored and amended to suit shifting risk priorities as the burn progresses
Crew safety	site hazards, hazardous trees and smoke conditions
Public safety	individuals near the burn, smoke emissions and traffic safety
Values	success of any specified mitigation strategies to protect at-risk values and impacts such as erosion or weed spread.

Salient information is recording during the burn, in logs or in situation reports.

Reviewing risks

After the prescribed burn is usually the best time to evaluate the success of risk control strategies. This is done through:

Debriefings	casual debriefs after shifts or formal debriefs
Post-burn evaluation and reporting	evaluation of stated burn objectives
Formal investigations	in the event of major incidences.

Reviewing of risks allows for adaptive management and continuous improvement of prescribed burning practices.

Section 4 summary

- Risk management is an integral part of any sound management system, and agencies are increasingly requiring an assessment of the risk level of burns and burn plans as part of the approval process.
- Risk control strategies can be layered for increased protection, and thereby limit the potential for holes through which risk can manifest in accidents, injuries or losses.
- Sound risk management involves stages whereby:
  - the values are **identified**
  - the risks to those values are **assessed** to determine if they require mitigation
  - the risks requiring mitigation are **treated** to eliminate or reduce the risk level
  - these risk-treatments are **monitored** to ensure their effectiveness
- the success of the risk-management process is **reviewed** with a view to its improvement.
- Prescribed burning is a risk-treatment that reduces fuel hazard in order to reduce the risks associated with severe bushfire. However, prescribed burning involves significant, inherent, short-terms risks which require management.
- Fuel hazards, considered in isolation, do not constitute a fire risk, but need to be in a flammable state, have an ignition source, and be located in sufficient proximity to items of value to affect them.
- In a bushfire context, risk should be understood as arising from the intersection of hazards with values, such that the combined attributes of all the hazards, *plus* the combined attributes of all potentially affected values, together, contribute to the degree of risk.
- Risk-assessment activities need to be adapted to appropriate spatial and temporal scales. These include:
  - **operational-level planning for works implementation** at site-specific scale for periods ranging from weeks or months
  - **work-method tactics during the execution of burning operations** (to take account of fine scale, intra-site fuel variability and weather-driven variability in fuel conditions).
- After a burn is completed it is important to assess the degree to which risk management treatments were successful.

Self-assessment questions

1. Name five dimensions of prescribed burn risk.
2. What is the different between a static and dynamic risk?
3. The process of managing risks in a prescribed burning context should ideally take what form?

Figure 11: A prescribed burn debrief (Source: DEWNR, SA)

Section

5

Safety

While the safety of people and assets will be a key responsibility for the burn manager at a prescribed burn, many problems can be avoided through identification at the planning stage. Any prescribed burn presents some threat to the safety of:

- personnel managing and conducting the burn
- people near the burn
- assets within or near the burn
- people, perhaps some distance from the burn, who may be affected by heavy smoke.

Planning must include a hazard assessment, including a comprehensive check of the proposed burn area in order to identify and predict potential hazards, and the proposed means to eliminate them or minimise their impact. Some examples are discussed below under 'Site safety'.

Personnel safety

It is essential that all personnel involved in prescribed burning operations are competent in the tasks assigned to them. Some tasks, such as those involved in aerial ignition operations, may require specific accreditations. Others may simply require general firefighter competencies.

Activity 5.1

Identify the competencies and accreditations required of personnel in your organisation involved in prescribed burning.

Personal protective equipment (PPE)

Due to the residual risk that unable to be eliminated from prescribed-burning and fire-suppression work, PPE forms a vital layer within a broader risk-management approach. All personnel working at a prescribed burn must wear appropriate PPE, as issued by their agency, in accordance with their assigned roles. Some personnel may exercise personal preference in obtaining and using additional items of PPE not issued by their agency, however, in all cases these must conform to the relevant Australian or international standards, and must not replace agency issued items.

A more detailed account of the requirements relating to PPE can be found in the *PUAFIR204B Respond to Wildfire Learner Resource.*

Safe use of equipment

Each agency will have its own procedures regulating the safe use of equipment. For mechanical items, these procedures may simply require the operating instructions published by the manufacturer be followed, or there may be procedures that augment the manufacturer's instructions. It is imperative that all personnel familiarise themselves with the relevant instructions and procedures. Personnel may require training prior to being endorsed to use specific items of equipment, such as chainsaws, flamethrowers or propelled incendiary devices.

Personnel should also be reminded of key safety points at briefings, such as staying clear of, and not crossing behind bulldozers at work constructing control lines, and not approaching them unless the operator has indicated that it is safe to do so.

Site safety

Safety issues inherent to the burn site need consideration. These include a broad range of issues such as vehicle movement, localised areas of high fuel, mine shafts, cliffs and hazardous trees.

Risks to users of roads in and around the burn area need to be identified, and appropriate risk-mitigation treatments planned and implemented. The public may be at risk from the burn impacting on roads, particularly from smoke affecting visibility or through trees falling onto the road. The conduct of the burn could also pose a risk to road users, due to the presence of slow moving or parked fire vehicles along the edge of the road. Conversely, road users can pose a risk to personnel conducting the burn, such as the risk of a motorist hitting a worker mopping up a burn along the edge of a road.

Vehicle movement on narrow, sometimes freshly formed, boundary tracks increases the risk of accidents, particularly when crews may be responding with some urgency to an escape. For certain complex burns where this could become a concern a traffic-control plan may be required identifying:

- direction of traffic movement, if one-way only
- location of passing-bays and turning points
- dead-end tracks
- safety zones.

Beyond vehicle movement issues, Table 5 contains a summary of typical hazards encountered by burn personnel on and around burn sites, and suggested means of addressing them.

Where hazards are identified, crews must be made aware of them. This can be done by:

- addressing the hazard and minimisation procedures in the burn plan
- carefully identifying hazards in the pre-burn briefing
- marking (flagging) hazards in the field prior to crew deployment.

Table 5: Hazards to burn personnel and methods to minimise each hazard's impact

Hazards to personnel	Methods to minimise the impact of hazards
Localised steep slopes or rocky ground	**Plan** Show on map. Remote ignition techniques considered. **Conduct** Remote ignition techniques considered.
Wind funnel	**Plan** Weather prescribed to reduce wind speed. **Conduct** Ignition pattern modified, extra patrol resources assigned.
Localised areas of high fuel	**Plan** Show on map. Exclude from the burn with additional control lines. **Conduct** Ignition pattern modified, extra patrol resources assigned if near control lines.
Vegetation with flash fuels	**Plan** Prescribed fuel moisture content raised. Prior ignition under very mild conditions considered.
Areas of elevated fuels	**Plan** Prescribed fuel moisture content raised. Prior ignition under very mild conditions considered. Remote ignition techniques considered.
Communications blackspots	**Plan** Radio repeater station or radio relay point established.
Changes in aspect, slope or vegetation	**Conduct** Brief crews on likely changes to fire behaviour. Modify ignition pattern.
Mine shafts	**Plan** Mark hazard on map. **Conduct** Brief crews. Work crews in pairs (buddy system).
Cliffs	**Conduct** Equip crews with high quality topographic maps. Do not deploy crews near cliffs.
Dead standing trees	**Plan** Mark on map. **Conduct** Construct a control line around trees if they present a spotting hazard, or mechanically fall if a hazard to personnel on the control line.
Powerlines, gas pipelines, etc.	**Plan** Exclude from burn area if possible. Prescribe wind conditions to avoid smoke through powerlines. Notify utility companies. **Conduct** Brief crews regarding hazard. Monitor progression of burn

Smoke

For a detailed discussion see *A Risk Framework — Smoke Hazard and Greenhouse Gas* (AFAC 2015b).

Smoke generated from a burn may also create a substantial hazard or public nuisance under some circumstances, and may be subject to legislated requirements that must be considered when planning any burn. Potential smoke hazards may include:

- road and transport safety
- public health, e.g. people with respiratory conditions
- ventilation facilities for transport tunnels or mines.

Smoke impacting on roads is a significant safety hazard. Several fatalities have occurred as a result of smoke from a prescribed burn causing traffic accidents. Overnight inversions during stable weather can cause smoke to settle over roads and significantly reduce visibility. Traffic control plans could be required where there is likely to be an impact on traffic.

Smoke may also impact on various forms of agriculture and industry such as grape growers and apiarists. Smoke is a particular problem which it pools for long periods or occurs when grapes are at their ripest just prior to harvesting (the time of year that this occurs depends on the grape variety).

Wind direction requirements may need to be identified in the weather component of burn prescription.

Burn security

Burn security involves ensuring that the burn does not escape control lines. The planning of any prescribed burn requires the identification of logical boundaries for the burning unit. Considerations of land tenure, vegetation type, and changes in fuel type or structure may initially dictate burning unit perimeters. However, the availability of control lines that will allow fire to be confined to the target area will ultimately determine the boundaries of a prescribed burn.

Control lines can be natural barriers, such as streams, wet gullies, bare rocky areas, or other areas that will naturally slow or extinguish the fire; or be constructed barriers, such as roads, tracks, mineral earth breaks, slashed vegetation, wet lines created with foam or retardant, or adjacent, recently burnt areas.

The key is that control lines need to prevent fire escape, either through their physical attributes or by providing safe and adequate access for crews to control the edge. The nature of control lines and their width should be commensurate to containing the likely fire behaviour adjacent to them (both on the day of the proposed burn and on subsequent days when conditions may potentially be more severe).

In planning the location and nature of control lines, the influence of topography and fuels on fire behaviour must be taken into account. (See Section 11 for fire behaviour.) Upslope control lines will always come under more pressure from fire behaviour than downslope areas, although appropriate lighting patterns can reduce this. Likewise, control lines that avoid areas of heavy fuel and trees with high bark hazard will be defended more easily during the burn.

Preferred control line locations need to be identified at an early stage to ensure that sufficient time is available to:

- improve existing roads, tracks or firebreaks to the standard necessary for the burn
- construct new control lines where necessary
- gain approvals to undertake work on the land of other agencies or property-owners.

Contingency planning

Even a well-planned prescribed burn may still escape control lines if a thorough risk-management process has not been undertaken and implemented.

Factors that can contribute to burn escape risk include:

- the burn is undertaken either just within or outside of planned prescriptions for burning
- changes to fuel conditions between planning and implementation
- fire behaviour either on the day of the burn or in the days following ignition greatly exceeds expectations or has not been factored into the risk assessment
- burn coverage leaves significant areas of unburnt fuel within the burn area that could reignite later
- fuel type (spotting potential) makes it difficult to keep the burn within control lines
- control/patrol resources are inadequate
- control lines are inadequate.

Good planning can minimise these factors but there is always the potential for a burn to escape.

Topography and weather will make some parts of the perimeter much more secure than others. Contingency planning is recommended for an escape over any part of the burn perimeter for complex prescribed burns. Contingency planning should address what actions will be initiated to control an escape and may consider:

- weather and fire behaviour likely to lead to an escape occurring either on the day or in subsequent days/weeks
- weaknesses in burn control lines/boundaries
- whether the burn can be completed in the time planned
- location of high value assets (structural, cultural, natural) potentially threatened by an escape
- potential or existing fall back control lines
- crew safety considerations (escape routes, safety zones)
- crew redeployment options (ensuring vital on-going tasks continue to be resourced)
- availability and sources of additional resources external to the burn
- reporting of incidents and who needs to be informed
- what happens in the event of major resources (items of equipment and personnel) suddenly not being available
- public safety arrangements (road closures, warnings, property protection).

Safety zones and escape routes

For complex prescribed burns, most agencies will require planning the location of safety zones and escape routes, as these may be required in the event of unexpected fire behaviour. Some agencies require this to be included in the burn plan whilst other agencies leave it to the discretion of the burn manager.

Safety zones should be low-fuel zones (on the likely upwind side of the burn) large enough to cater for all burn personnel, and able to be easily reached from the burn perimeter. Large burns or burns with difficult terrain or limited access may require more than one safety zone. Safety zones may need some additional work to make them adequate. This is most efficiently done by crews preparing control lines.

Also, ensure crews are aware of the best routes to take should it be necessary to escape from the burn site. These are often marked on maps.

Fall-back control lines

It is best practice to identify fall-back control lines as a secondary line of defence in the event of a fire escaping the nominated burn boundary. This is particularly important where boundary access is difficult, where natural boundaries are being used (such as waterways or gullies) or where burns are unbounded (and are expected to self-extinguish due to overnight conditions). Fall-back lines may comprise existing roads, tracks or other features that would impede the spread of fire (e.g. major creeks, railway lines, cleared easements). Where these do not exist and an escape of the burn could lead to a large unplanned area being burnt, additional fall-back lines may need to be able to be constructed and therefore equipment such as a bulldozer may need to be available.

Other contingencies to be prepared for

While the risk of the burn escaping is the key risk that must be taken into consideration, effective planning and burn preparations will also consider other potential problems for which contingent actions may need to be planned (see Table 6).

Table 6: Other contingencies to be prepared for

Issue	Contingency planning options
Failure of aerial ignition resources to arrive as planned	• Ensure alternative means of ignition (driptorches, flamethrowers, propelled incendiaries) are on hand or on stand-by.
Equipment breakdown	• Plan burn to incorporate more than the bare minimum of resources. • Ensure additional items of key equipment are on stand-by or near at hand.
Injury	• Check first-aid equipment is adequate for treat the list of potential injuries. • Include ambulance service in the notifications plan, and specify a safe ambulance and helicopter medevac points in burn plan. • Plan and communicate which roles can be recalled to assist in a medical emergency, and which roles must be maintained to ensure burn security.

Section 5 summary

- While the safety of people and assets will be a key responsibility for the burn manager at a prescribed burn, many problems can be avoided by careful planning.
- Any prescribed burn presents some threat to the safety of:
  - personnel managing and conducting the burn
  - people near the burn
  - values and/or assets within or near the burn
  - people, perhaps some distance from the burn, who may be affected by heavy smoke.
- Planning must include a hazard assessment, including a comprehensive check of the proposed burn area, to identify and predict potential hazards and the proposed means to eliminate them or minimise their impact.
- It is essential that all personnel are competent in the tasks assigned to them; some tasks may require specific accreditations.
- Due to the residual risk that is unable to be eliminated from prescribed-burning and fire suppression work, personal protective equipment (PPE) forms a vital layer within a broader risk-management approach. All personnel working at a prescribed burn must wear appropriate PPE as issued by their agency in accordance with their assigned roles.
- Smoke generated from a burn may create a substantial hazard or public nuisance under some circumstances, and may be subject to legislated requirements that must be considered when planning any burn. Smoke may potentially impact on:
  - road and transport safety
  - public health, e.g. people with respiratory conditions
  - ventilation facilities for transport tunnels or mines.
- Control lines need to prevent fire escape either through their physical attributes or by providing safe and adequate access for crews to control the edge.
- Contingency planning is recommended for complex prescribed burns, in the event of burns escaping any boundary. This is especially the case in areas where access to the burn perimeter is difficult. Contingency planning may include:
  - identification of fall back control lines
  - having additional and special resources on standby
  - selecting and/or building safety zones and fall back lines.
- A traffic control plan should be developed where necessary. It should identify:
  - direction of traffic movement, if one-way only
  - location of passing-bays and turning points
  - dead-end tracks
  - safety zones.

- Site hazards should be:
  - addressed in the burn plan
  - carefully identified in the pre-burn briefing
  - marked clearly in the field prior to crew deployment.
- Each agency will have its own procedures regulating the safe use of equipment. For mechanical items, these procedures may incorporate or augment the operating instructions published by the manufacturer. Specific items of equipment may require training prior to being endorsed to use them.

Self-assessment questions

1. What ultimately dictates the necessary nature and dimension of prescribed-burn control lines?
2. Why is it important to plan control lines well before the proposed burn?
3. What are some of possible site-safety hazards at a burn site?
4. Why is use of PPE important?
5. What are the possible adverse effects of smoke from prescribed burns?
6. What is required when smoke may affect traffic on public roads?
7. Areas nominated as safety zones should have what characteristic?

Section

6

Values

In addition to the safety of personnel and the public, another key domain of risk relates to items of value in and around the burn area. Prescribed burns have the potential to impact on a range of values and assets, such as:

- built assets (i.e. property, utilities and infrastructure)
- environmental values (e.g. soil conservation, ecosystem health, biodiversity maintenance)
- cultural-heritage values (e.g. public amenities, sites of historical interest)
- land-use values (e.g. water sourcing, timber production, grazing, bee keeping).

As described in Section 4, values need to be identified, assessed to determine their exposure to risk from the burn, protected where necessary, and monitored during the burn. The success or failure of these risk-assessment and protection measures will later form part of a post-fire evaluation process, which should be planned for at the time the risks are assessed and evaluated (see Section 14).

Built assets

One of the risks of prescribed burning is flames, heat, smoke or embers damaging or affecting property and infrastructure. This is a risk for all burns, but particularly prescribed burns near the urban—rural interface.

Property and infrastructure potentially damaged by prescribed burns includes (but is not limited to):

- residential homes, sheds, barns, fences and other residential structures
- schools, halls, hospitals and other community buildings
- factories, warehouses and other types of industrial site
- park and forestry structures, such as benches, walkways and mills
- essential infrastructure, such as power and telephone lines, power substations and pipelines.

Identification

When planning a prescribed burn, it is essential to gain familiarity with the built values that are on or near the burn site. Strategic-level planning documents are a good place to start, and most agencies will have GIS resources that identify the location of many built assets. However, to properly identify built assets, it is necessary to visit the site of the burn and nearby areas. Engagement with stakeholders will also often yield important information about assets requiring protection.

Assessment

Not all built assets on or near the burn area will be vulnerable to prescribe fire. For them to be vulnerable they need to be potentially damaged by flames, radiant heat or embers, or else impacted by smoke. Built assets that are assessed to be vulnerable should be included in the burn plan. Consult the opinions of experienced practitioners, if necessary, to determine whether assets are vulnerable. Irrespective of their vulnerability or not, all built assets should be identified on the prescribed burning map.

Protection

Burning in appropriate conditions is the key strategy for ensuring built assets are protected. However, many built assets may require additional strategies in order to protect them, and these strategies should be documented in the burn plan. These may include:

- ensuring fire control lines are sufficient to contain burns
- establishing temporary control lines, which may include slashed lines, rakehoe lines, wet lines or areas cleared of all fuel
- using appropriate ignition strategies to back fire away from built assets
- burning with appropriate winds so that embers, smoke and flames are directed away from built assets
- preliminary burns in areas adjacent to built assets under very mild conditions to establish a burnt buffer prior to conducting the main prescribed burn
- notification of owners of the built assets so that they are aware and may potentially assist by preparing their property
- notification of additional resources, so that they can be ready to respond, or so that they can be in attendance with suitable appliances to assist in protecting built assets
- notification of local brigades so that they are aware of burn operations in their area.

Figure 12: Structures damaged by fire (Source: Office of Bushfire Risk Management, WA)

Ecological and environmental values

Most burn areas warrant detailed consideration of the risks posed to ecological and environmental values. At a strategic and program planning level, the issues are quite technical and require consideration of ecosystem health, fire tolerance intervals, appropriate fire regimes, mosaics, the health of fauna and flora populations, biodiversity conservation and scheduling burns appropriately. These strategic and program planning issues are not addressed in this learner resource, which focuses on issues to be considered at an operational planning level.

For a detailed discussion of evaluating ecological and environmental risks within a prescribed burning context see *A Risk Framework for Ecological Risks Associated with Prescribed Burning* (AFAC 2016b).

Identification

When planning and implementing a prescribed burn, it is important to not only reflect objectives set at a strategic or program planning level, but also to be aware of ecological health issues specific to the site. For example, a poor fire regime might have led to an overabundance of a single species that can be controlled by using prescribed fire. (See Section 8 for more information on fire ecology.) To this end, you should examine the proposed burn area to:

- identify ecological communities that are fire sensitive
- give special consideration to rare, vulnerable, endangered or regionally/locally significant species
- record the location of habitats that require protection for these species
- determine what environmental impacts may arise from erosion, pollution and weed spread.

Ecological values may have already been identified in strategic plans, but most agencies will utilise GIS to identify and spatially locate values within proximity to the burn. It may also be necessary to consult with internal staff and/or external experts to help identify and assess specific values. Some agencies have formal ecological assessment procedures which may be documented as a separate but associated report supporting a burn plan. Most agencies however, include ecological assessments as part of the burn plan.

Assessment

It needs to be understood that just because an ecological value is at or near a burn site does not mean it is at risk from prescribed burning. In terms of natural values, many species have either evolved with fire or are self-protecting from fire (under suitably mild conditions) or tolerate some amount of fire and are therefore not vulnerable to prescribed burning undertaken in suitable conditions.

However, there are cases where specific species, habitats or features need some sort of additional mitigation strategy during a prescribed burn. Values that require specific mitigating strategies during a planned burn should be documented in the burn plan so they can be brought to the attention of the burn manager.

Protection

There are a range of strategies available for protecting ecological values such as planning ignition to back fire away from fire-sensitive areas, raking around habitat features, rakehoe lines or wet lines, weed hygiene and erosion controls, or choosing conditions where fire will not penetrate beyond a moisture gradient thereby protecting the moister fire-sensitive ecosystem. Your agency will have procedures for managing ecological values in prescribed-burn operations.

Figure 13: Fire extinguishing along the edge of a moisture gradient (Source: Queensland Parks and Wildlife Service)

Cultural heritage values

Large scale wildfires are known to damage cultural heritage values, and prescribed burning will help protect these features. However, they can also be damaged by prescribed burns. Where cultural heritage items exist on or adjacent to the burn site, consider if they require particular mitigation strategies to protect them during the prescribed burn.

In terms of operational planning, values at risk may include:

- middens
- rock-art sites
- stone tools, wrapped bundles and burial sites
- engravings on trees and rock faces
- arrangements of stones or raised earth patterns,
- scarred or carved trees
- natural features with cultural significance
- historic infrastructure, building and fence remains
- quarries and mine sites
- forestry artefacts such as marked trees and forestry equipment
- military artefacts
- survey and trig points
- markers from early European exploration.

These can be impacted through mechanical disturbance (vehicles, rakehoe lines, tractors), direct contact from fire, radiant heat from fire and smoke (especially sooty smoke effecting rock art sites).

Land-use values

Prescribed burning is part of a range of strategies that help protect primary industries from bushfire impacts. However, prescribed burning can have an impact on:

- water sources
- grazing resources
- silvicultural resources
- apiary resources
- grape growing.

Impacts on grazing and silviculture resources may arise when burns escape their boundaries and burn nearby areas. Impacts on grape growers are more likely to arise from smoke pooling and then tainting grapes that are at a late stage or ripening just prior to harvest. Impacts on beekeepers can arise from fire impacting on hives or burning out particular species during times of abundant flowering.

Strategies to protect primary industry resources are similar to those already mentioned above including burning under appropriate conditions, choosing appropriate wind directions, ensuring control lines are sufficient and backing fire aware from vulnerable areas or areas where there is a risk of fire escaping and impacting resources.

Section 6 summary

- Prescribed burns have the potential to impact on a range of values and assets including:
  - built assets (i.e. property, utilities and infrastructure)
  - environmental values (e.g. soil conservation, ecosystem health, biodiversity maintenance)
  - cultural-heritage values (e.g. public amenities, sites of historical interest)
  - land-use values (e.g. water sourcing, timber production, grazing, bee keeping).
- Property and infrastructure potentially damaged by prescribed burns includes (but is not limited to):
  - residential homes, sheds, barns, fences and other residential structures
  - schools, halls, hospitals and other community buildings
  - park and forestry structures such as benches, walkways and mills
  - community infrastructure such as powerlines.
- Ecological and environmental issues that should be considered during operational planning include:
  - the identification of ecological values
  - the need to reflect objectives set at a strategic or program planning level
  - being aware of ecological health issues that require attention (e.g. a poor fire regime might have led to an overabundance of a single species that can be controlled by using prescribed fire)
  - identifying environmental impacts that may arise from erosion, pollution and weed spread.
- Burning in appropriate conditions is a key strategy to ensure values are protected. However, many may require additional strategies which should be flagged in the burn plan. These may include:
  - notification of owners of built assets so that they can be aware and potentially assist by preparing their property
  - ensuring fire control lines are sufficient to contain burns
  - establishing temporary control lines which may include slashed lines, rakehoe lines, wet lines or areas cleared of fuel
  - using backing fire to burn away from an identified value
  - burning with appropriate winds so that embers, smoke and flames are directed away from built assets.

Self-assessment questions

1. What are some of the values and assets potentially affected by prescribed burning?
2. What are the best ways to identify values that may be impacted by prescribed burning?
3. When do the values identified during operational planning require mitigation strategies in the burn plan?
4. How are cultural heritage items potentially impacted by prescribed burns?

Section

7

The urban–rural interface

The urban–rural interface is a transition zone where structures, modified environments and other human development adjoin or overlap with bushland fuels (NWCG 2011). Bushfires that impact on the urban interface have a large potential for loss of life and assets due to the density of development (AFAC 2016e). Using fire proactively in these areas can provide significant protection by modifying fire behaviour and increasing suppression effectiveness (AFAC 2016e), and is therefore one of a number of strategies used to mitigate the damaging effects of bushfire. However, prescribed burning in interface areas also contains inherent risks that must be carefully considered during planning and implementation phases. Increasingly, mechanical removal of fuel is being used as a way to mitigate risks; however, mechanical removal of fuel also has its own impacts and limitations.

Identifying the urban–rural interface

In order to help identify and characterise urban–rural interface areas, three categories are offered:

- classic
- mixed
- occluded.

Classic Interface

This interface is typically found on the edges of cities and towns where development has extended into the surrounding natural landscape (see Figure 14). There is a distinct border between vegetation and residential or industrial development. Assets closest to this edge will be at the most immediate risk.

Figure 14: Classic interface

Mixed interface

This interface is often found outside of defined township boundaries and involves isolated developments surrounded by vegetation (see Figure 15). This type of interface can include farm houses, hobby farms, rural lifestyle developments, 'retreat' type accommodation and associated structures, such as sheds, stables and grain stores. The mixed interface may also include important utility installations such as electrical substations, telephone exchanges and communications towers.

Figure 15: Mixed interface

Occluded interface

This interface is defined as areas of vegetation being surrounded by development (see Figure 16). Examples include reserves, sanctuaries, water catchments, remnant natural vegetation and recreation parks within township or development boundaries.

Figure 16: Occluded interface

Considerations when working in the urban—rural interface

- Fuels can vary significantly over small areas in urban—rural interface zones, due to the prevalence of modified landscapes, such as lawns, gardens, assets, utilities, fences and non-burnable surfaces. These complex urban interface fuels are poorly understood, but are known to exhibit a broad range of fire behaviours (AFAC 2016e). Using available fire behaviour models will often be unreliable in the urban—rural interface zone.
- Smoke impacting roads, residences, hospitals, nursing homes, schools, etc., must be considered. Smoke can cause significant health and safety risks. Planning should carefully consider smoke generation, plume behaviour and locations where smoke may pool and settle (refer to Section 5).
- Creation of permanent or temporary fire control lines is often used as part of fire management in these areas, and can assist with control options, containment and crew access.
- The importance of timely and well-worded public notifications (be it through letter-box drops, signage, and, increasingly, via electronic messaging systems) prior to prescribed burning is an important aspect of gaining community trust and support, and allowing residents to make any necessary preparations.
- Traffic management is likely to require careful planning. Disruption to commuter traffic by smoke or fire-management vehicles, and increased risk of accidents or delays associated with the public unexpectedly appearing on roads in burn areas must be considered during prescribed burn planning and operations. A traffic management plan may be required.
- There is a greater likelihood of the presence of the media, which may demand the attention of the burn manager or crews. A media management plan is sometimes required.
- It may be necessary to black-out larger areas than usual to minimise calls to brigades or other government authorities from residents concerned about visible flames after operations are complete.
- It is important to patrol the site of hazard reduction burns in the urban—rural interface after the burn is complete to ensure smouldering areas are not subject to escalation through

changes in weather, such as strong winds. (There are many examples of burns that have been implemented successfully, but not subsequently patrolled, reigniting under strong winds, and resulting in embers escaping the area and damaging nearby values and assets.)

Prescribed burning strategies in the urban—rural interface

Burning in appropriate conditions is the key strategy to achieving the burn objectives. However, there may be the need for additional strategies when burning in urban—rural interface which should be documented in the burn plan. These may include:

- ensuring values at risk are clearly identified and assessed for their vulnerability (see Section 12)
- having a good public-notification plan and a list of contacts for notification purposes, to ensure residents and local brigades are aware of prescribed burning activities
- a traffic management plan and qualified traffic contractors
- ensuring fire control lines are sufficient to contain burns
- establishing temporary control lines which may include slashed lines, rakehoe lines, wet lines or areas cleared of all fuel
- using appropriate ignition strategies to back fire away from built assets
- burning with appropriate winds, so that embers, smoke and flames are directed away from built assets
- being aware of smoke plume dynamics and being mindful of where smoke is likely to pool, even after prescribed burning operations are complete, including overnight
- conducting preliminary burns in areas adjacent to assets under very mild conditions to establish a burnt buffer area prior to conducting the main prescribed burn
- notification of owners of the built assets so that they can be aware and potentially assist by preparing their property
- notification of additional resources, so that they can be in attendance or ready to respond with appliances suitable for assisting in the protection of built assets
- notification of local brigades, so that they are aware of burn operations taking place in their area.

Section 7 summary

- The urban—rural interface is defined as a transition zone where structures, modified environments and other human development adjoin or overlap with bushland fuels.
- Using fire proactively in these areas can provide significant protection by modifying fire behaviour and increasing suppression effectiveness, however prescribed burning in these areas also carries risks.
- Interface areas can be characterised as:
  - classic
  - mixed
  - occluded.
- Fuels can vary significantly over small scales in urban—rural interface areas.
- Smoke impacting roads, residences, hospitals, nursing homes, schools, etc., must be considered (refer to Section 5).
- Public notification, education and awareness-raising activities are important aspects of managing risks.
- Traffic management is likely to require careful planning. A traffic management plan and qualified traffic contractors may be required.
- Key prescribed burning strategies in urban—rural interface areas include:
  - ensuring values at risk are clearly identified and assessed for their vulnerability (see Section 7)
  - having a good public-notification plan/list, ensuring residents and local brigades are aware of prescribed burning activities
  - a traffic management plan and qualified traffic contractors
  - ensuring fire control lines are sufficient to contain burns
  - establishing temporary control lines which may include slashed lines, rakehoe lines, wet lines or areas cleared of all fuel
  - using appropriate ignition strategies to back fire away from built assets
  - burning with appropriate winds, so that embers, smoke and flames are directed away from built assets
  - being aware of smoke plume dynamics and being mindful of where smoke is likely to pool, even after prescribed burning operations are complete, including overnight
  - conducting preliminary burns in areas adjacent to assets under very mild conditions to establish a burnt buffer area prior to conducting the main prescribed burn
  - notification of owners of the built assets so that they can be aware and potentially assist by preparing their property
  - notification of additional resources (and local brigades), so that they can be in attendance or ready to respond with appliances suitable for assisting in the protection of built assets
  - patrolling the burn site until all smouldering areas have been extinguished, to ensure it is not subject to re-ignition or escalation as a result of weather changes, especially strong winds.

Self-assessment questions

1. Describe the characteristics of a 'classic' urban—rural interface?
2. What are four important considerations when planning or implementing prescribed burns in the urban—rural interface?
3. What are four important strategies used when undertaking prescribed burning in the urban—rural interface?

Section

8

Fire ecology

For millennia, fire has played an important role in shaping Australian environments, ecosystems and biota, both through natural ignitions, such as lightning strikes, and through aboriginal burning practices. The distribution of ecosystems and species across landscapes has been shaped by fire, such that fire plays an important part in maintaining the health, diversity and sometimes the survival of an ecosystem.

Many Australian species exhibit characteristics that enable them to survive fire, with many flourishing after a fire, and a number requiring fire to regenerate or renew their habitats. However, others are more sensitive to fire, requiring no fire, or very long intervals between fire, if their populations are to be maintained (AFAC 2016d). Fire management needs to take this diversity of responses to fire into account when identifying suitable patterns of fire (fire regimes) in a landscape.

Fire ecology aims to understand how ecosystems, flora and fauna are influenced by fire in order to:

- maintain healthy ecosystems and healthy ecosystem functioning
- maintain or improve the abundance and composition of species within an ecosystem
- maintain populations of and habitat for flora and fauna
- maintain or enhance the diversity of landscapes, ecosystems and species
- protect endangered, threatened or vulnerable species
- protect ecosystems that are fire-adapted and those that are fire-sensitive
- rehabilitate environments that are in poor condition
- maintain ecosystem services (such as carbon and water cycles)
- manipulate an aspect of an ecosystem for any other management objectives (there are many different objectives that are possible).

Most of the difficult work of identifying suitable fire regimes for ecosystems is done within the strategic-planning stage of fire management planning, and is therefore not addressed in detail in this learner resource. However, those planning and implementing individual fires ought to have a good understanding of basic fire ecology concepts as discussed below. Ideally, over time, practitioners gain experience and develop a detailed understanding of local environments, by observing how they respond to fire and through discussions with local experts.

Figure 17: Photographic series depicting ecosystem rejuvenation after a prescribed burn (Source: Queensland Parks and Wildlife Service)

Fire ecology concepts

A **fire regime** is the pattern of fire within an ecosystem or area, and refers to the frequency, extent, patchiness, season and intensity.

The type and regime of fire used within an ecosystem is important. Ecosystems are systems constituted by parts that, when healthy, work together to maintain the ongoing health and survival of the ecosystem as a whole. Applying fire or a regime of fire to an ecosystem, without considering how that ecosystem will respond in its current condition, is a risk. However, to withhold from applying fire is also a risk, since this this may result in other, unintended impacts, including subsequent, unplanned, environmentally damaging fires.

Knowledge of the ecosystem's **fire regime**, sensitivity to its **current condition**, and an understanding of the specific needs of local **flora and fauna** are all required to perform beneficial ecological burning. There three topics will be discussed in greater detail, before examining **mosaic burning** as a useful strategy for promoting ecological diversity and ecosystem health.

Fire regime

The fire regime of an ecosystem will greatly influence the health, functioning, composition and diversity of that ecosystem; much more so than any single fire event (AFAC 2015b).

The concept of fire regime describes the general pattern of fires that has occurred, or is desirable to occur, in an ecosystem over space and time. This includes both planned fires and naturally occurring bushfire. A fire regime includes consideration of fire frequency, fire extent, fire season, fire intensity, fire patchiness, and the ongoing combination of these factors (AFAC 2015b).

Much work has been done (and continues to be done) on identifying suitable fire regimes for Australian ecosystems. Usually it is recommended that the elements of a fire regime vary (in other words, do not interpret the required spatial proportions and time intervals too formulaically). To avoid an overly reductive interpretation, recommended fire regimes are ideally described in terms that are broad and which invite deliberate variation within the ranges specified. The following example is from the *Queensland Planned Burn Guidelines* (DNPRSR 2013) and is for spinifex woodlands:

> Apply mosaic planned burns across the landscape at a range of frequencies to create varying stages of post-fire response (recently burnt through to the maximum time

frame). For eucalypt woodland with a spinifex understorey consider a broad fire interval range of between five to ten years. A mosaic is achieved with generally 50—80 per cent burnt within the target communities. Burn anytime from the wet season to the mid-dry season, while the soil retains moisture. Do not burn in the late dry season to avoid high-severity fires.

Fire frequency

Fire frequency is the period of time between fire events, but is sometimes expressed as the number of times fire has occurred over a particular period (South East Queensland Fire and Biodiversity Consortium 2013, p.2). Fire frequency is heavily influenced by the concept of **tolerable fire intervals** (sometimes called ‘inter-fire interval’, ‘tolerable fire interval’, ‘fire interval threshold’ and ‘thresholds of potential concern’).

A **tolerable fire interval** reflects the accumulated knowledge regarding how an ecosystem’s individual species respond to fire (although this is usually limited to plants, since they are easier to survey), and is usually expressed as a range in years (e.g. 7—16 years).

The minimum interval often reflects the needs of **obligate seeder** species (i.e. those plant species that are killed by fire and have no choice but to recover by seed) and the minimum interval of time they take to mature and set seed. Species that are **resprouters** (i.e. those that recover from epicormic or basal shoots) are usually of less concern, although fires that are too frequent can sometimes affect these too. Other species are **fire-sensitive** (i.e. have no recovery response) and must re-colonise from nearby areas. The maximum interval tends to reflect the amount of time it takes for the species to **senesce** (i.e. to age to the extent that their health is affected).

The concept of tolerable fire intervals have come under criticism because it do not account well for a mosaic approach to burning, and if used as a formula for applying fire, can result in an overly conservative fire regime (i.e. not burning frequently enough). It is recommended that fire frequency recommendations are not interpreted as a precise formula.

Vegetation growth stage structure is perhaps a more contemporary approach to fire frequency. It is based on the premise that, as a result of mosaic burning, the ecosystem is in a condition whereby different areas are in different stages of recovery from fire. Maximising the different age classes of vegetation recovery over time (though judicious application of mosaic burning) is considered to be a desirable way of creating or maintaining biodiversity, because each age class tends to form suitable habitats for a different range of flora and fauna.

Other indices of ecosystem health, such as Geometric Mean Abundance (DELWP 2015, p.21), are being developed and may provide greater insights in the future.

Fire extent

Fire extent is the area burnt by a fire. Fire extent affects the mosaic pattern of a fire at a landscape level, reflecting that different parts of the landscape have been targeted for prescribed burning at different times.

Fire patchiness

Fire patchiness is the pattern of burnt and unburnt fuel within the footprint of an individual burn, reflecting the in-burn mosaic or micro-mosaic of a fire.

Fire season

Fire season is the time of year that a fire occurs. Some ecosystems will have preferred seasons for fire, many will have a season in which fire is not recommended, but often some variation in fire season is desirable, so that the benefit to or impact on different species is balanced. Sometimes it is important to avoid a particular season or month of burning due to the presence of endangered, vulnerable or rare species that may be vulnerable to fire at that time, for example, because they are nesting.

Fire intensity

Fire intensity is defined as the rate of heat output in units of kilowatts per metre (kW/m) (See Section 11). Low intensity fires are usually recommended for prescribed burning, because most species have recovery or survival responses for these kinds of fires. However, in some instances high intensity fire is desirable (e.g. to rehabilitate an area by reducing overabundant trees, to remove certain weed species, or because certain species are present that require sufficient heat to stimulate seed germination). Some fire regimes recommend mostly low intensity fires with an occasional higher intensity fire. Often the higher intensity fire does not need to be programmed since it is likely to occur at some stage without planning as a result of bushfire.

Ecosystem condition

Visual indicators of certain elements of an ecosystem can be a useful guide to practitioners interested in maintaining healthy ecosystems. Indicators can include the presence of certain migratory species or the flowering of a particular plant, and can also include positive and negative system-health indicators, such as the appearance of understorey, a build-up of certain weeds, the presence of canopy die-back, or a thickening of woody species.

Such indicators are useful to build an understanding of the condition of ecosystems within a given area. Learning to read these indicators (sometimes called 'reading the country') is a useful art that many experienced practitioners acquire. Inferring ecosystem condition is a useful supplement to fire regimes, since deleterious results can occur if fire is applied to an ecosystem without its current condition being taken into account. Examples of where an ecosystem might require an altered approach (from the recommended fire regime) based on visual indicators include:

- an area being due for fire (theoretically, according to GIS analysis), but is still in a healthy or prime state, and so does not yet require fire
- an area not being due for fire (theoretically, according to GIS analysis), but is showing signs of senescing, such that fire may in fact be beneficial
- a particular species is flowering and this is known to be a sign that the area is ready for burning
- there are signs of drought, and therefore burning at this time may stress the system
- there are signs of tree die-back, and a different style of burning is required to rehabilitate the area
- there is an overabundance of a particular tree species colonising the area, and an altered approach is required to thin the tree species
- there are signs of weed infestation, and introducing fire at this time might provide a competitive advantage to the weed

- there are signs of weed infestation, and introducing a more intense fire than recommended might help control the weed
- there are signs of invasive grass infestation, and introducing fire at this time might cause more intense fire behaviour than expected, causing damage to native vegetation.

Fire ecology and species

Species vary considerably in their response to fire, and these are generally categorised into responses that are fire-adapted and those that are fire-sensitive. Ecosystems often constitute a blend of species with different responses to fire.

Fire-adapted species

These species are adapted to a suitable fire regime. Plants and animals within an ecosystem generally have a range of strategies or adaptations evolved over time that help them survive or benefit from fire. These can include flora taking advantage of new ash-beds, re-sprouting, dropping seeds, or fauna running away or moving underground to avoid the fire. Species are not usually adapted to just any fire, but rather the specific range of fire regimes that they have evolved to cope with. Some species are dependent on fire for their survival. Others are killed by fire, yet paradoxically require fire to stimulate seed germination (e.g. some acacias).

Fire-sensitive species

Fire-sensitive species are damaged or killed by fire, and lack strategies to successfully recover. Some ecosystems, such as rainforests, are dominated by fire-sensitive species, and therefore fire is avoided in these ecosystems. Fire-sensitive species also occur in ecosystems that tolerate a certain amount of fire or require long fire intervals. Fire-sensitive species may be a component of an ecosystem generally adapted to fire, and may occur in naturally sheltered areas, or be a transient component that disappears after a fire only to re-colonise the area later. Some species, such as Casuarina, Callitris and Cypress species can tolerate low intensity fire, but will perish if their growing tips are scorched or if their basal bark is collared (burnt on all sides).

Endangered, rare and vulnerable species

These species vary considerably in their fire response and may be either fire-adapted or fire-sensitive.

A prescribed burn program should principally aim to consider the regime requirements of an ecosystem, rather than be designed around the needs of a particular species. Generally speaking, if a species evolved to live within an ecosystem, then that ecosystem's recommended regime ought to be suitable for that species. However there are situations where the needs of a threatened species must be elevated and a burn program may need to be designed for it. For example, the species may be highly endangered with very few remaining populations, any one of which could be devastated by a single fire event. Or little is known about the species and a conservative approach is being taken. There may be legal requirements for particular species that you should be aware of within your jurisdiction.

Some jurisdictions have developed fire regime recommendations for individual species. These should be interpreted within the context of the fire regime recommendation for the ecosystem in which it occurs.

Mosaic burning

Mosaic burning acts to maximise or retain biodiversity through deliberately applying fire in a manner that is patchy (resulting in some areas that are burnt and some that are unburnt). Mosaics can be created at a landscape level by targeting different areas of a region at different times or in different years. Mosaics can also be created within the area of an individual burn through using appropriate weather conditions and ignition techniques (such as widely spaced spot ignition). Mosaics at all scales are important (DNPRSR 2012).

Mosaic burning aims to create or maintain an ecosystem such that different areas are always at different stages of recovery from fire. This creates a diversity of habitats suitable for a diverse range of species. Mosaic burning also creates resilience in an ecosystem, since the species within the ecosystem have a wider variety of habitat options available to them in the event of changing conditions (e.g. climate change). Mosaics also create stability in the sense that they help buffer the movement, severity and impacts of bushfire.

As shown in Figure 18, the more detailed the pattern of mosaic is, the greater the habitat diversity and resilience of the ecosystem will generally be.

Not all ecosystems are suited to mosaic burning, for example, heath and mallee vegetation is difficult to burn in a mosaic pattern. Also, there are many cases in which a mosaic pattern is undesirable, such as when the overriding objective is property protection or bushfire mitigation. Being aware of the strategic and program plan objectives (see Section 3) is important in order to understand what sort of objectives are desirable for individual burns.

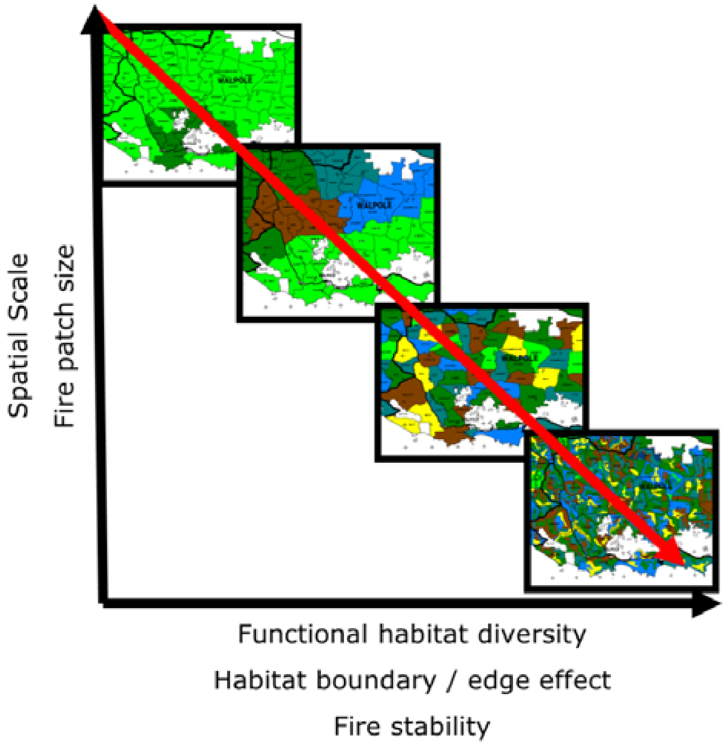


Figure 18: Fire mosaic possibilities from the least desirable (top left) to the most desirable (bottom right) (Source: DPAW, WA)

Section 8 summary

- Fire ecology aims to understand how ecosystems, flora and fauna are influenced by fire for a range of purposes including maintenance, protection or rehabilitation for environmental purposes.
- Most of the difficult work of identifying suitable fire regimes for ecosystems is done within the strategic-planning stage of fire-management planning, however, those planning and implementing individual fires ought to have a good understanding of basic fire ecology concepts.
- Applying fire or a regime of fire to an ecosystem, without considering how that ecosystem will respond in its current condition, is a risk. However, to withhold from applying fire can also be a risk.
- The concept of fire regime describes the general pattern of planned and natural fires that have occurred, or is desirable to occur, in an ecosystem over space and time. A fire regime includes consideration of fire frequency, fire extent, fire season, fire intensity, fire patchiness, and the ongoing combination of these factors.
- Tolerable fire interval is concept that describes the frequency of fire events. It is expressed as a range that takes into consideration the needs of:
  - obligate seeders
  - resprouters
  - fire-sensitive species
  - maturation and senescence intervals.
  - vegetation growth-stage structure is a means of assessing the need for fire appropriate to a mosaic burning regime where different areas are in different stages of recovery from fire.
- Other concepts to be taken into consideration include:
  - fire extent (the footprint of a fire)
  - fire patchiness (the pattern of burnt and unburnt fuel within the footprint)
  - fire season (the time of year that a fire typically occurs)
  - fire intensity.
- Low intensity fires are usually recommended for prescribed burning, because most species have recovery or survival responses for these kinds of fires, but occasionally higher intensity fire may be desirable.
- Reading the visual indicators of a local ecosystem's condition is a useful way of checking whether the application of specific fire treatments (in accordance with the recorded fire regime) is desirable at a particular time. For example:
  - if there are signs of drought, burning at this time may stress the ecosystem
  - if there is an overabundance of tree species colonising the area, and an altered approach may be required to thin the tree species.
- Species vary considerably in their response to fire, but can generally be divided into:
  - fire-adapted species
  - fire-sensitive species.

- Endangered, rare and vulnerable species may need special consideration when planning and implementing prescribed burns.
- Mosaic burning acts to maximise or retain biodiversity through deliberately applying fire in a manner that is patchy, thereby creating or maintaining an ecosystem with different areas at different stages of recovery from fire. The more detailed the pattern of mosaic is, the greater the habitat diversity and resilience of the ecosystem will generally be.

Self-assessment questions

1. What is the relationship between burn mosaics and fire patchiness?
2. What is a fire regime?
3. When determining minimum tolerable fire intervals for particular ecosystems, the maturation cycles of plants in what three floral categories need to be considered?
4. Describe an example of when an instance of medium or high intensity fire might be desirable in an ecosystem adapted to recurring instances of low intensity fire.
5. Nominate three situations when 'reading' an ecosystem's condition from visual indicators might lead you to advance, delay or alter treating it with fire.

Section

9

Burn management

Managing prescribed burns requires achieving the burn objectives while ensuring containment, suppression and security at the burn site. Doing this also requires:

- appreciating the difference in ignition tactics used at a prescribed burn as opposed to a bushfire-suppression backburn
- establishing and maintaining situational awareness, and ensuring it is effectively shared between team members
- communicating effectively with team members and members of the public, both in performance of one's role and at briefings and debriefings
- developing and implementing strategies to coordinate burn operations
- implementing and effective structure for coordinating the team's activities.

Differences between prescribed burning and bushfire suppression

Some agencies, by necessity, have a stronger focus on suppression training and response to bushfires rather than prescribed burning. Consequently, burn management can at times require a change in emphasis and thinking from managing unplanned fires to successfully managing prescribed burns.

Whilst many of the skills and the knowledge required for suppression are also important for prescribed burning, there is often a different application, e.g. ignition tactics for a prescribed burn lit under favourable conditions will be different than those used for a backburn as part of bushfire suppression (for example, spot ignition techniques are common for prescribed burns).

Suppression generally has a single aim: to limit the extent of unplanned fires that can be suppressed, whereas prescribed burning can have broad and varied aims and requires a focus on meeting defined objectives and outcomes. Also prescribed burns are usually conducted with lower fire intensity and in some cases the objective may not be to burn out the whole area, but rather leave a mosaic of unburnt areas for habitat-diversity reasons.

Situational awareness

Situational awareness can be described as 'dynamic awareness of the on-going situation' (Salmon *et al.* 2008, p. 299). It not only includes understanding of the burn, its progress and the changing weather and fuel conditions as the day wears on, but also what is occurring for your teammates and for yourself.

The ability of a team to make sense of a situation, and to make timely decisions, is a key requirement for effective team performance. Developing situational awareness is highly dependent upon good information, skill and experience. For example, experienced crew members will obtain clues about the nature of fire from the smoke emanating from it, and from the fireground radio traffic that they may be listening to. Similarly, where the burn manager decides to place him or herself during any particular burn may vary depending on the experience of the lighting crews, the topography of the site, the variation of fuel types and density, and the risk-level associated with the burn.

Situational awareness becomes even more critical when a team is dealing with an emergency. In a team setting, no one member may have a full understanding of the current situation, requiring members to share their understanding through effective communication.

One of the ways we can share situational awareness within a team, or to help an incoming team develop sound situational awareness, is by providing briefings and debriefings that communicate clearly all the essential facts. There should be standard briefing practices that are given and expected. Briefings should be face-to-face whenever possible. When giving a briefing, ask questions to check that the essential content of the briefing has been understood.

Communication skills

Communication is vital when the safe and effective undertaking of tasks requires the coordinated action of team members. It is also the means by which shared situational awareness among teams can be established and maintained, especially when crews are dispersed to different sectors of a burn site or incident ground.

Briefings

The aim of a briefing is to ensure that personnel are adequately prepared to undertake the role or activity that they been allocated. By providing key information about the conditions and operating environment within which personnel are being asked to work, we can make them aware of the situation they are likely to face, how this may change, and what tactics and equipment will be best suited to the task at hand. Effective briefings therefore reduce uncertainty and promote co-ordination between team members.

When planning a briefing, clearly define what participants must know and do to complete their task once the briefing has concluded. When the briefing is intended to prepare people for participation in an operational activity, it must tell the audience:

- what is to be achieved (the objectives)
- how it is to be done (the strategies)
- what part each of them has to play (the tactics).

The SMEACS acronym represents the key elements of a briefing.

S	**Situation** – the current and predicted situation, including: • the burn site and reason(s) for the burn • current and expected weather and fire behaviour • at-risk values to be protected • a summary of resources deployed.
M	**Mission** – the statement of the specific objectives set for the burn.
E	**Execution** – how the mission will be accomplished; that is: • strategies and tactics, including lighting patterns • constraints • task and resource allocation • access around the burn site • ignition times • immediate tasks after briefing • contingency plans.
A	**Administration** – Logistics for the operation including: • key support locations and roles • burn staging area • catering • supply • ground/medical support.
C	**Command and Communications** – Burn Management Structure including: • sectorisation • reporting relationships and times • the Communications Plan • contact numbers, radio channels.
S	**Safety** – Identification of known or likely hazards including: • weather • 'Watch-out' situations • safety equipment required and protective clothing standards • welfare, hydration and first aid.

Note: Those receiving a briefing should be encouraged to ask questions for clarification, or to seek additional detail, to ensure they have a full understanding of what is required of them.

Debriefings

Debriefings provide the opportunity for individuals, teams and organisations to learn by reflecting on activities undertaken, and the outcomes of those activities.

The purpose of the debriefing is to identify factors or information about the conduct of the burn that may be relevant to operational procedure, safety and logistical issues. Points for discussion may include:

- what the objectives were
- what actually happened (were the objectives achieved?)
- why it happened
- what could be done better.

We tend to learn by doing, and an effective debriefing provides important feedback that can support the refinement of the way we, as individuals or as a team, conduct our activities (i.e. they are a means of learning how to do what we do better).

The three types of debriefing most relevant to prescribed burning are hot debriefs, shift debriefs and after action reviews:

Hot	Conducted with personnel during a shift, immediately after a significant event or a near-miss situation to determine: • how it occurred • who was affected • whether there is any ongoing risk to personnel • how the risk might be eliminated or mitigated.
Shift	Conducted at the conclusion of a shift or work period. It provides an opportunity to review work undertaken throughout the shift, to identify any issues, so that they can be addressed and reported to appropriate supervisors, and to personnel participating in the next shift.
After action review	Conducted after a burn with the purpose of assessing the conduct or results of an operation. After action reviews (AAR) may be conducted some weeks after a burn or series of burns, and may be conducted at the crew, agency or inter-agency level.

If the burn is to progress beyond one shift, debriefings may be just as important as briefings. Debriefings can provide valuable new information and confirm details concerning the burn through feedback from crews and personnel completing their shift. The SMEACS format can be used to structure shift debriefings. Ensure that there is follow-up to issues raised at debriefings.

Situation reporting

Situation reports (SITREPs) should be compiled from updates received from fireline crews or sector leaders (often via radio, a phone-in procedure or via a software form). They can also be integrated into software portals that are accessed by senior staff and sometimes the media and public. They usually include:

- current conditions on the fireline and fire behaviour
- progress of fire lighting since previous report
- tasks to be undertaken.

Situation reports are usually provided at pre-determined regular intervals, but should also be provided whenever there is a significant variation from the desired fire behaviour.

Figure 19: Prescribed burning in mallee heath (Source: DEWNR, SA)

Coordination of burns

Planning for any prescribed burn must account for the requirements of people and equipment to:

- prepare for the burn, e.g. maintenance/preparation of control lines, field assessments, consultation
- implement the burn safely (considering ignition techniques)
- implement mop up and patrol of the burn
- cater for contingencies to ensure that additional resources can be called upon in the event of worse-than-expected fire behaviour and escapes.

Consideration of resources required should be done after the prescriptions have been developed. In summary you are saying: ‘This is what we need to do; now how many people and what types of equipment do we need to do this safely?’ This means that safety is driving the process.

This process needs to occur with plenty of time prior to the prescribed burning date because:

- If there are not adequate resources the burn may have to be postponed, the burn plan altered or another site chosen that will achieve the objectives with less resources.
- Preparation of control lines may need to be undertaken weeks or months ahead of the proposed period of burning.
- Scarce resources may be required (such as heavy machinery and skilled personnel) or specialist resources may have to be scheduled in consultation with other areas that are competing for those resources.

The different nature of every prescribed burn will demand a different mix of resources to manage it. However, resource needs can be planned for under the following broad role types:

- burn manager
- lighting personnel and equipment
- patrol/control/mop-up personnel and equipment
- technical support personnel and equipment
- logistical support personnel and equipment.

Planning must ensure that all personnel are competent/accredited for the roles or tasks likely to be assigned to them. Specialist or technical roles, particularly those involving aircraft, may require personnel from outside the local area. Cooperative scheduling with other burn planners may be necessary to ensure their availability.

Command structure (AIIMS)

A strong chain of command must be established at the burn to manage all resources. This is best done by adopting a command structure consistent with the Australian Inter-service Incident Management System (AIIMS):

- Some land management agencies undertaking a program of prescribed burning may do this by appointing a burn manager to act in the role of Operations Officer, and having an Incident Controller monitoring the project of the burn from an appropriate administrative centre, also providing planning and logistical support.
- Other agencies might choose to nominate the Officer in Charge at a burn site act as the Incident Controller.

Whatever command structure is used, it is important that it is simple, and is clearly explained to all personnel during pre-burn briefings. It is important that one person is clearly identified as being in charge.

Activity 9.1

For a proposed prescribed burn in your area, develop a list of the resources necessary to execute the burn plan. Explain the procedures to be used in your organisation to obtain specialist resources from outside your immediate area.

Section 9 summary

- Ignition tactics for a prescribed burn (lit under favourable conditions) will be different than those used for a back-burn as part of bushfire suppression:
  - Suppression generally has a single aim (to limit the extent of unplanned fires that can be suppressed), whereas prescribed burning can have broad and varied aims and requires a focus on meeting defined objectives and outcomes.
  - Prescribed burns are usually conducted with lower fire intensity and in some cases the objective may not be to burn out the whole area, but rather leave a mosaic of unburnt areas for habitat-diversity reasons.
- Situational awareness includes three elements:
  - understanding of **the situation**, the burn's progress and the changing weather and fuel conditions as the day wears on
  - understanding how our **teammates** are faring
  - understanding how **you** are faring.
- Briefings and ongoing communication are critical to creating and maintaining shared situational awareness.
- Communication is critical to maintaining shared situational awareness especially when crews are dispersed to different sectors of a burn site or incident ground.
- The SMEACS briefing format effectively structures information in a way most easily understood and retained. Those receiving a briefing should be encouraged to ask questions.
- If the burn is to progress beyond one shift, debriefings may be just as important as briefings. Debriefings can provide valuable new information and confirm details concerning the burn.
- Planning for any prescribed burn must account for the requirements of people and equipment to:
  - prepare for the burn
  - ignite the burn
  - control the burn
  - cater for contingencies, such as the suppression of escapes.
- Consideration of resources required should be done after the prescriptions have been developed.
- Planning needs to occur with plenty of time to ensure sufficient resources and adequate control lines. In every case, contingency planning should ensure that resources are adequate to deal with worse-than-expected fire behaviour and escapes.
- Whatever command structure is used, it is important that it is simple, and is clearly explained to all personnel during pre-burn briefings.

Self-assessment questions

1. What is situational awareness?
2. What are the key elements of a briefing?
3. When articulating the ‘mission’ at pre-burn briefings, in addition to informing crews what the burn is to achieve, what additional, directly relevant information should you tell them?
4. What three types of debriefing are most relevant to prescribed burning operations?
5. When should a hot debriefing be held, and what four questions does it seek to answer?
6. What are the five role types that need to be resourced at a prescribed burn?

Section

10

Fuel assessment

The fuel conditions important to consider as part of a fuel assessment for a low intensity prescribed burn are fuel type, fuel quantity, fuel arrangement (these three being summarised together under the concept of fuel hazard), fuel distribution, and fuel moisture content. This section will discuss each briefly. More detailed information can be found in the PUAFIR303B *Suppress Wildfire Learner Resource*.

Fuel type

Vegetation type is usually used to describe fuel type. Differences in fuel type may mean differences in general arrangement and bark and fuel size characteristics. This will influence flame heights and rates of spread and hence fire intensities.

The major types for which fire behaviour characteristics are known and predictions can be made, include:

- dry eucalypt forest
- sub-tropical eucalypt plantation
- logging slash
- southern pasture grassland
- northern grassland, including sparse grassland or grassland in association with open forest or woodland
- buttongrass moorland
- semi-arid mallee/heathland
- coastal heathland
- spinifex hummock grassland. (Cruz *et al.* 2015).

Available fuel quantity

Weight in tonnes per hectare is used to describe available fuel quantity. It is used in many fire spread models to predict fire intensity and rate of spread. Various methods are available to ascertain fuel quantity, from visual estimation guides to fuel sampling surveys requiring precise measurements. It is recommended that you familiarise yourself with the assessment tools used in your agency.

Fuel arrangement

Flame height, intensity and rate of spread are influenced by vertical arrangement of fuel. Well aerated elevated fuels will promote taller flames, greater intensities and more rapid rates of spread.

In forests, surface dead fine fuel quantities can be sampled, but it is much more important to integrate information on surface fuels with the contribution of bark fuels and elevated fine fuels such as shrubs, heath and suspended dead litter fuels.

When elevated fine fuel…

- is very fine (< 2mm thick)
- contains volatile oils (live foliage)
- has a high proportion of dead material
- has vertical and horizontal continuity

…it will be highly flammable, and promote high flames and rapid rate of fire spread if other conditions are favourable.

Fuel hazard

Given the effort required to estimate fuel quantity and the critical role that fuel arrangement plays, greater emphasis is being given to field guides for visual assessment of fuel hazard presented by elevated fine fuels, and surface fuels. The *Overall fuel hazard assessment guide* (Hines *et al.*, 2010) has been adopted by a number of fire and land management agencies for fuel assessment in forest fuel types.

To enable use of the McArthur Forest Fire Danger Meter mk.V — which uses fuel loads rather than fuel hazard for predictions of forward rate of spread, flame height and potential spotting distance — the guide in Table 6 can be used, which shows equivalent fuel loads for given fuel hazard ratings for various fuel components in foothill forests in southern Australia. These equivalent fuel loads estimate the quantity of surface, near-surface elevated, and bark fuels.

Table 6: Equivalent fuel loads (tonnes/ha) for given fuel hazard ratings

Fuel component	**Fuel hazard rating**				**(Hines *et al.* 2010, p.36)**
	Low	Moderate	High	Very High	Extreme
Bark	0	1	2	5	7
Elevated	0–1	1–2	2–3	3–5	5–8
Near-surface	1–2	2–3	3–4	4–6	6–8
Surface	2–4	4–10	8–14	12–20	16–20+

An overall value of fuel load can be estimated at any location where a subjective appraisal of fuel hazard by component has been made.

For example, where a site carries a 'High' bark hazard, a 'High' surface fuel hazard and a 'Very High' elevated fuel hazard, the overall fuel load may be:

$$2 + 11 + 4 = 17 \text{ tonnes/ha.}$$

This total could then be used, for example, with the McArthur Forest Fire Danger Meter mk.V for predictions of forward rate of spread, flame height and potential spotting distance (see 'Predicting fire behaviour' in Section 11).

Fuel distribution

If fuels vary considerably across the proposed burn area, the subsequent ignition pattern may need to vary across the burn area to accommodate these differences. For example, decreasing ignition spacing (that is, lighting closer together) in areas of very light fuels compensates for slower rates of spread. Sometimes staging burns to target different fuel types on different days under different weather conditions is necessary. (See Ignition spacing in Section 12).

Assessments of fuels beyond the proposed burn boundaries are also important as these will indicate the likely difficulty of control of escapes or spot fires.

Activity 10.1

For a proposed low intensity prescribed burn in your locality, demonstrate how you would assess fuels, and how you would use the information gained to plan the ignition of the burn.

Fuel moisture content

Fuel moisture content (FMC) is the proportion of free and absorbed water in the fuel expressed as a percentage of the oven-dry weight of the fuel (%ODW). FMC is highly dependent on relative humidity (RH) at any given time.

FMC is fundamental to determining whether fuels will burn, and if so, how rapidly (and intensely).The distribution of moisture in fuel beds also determines the proportion of fuel available to burn with periods of low FMC corresponding with maximum fuel availability, and, consequently, maximum fire intensity.

Due to their fine structure, flammability of grassland and heathland fuels is more sensitive to changes in RH than other, courser fuel types. Where changes to fuel moisture content within forest fuels may lag two hours behind changes in RH, the lag affecting grassland fuels is only 30 minutes (see Figure 20).

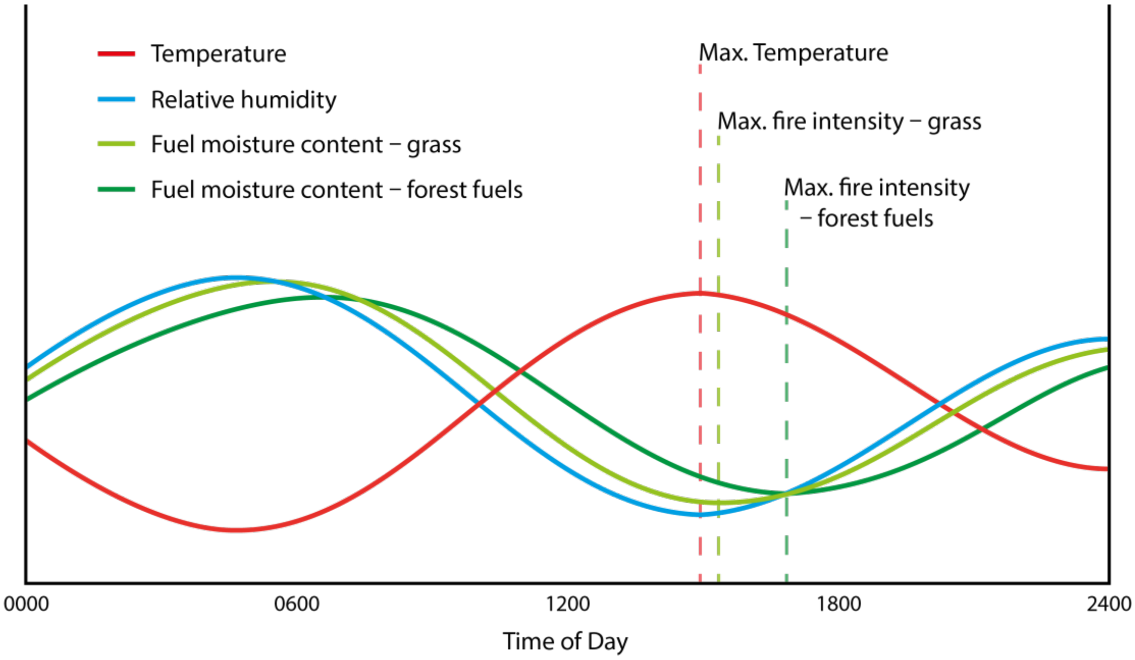


Figure 20: Variations to temperature and relative humidity throughout the day, and the respective lags in changing FMC in grass and forest fuels.

A good knowledge of FMC is essential to predict likely fire behaviour, and related things such as smoke properties and difficulty of fire control. Figure 21 shows the relationship between fuel moisture content and rate of spread under varying wind speeds, with other factors assumed constant. The dramatic increase in rate of spread when fuel moisture falls below 8% illustrates the importance of monitoring this parameter.

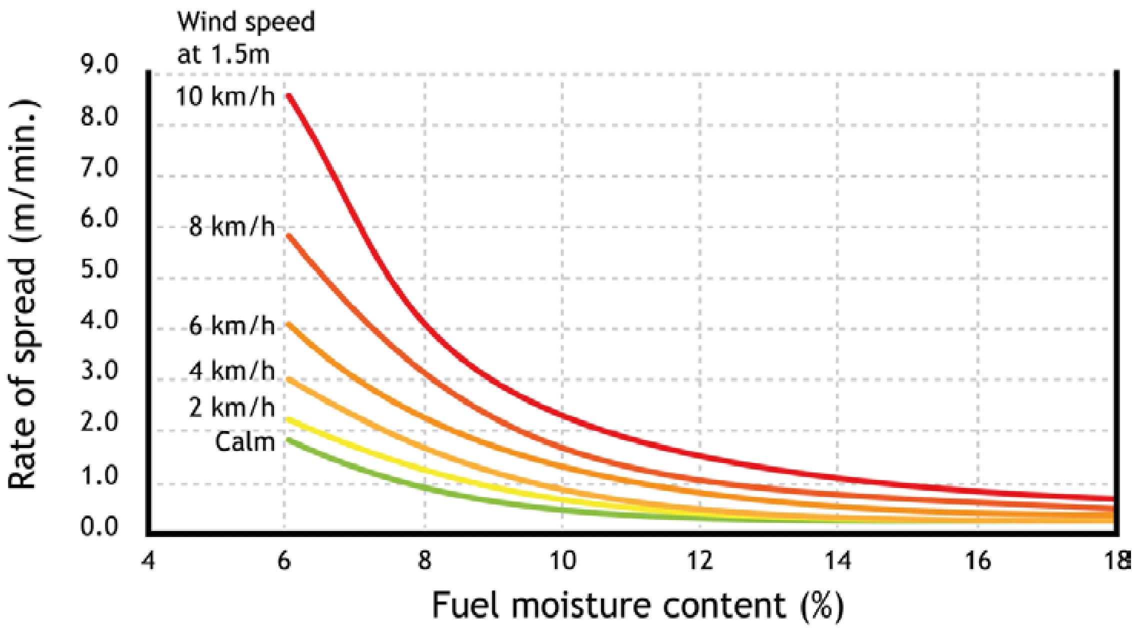


Figure 21: Relationship between FMC and forward rate of spread in open forest (Source: Tolhurst and Cheney 1999)

Prescribed limits on fine fuel moisture content will depend on the nature of fire behaviour desired (as dictated by the burn objective), and other site factors such as the typical fuel arrangement.

Table 7 provides descriptions of indicative fire behaviour for a range of moisture contents in surface fine fuels, the fine fuels in the upper 10 mm of the litter bed. If a high proportion of fuel is elevated it will be drier than surface fuels and will burn more readily. Fuel moisture (and therefore fire intensity) will vary significantly across a burn area according to changes in aspect and slope. This is due to the different angles at which the sun's rays strike the fuel, and is responsible for greater fire intensity on steeper, north-facing aspects.

Table 7: A guide to fuel moisture content and fire behaviour in eucalypt forests (Tolhurst and Cheney, 1999)

Surface moisture content (% ODW)	Indicative fire behaviour in eucalypt fuels
<4	Litter extremely dry. Potential for extreme fire behaviour with intense short-distance spotting and crown fire at moderate wind speeds.
4–6	Litter very dry. Very rapid ignition from small smouldering firebrands. Fire behaviour could be severe, spotting likely, possible crown fire under strong winds.
6–9	Litter dry. Conditions may not be suitable for fuel reduction burning. Fuel very easy to ignite, spotting initiated by large smouldering firebrands. High intensity fire may develop under strong winds.
9–13	Litter is reasonably dry. Eucalypt litter easy to ignite. Burning readily sustained. Fuel reduction may be carried out in light fuels under very mild weather conditions. Limited spotting from large flaming firebrands.
13–16	Litter just moist. Eucalypt litter moderately easy to ignite. Burning is sustained. A suitable range for fuel reduction when other conditions, particularly wind, are suitable. Spotting unlikely.
16–22	Litter is damp. Eucalypt litter is difficult to ignite. Burning difficult to sustain. Low intensity burning could be patchy. No spotting.
22–28	Litter is wet. Fuel very difficult to ignite. Burning very difficult to sustain. Candling operations (charring the bark of eucalypts to reduce spotting activity and the intensity of future bushfires) may be undertaken.

FMC can be measured or monitored in a variety of ways in different jurisdictions including: predictions from temperature and RH (an example of which can be found in Table 8), in-field moisture meters, fuel analogues such as hazard sticks or hazard bags, by oven-drying fuel samples, or estimates from a burning leaf test (see Figure 22).

The burning leaf test provides a simple and quick estimate of FMC from the angle at which a cured eucalypt leaf from the litter layer burns. The angle to which a burning leaf is tilted so that combustion is just sustained will depend largely on the leaf's moisture content.

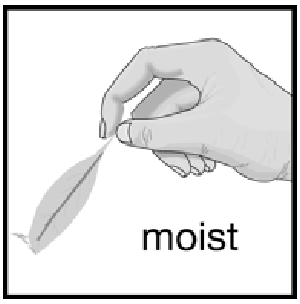
Table 8: Predicted daytime fine dead fuel moisture content (%), as a function of ambient air temperature, relative humidity and cloud cover for application of the Dry Eucalypt Forest Fire Model (Cruz et al. 2015, p.89)

Relative humidity (%)	Clear sky, peak burning period*				Overcast sky, other daytime period			
	Air temperature (°C)				Air temperature (°C)			
	10	20	30	40	10	20	30	40
5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10	4.0	3.0	3.0	3.5	4.5	4.5	4.0	3.5
15	4.5	4.0	4.0	3.5	5.5	5.5	5.0	4.5
20	5.0	4.5	4.5	4.5	6.5	6.5	6.0	5.5
25	6.0	5.5	5.5	5.0	7.5	7.0	6.5	6.5
30	6.5	6.0	6.0	6.0	8.5	8.0	7.5	7.0
35	7.0	7.0	7.0	6.5	9.5	9.0	8.5	8.0
40	8.0	7.5	7.5	7.0	10.0	9.5	9.0	8.5
45	8.5	8.0	8.0	7.5	11.0	10.0	10.0	9.5
50	9.0	8.5	8.5	8.5	11.5	11.0	10.5	10.0
55	9.5	9.5	9.0	9.0	12.5	12.0	11.5	11.0
60	10.0	10.0	9.5	9.5	13.0	12.5	12.0	12.0
65	10.5	10.5	10.5	10.0	14.0	13.5	13.0	12.5
70	11.0	11.0	11.0	10.5	15.0	14.5	14.0	13.5
75	11.5	11.5	11.5	11.0	16.0	15.0	14.5	14.0
80	12.5	12.0	12.0	12.0	17.0	16.0	15.5	15.0
85	Outside range of model applicability				18.0	17.0	16.5	16.0
90					19.0	18.5	18.0	17.5

***Applicable for clear sky conditions between October and March for the 12:00–17:00 period.**

Leaf burns if held straight down or does not burn at all

- All fuels too wet if this leaf is in the area to be burnt.
- OK if only in wet area not to be burnt.



Leaf burns if angled downwards

- Fine fuels from this leaf's position will only burn if on a slope or in the wind.
- OK if the leaf was from the bottom of the litter in the burn area, or from a wet area not to be burnt.

Leaf burns if level

- Fine fuels from this leaf's position will burn, but very slowly unless helped by wind, slope and fuel continuity.

Leaf can be angled upwards and still burns

- Fine fuels from this leaf position are dry enough to burn.
- OK if this leaf is from the top of the litter, risky if from the bottom.

Leaf burns if held straight up

- All fine fuels are very dry and flammable. Fire will spot if windy.
- DON'T BURN.

Figure 22: Estimating FMC from burning-leaf test (using a dry eucalypt leaf) (Source: DELWP, Vic.)

Section 10 summary

- Differences in fuel type may mean differences in general arrangement and bark and fuel size characteristics. This will influence flame heights and rates of spread and hence fire intensities.
- Available fuel is quantified in tonnes per hectare and used to predict fire intensity and rate of spread. Fuel quantity can be calculated using precise sampling or estimated roughly using visual guides.
- Vertical arrangement of fuel will influence flame height, intensity and rate of spread. In forests it is much more important to integrate information on surface fuels with the contribution of bark fuels and elevated fine fuels such as shrubs, heath and suspended dead litter fuels.
- Given the effort required to estimate fuel quantity and the critical role that fuel arrangement plays, greater emphasis is being given to field guides for visual assessment of fuel hazard presented by elevated fine fuels and surface fuels.
- If fuels vary considerably across the proposed burn area, the subsequent ignition pattern may need to vary across the burn area to accommodate these differences.
- Fuel moisture content (FMC) is fundamental to determining whether fuels burn, and if so, how rapidly (and intensely). The distribution of moisture in fuel beds also determines the proportion of fuel available to burn.
- If a high proportion of fuel is elevated it will be drier than surface fuels and will burn more readily.

Self-assessment questions

1. What fuel conditions should you consider as part of a fuel assessment for a low intensity prescribed burn?
2. How does the vertical structure of fuel affect fire behaviour?
3. What is a simple method for estimating fuel moisture content?
4. Why is knowing fuel moisture content important?
5. Name a common method for estimating fuel hazard.

Section

11

Fire behaviour

Fires are dynamic, and the character of any particular fire is the result of a combination of factors, including:

- **topographical influences** that affect fuel-drying patterns and fire spread
- **weather conditions**
- **local climate**, including local season, seasonal variation in humidity, and fuel-drying patterns
- **factors relating to fuel**, including type, quantity, spatial distribution and fuel-moisture content (as discussed in Section 10).

This section will start with a brief recap of fire development, focusing on aspects especially relevant in a prescribed burning context, such as fire intensity, rates of spread and junction zone effects, before considering topographical influences, weather conditions, and local climatic and seasonal variations. We will conclude tying these considerations together with Section 10's discussion of fuel into the process of predicting desired fire behaviour at a prescribed burn.

Fire characteristics

Any fire will grow and build in intensity until its growth cannot be further promoted by the conditions under which it is burning. These conditions include weather, topography and the condition of the available fuels. When the fire reaches full development, the conditions affecting it have reached a state of equilibrium. Once this equilibrium is reached, the intensity with which the fire burns, and the rate at which it spreads, will remain more or less steady until one or more of these conditions change. The period of growth between ignition and full development takes time.

Under mild conditions, a fire ignited from a single point may take as long as 20 minutes before it reaches its full state of development. If line ignition is used, the time taken for it to reach maximum growth will be considerably shorter. Finer fuels and better aerated fuels will also shorten the time required for a fire to reach its maximum development.

If unaffected by wind, slope or fuel variation, a fire will spread outwards in a gradually widening circle. This circular pattern of spread will radiate out in a uniform manner unless the fire comes under the influence of slope, prevailing winds or both. Under neutral wind and slope conditions, the intensity of a fully developed fire, and the strength of its convection, is dependent on the amount of fuel being consumed.

The convective force produced by a fire will also affect how strongly it is affected by these other conditions. The stronger a fire's convection, the greater the effects of wind or slope need to be to overcome the convection and affect the fire's behaviour. The behaviour of a fire will change during the course of its development according to the shifting balance between slope, wind and the convective forces produced as fuels burn.

If fuels nearby one part of a fire are heated by flames faster than elsewhere, this part of the fire will tend to grow more rapidly. Where a slope is present, this will happen on the upslope edge, where fuels are closer to the flames. Flames on the downslope edge will also heat the fuels adjacent to them, but at a much slower rate.

This uneven preheating of surrounding fuels also happens when a prevailing wind predominates over convection, bending flames on the downwind edge toward unburnt fuels, and bending flames away from unburnt fuels on the upwind side.

Parts of a fire

When a spot fire grows under the influence of slope or wind, various edges advance outward at different rates, such that its circular pattern of spread becomes elongated (Figure 23). Typically, four parts of the fire can be identified:

- The **head fire**, burning downwind or upslope, is the most intense part of the fire, has the greatest rate of spread, burning approximately one-third of the area burnt.
- The **back fire** (or tail fire) is the least intense part of the fire, burns upwind or downslope, has the least rate of spread, and burns about one-sixth of the area burnt. If the fuel has a high moisture content and the air temperature is low, the tail fire may self-extinguish. Tail fires may burn deeper into the fuel bed than head fires but produce less smoke and heat.
- The **flank fires** burning on either side extend roughly parallel to the main direction of spread and burning one-quarter the area burnt. Under strong wind, flank fire may make up most of a fire's perimeter. Fire intensity and average flame height along each flank will be greater at the head-fire end of each flank.

  Extended flank fires will increase the difficulty of suppression should a wind change cause a flank fire to become the head fire.

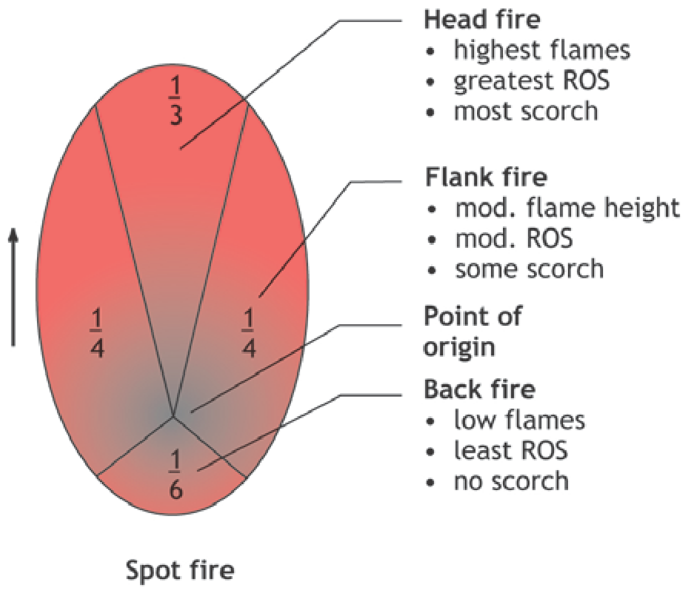


Figure 23: Parts of a fire and relative proportions burnt by each part

Features of a moving fire

As in indicated in Figure 23, there are a number of terms that can be used to describe the features of a fire edge, head fire or fire front:

Flame height	Average height of the flames (disregarding any high flashes) as measured vertically from ground level.
Flame length	Length of flames measures along their axis.
Flame angle	Angle between the inclined flames and the ground in front of the fire.
Flaming zone	Part of a moving fire which is actively burning (and used to determine flame depth).
Flame depth	Depth of the continuous flaming zone behind the front edge of the fire. (Fine fuels (less than 6 mm in diameter) are mostly consumed in this zone.)

Figure 24 contains a cross-section diagram of moving head fire in which the above parts are identified.

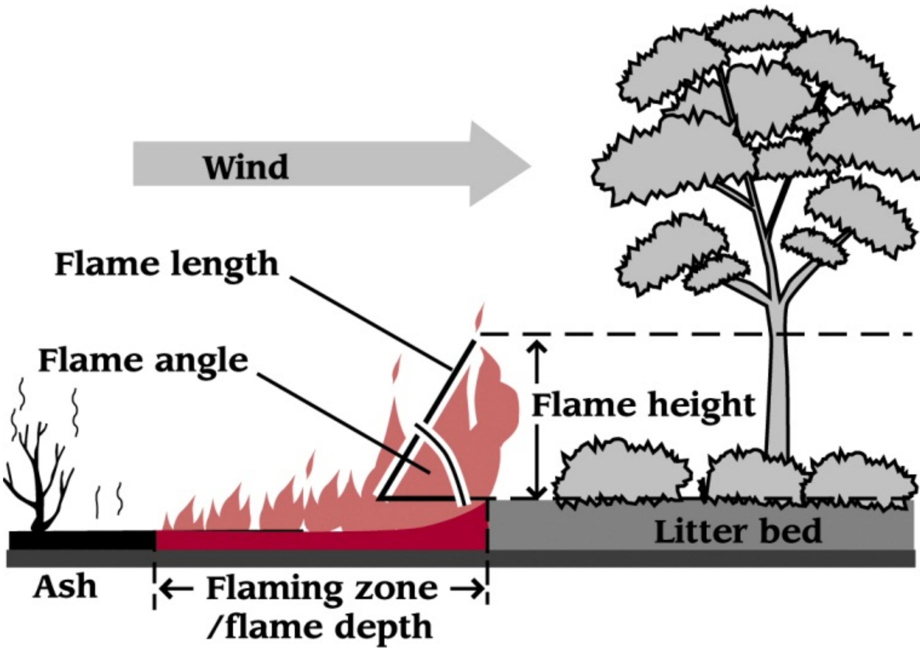


Figure 24: Features of a moving head fire (image courtesy of DPAW, WA)

Fire intensity

Fire intensity is defined as the rate of heat output in units of kilowatts per metre (kW/m). It is a function of the amount of fuel burnt in the flame front of the fire, the calorific value of that fuel, and the rate of spread of the fire.

Byram's Fire Intensity Equation is:

I=Hwr

— where: **I** is fire front intensity in kW/m

H is heat content of the fuel (heat yield) in kilojoules per kilogram (kJ/kg)

w is weight of fuel burnt per unit area, in kilograms per square metre (kg/m^2)

r is the rate of fire spread in metres per second (m/s).

If we assume that heat yield for woody or grassy fuels is about 18,000 kJ/kg, the equation can be acceptably simplified to:

I=wr/2

— where: **w** is weight of fuel burnt in tonnes per hectare (t/ha)

r is rate of fire spread in metres per hour (m/h).

Low intensity fire is defined as fire that travels slowly and only burns lower storey vegetation. Such fire has an average intensity that is less than 500 kW/m and an average flame height less than 1.5 m. Often, low intensity fire less than 350 kW/m will be aimed at. Such fire travels slowly and only burns lower storey vegetation, like grass and lower tree branches, causes little or no crown scorch, and is easily controlled.

High intensity fires are uncontrollable through direct attack, and typically burn with an average intensity greater than 3000 kW/m and flame heights greater than 3 m, causing complete crown scorch or possibly crown fires in forests. However, for burning purposes, some agencies quantify high intensity as exceeding than 2000 kW/m. The term is also applied to stationary fires burning in very high fuel loads (such as logging slash).

Any factor that influences available fuel load, or rate of spread of a fire, will influence fire intensity.

Fire severity

Fire severity is related to intensity and describes the effect of fire on vegetation. Setting prescriptions and determining desired fire behaviour requires determining what fire intensity is required to achieve the required degree of fire severity. Severity is typically assessed according to two measures: scorch height and char height.

Scorch height

Scorch refers to the killing of plant foliage as a result of convected and radiant heat from a fire. Scorch height is the height above ground level to which foliage has been browned by fire, and varies according to the intensity with which a fire burned. Post-fire assessment of scorch height often takes place one week after burning has taken place, once foliage killed by the fire has had time to turn brown and become clearly visible.

In spring, the scorch height will typically be 6—8 times higher than the flame height. In autumn, the scorch height will typically be 10—14 times higher the flame height.

Char height

Charring, which refers to blackening that results from exposure to intense heat or direct contact with flame, is another indicator of fire intensity. Like scorch, char height is an expression of a fire’s intensity, but unlike scorch it has the benefit of being visible immediately after a fire.

The relationship between char height and scorch height tends to vary according to vegetation type and season, and these conditions need to be factored into one’s estimations when making post-burn assessments. Figure 25 provides an example of the season dependent variation in the relationship between flame height and scorch height in west Australian jarrah forest. The nature of this seasonal difference will be different for other vegetation types.

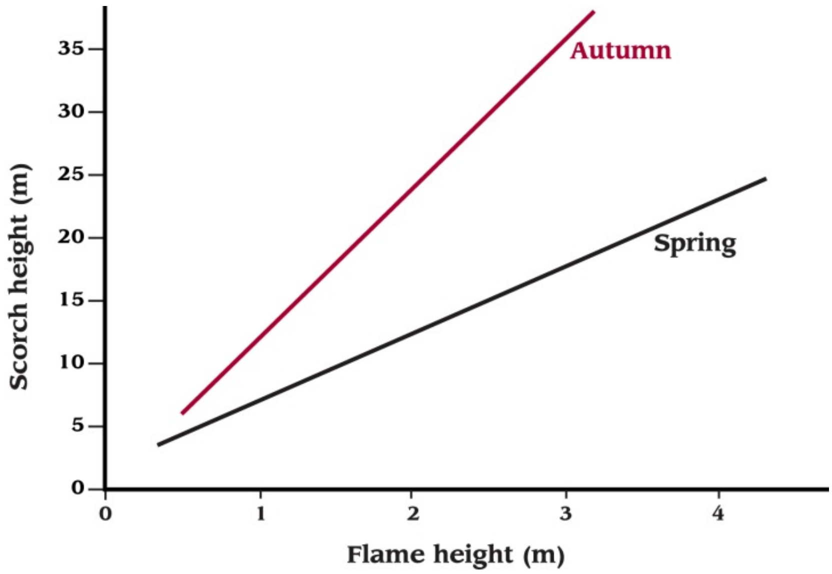


Figure 25: The correlations between crown scorch height and flame height in jarrah forests during autumn and spring (Image courtesy of DPAW, WA)

Rate of spread

The rate of spread (ROS) is the speed of a fire edge advancing along the ground. Typically ROS refers to the head fire ROS, however, when planning or adjusting and ignition pattern, the ROS of the flank fires or tail fires may also require consideration.

As mentioned earlier, fires lit from a single point do not usually reach their average rate of spread until 20 minutes after being lit, however fires lit via strip ignition, or head fires which develop from flank fires after a wind change, can reach their maximum rate of spread within 5 minutes.

When lighting test burns, the ROS of a fire can be measured by marking the position of the head fire with a rock (or some other non-flammable object) and measuring the distance that the head fire travels in 10 minutes. This distance is then multiplied by six (10 x 6 = 60 minutes) to get the ROS in metres per hour.

Residence time and burn out time

Residence time (or duration) is the time it takes for a flaming zone to pass over a given point. Depending on conditions, it is fairly typical for low intensity fires in forest fuels with a well-defined fine litter layer to have residence times 45—60 seconds, however residence times for ‘flashy’ and elevated fuels may be shorter.

Burnout time refers to the time it takes for fuel to burn out. In light, homogenous fuels, such as grass, the residence time and the burn out time may be very similar, but in heavy fuels or fuels with components of varied size, burnout time may be considerably longer than residence time. Larger fuel items (such as logs) may sometimes burn for hours or days.

Spotting

Spotting occurs when leaves, twigs and pieces of bark are ignited by flame and then carried aloft by the convection column before falling to earth and starting new fires beyond the fire perimeter. For significant spotting to occur, the surface layers of fine fuel usually have a moisture content less than or equal to 10%. Small embers tend not to ignite fuels with a higher moisture content.

Wind, atmospheric stability and fire intensity also affect the likelihood and distance over which spotting will occur. Some elevated fuels, such as fibrous bark are associated with higher potential for concentrated short-distance spotting, which can create a risk or fire escape if fuels in areas adjacent to the burn a very dry. Ribbon bark is associated with long distance spotting, as flaming ribbons of bark or embers can be carried for kilometres.

Short distance spotting may contribute to head fire ROS as spot fires are drawn back by convection-column indraughts and gradually overtaken by the advancing flame front.

While low intensity prescribed burns may produce some minor spotting, the potential for spotting increases markedly when high intensity burring is conducted, especially when burning is conducted in unstable atmospheric conditions (see ‘Atmospheric stability’ later in this section).

Junction zones

When two flame fronts approach one another, convection increases, and the fuel between them is preheated and dried by heat radiated from both fires. This increases the intensity, flame height and ROS of both flame fronts until they join together (See Figure 26).

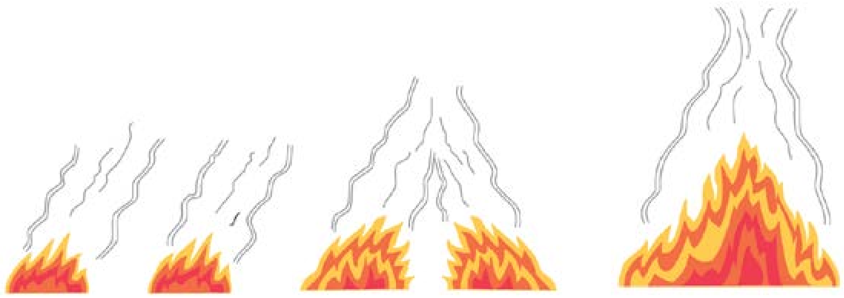


Figure 26: Junction zones

Because flank fires may account for about half the total area burnt by a spot fire, flank fire will account for much of the area burnt in grid-ignition junction zones. When the distance between ignition points (or strips) is decreased, the proportion of the total area burnt by junction-zone fire increases. For example, if ignition points are spaced according to a 60 m x 60 m grid pattern, approximately 20% of the total area will be burnt by junction-zone fire. However, if the size of the ignition grid is reduced to 20 m x 20 m, the total area burnt by junction-zone fire increases to approximately 50%.

The proportion of the burn that is burnt by junction-zone fire will affect the overall intensity of the burning, as well as influencing factors such as spotting activity, and scorch height and severity.

Topographical influences

Topography is a powerful influence on fire behaviour. **Slope** affects rates of fire spread (and hence fire intensity), **aspect** influences fuel types and moisture regimes, **elevation** typically affects exposure to wind and precipitation levels, which affects the wetting and drying regimes of fuels, and **land forms** can interact with weather to produce significant local effects on such things as wind speed and direction.

Topography is therefore an important consideration in planning ignition patterns, and anticipating variations in the fire behaviour of the prescribed burn. Good quality topographic maps are essential in planning and conducting prescribed burns.

For more information on the effects of topography on fire behaviour, refer to the *PUAFIR303C Respond to Wildfire Learner Resource*.

Weather conditions

Important weather indices often prescribed for burning include temperature, relative humidity, wind, atmospheric stability and drought index. These will influence the proportion of fuels available to burn, rate of fire spread, and fire intensity.

Air temperature will affect the dryness of fuels through its influence on relative humidity. The dryness of fuels will be reflected in the intensity of the fire and the scorch height of vegetation.

Relative humidity (RH) affects the moisture content of dead fine fuels through the processes of adsorption and desorption. Fuel moisture content is a critical factor in determining if fuels will burn, and how rapidly (and intensely) they will burn.

Due to their fine structure, flammability of grassland and heathland fuels is more sensitive to changes in RH than other, courser fuel types. Where changes to fuel moisture content within forest fuels may lag two hours behind changes in RH, the lag affecting grassland fuels is only 30 minutes.

Dew point (**dew point temperature** or **dewpoint**) is the temperature at which dew forms. It is the point to which temperature must drop before RH reaches 100% and water starts to condensate out of the air. Low dew points, especially those below 0° C, are indications that the RH will not rise significantly overnight and associated fuel moisture contents will continue to remain low or even fall. Under these conditions, prescribed burns may not self-extinguish overnight, especially if subject to strong winds.

Wind speed

Wind direction and speed is a key influence on the direction and rate of spread of fire. For low intensity burning in forest fuels, most guides suggest a maximum, unobstructed wind speed not exceeding 10—15 km at 10 m above the ground in open country, however this figure is open to variation based on fuel type, the density of the forest's canopy, and on the objectives one aims to achieve through the burn.

Higher wind speeds (sometimes up to 25km/h or more) may be required when burning spinifex or mallee heath, where higher wind speeds are required to push flames over to allow the flames to reach across gaps in vegetation and ignite adjacent foliage. Fire ROS calculations are based on the speed of the wind at the base of the fire. However the wind speed at ground level will be lower than the 10 metre wind speed due to the effect of friction between the wind and ground. On open, pasture land the open (10 m) wind speed will usually be 1.25 times faster than the 'ground' wind speed, which is measured at a standard height of 1.5 m. This ratio between the ground-level and the open wind speeds is 1:1.25.

In more densely foliaged terrain, wind ratios will be higher. Densely forested terrain may have a wind ratio of up to 9:1, meaning the open wind speed is 9 times higher than the ground wind speed. In such circumstances an open wind speed of 10 km/h will equate to a wind speed of approximately 1 km/h on the forest floor.

The relationship for well-stocked forests can be estimated from Table 9 (modified from the Beaufort wind scale), however wind speeds need to be checked on the day of the burn, and the wind ratio relevant to the burn site should be noted at the time and location of doing any fuel samples and recorded in the prescribed burn plan.

While use of the Beaufort scale to estimate wind speed can give useful information, it is still quite subjective. Use a good quality anemometer wherever possible. It is common to use an electronic handheld anemometer (such as a Kestrel) to measure wind speed, relative humidity and temperature.

Open (10 m high) wind speeds can be simulated by choosing an open location, holding the device at about 2 m above ground and then multiplying the result by 1.25 (CSIRO 1999). For example, if you record a 10 km/h winds at 2 m this is the same as (10 x 1.25 = 12.5) 12.5 km/h winds at 10 m. Conversely, if the forecast says you should have 20km/h winds (at 10 m), then you would measure a (20 ÷ 1.25 = 16) 16 km/h wind speed at 2 m in the open.

Table 9: Beaufort wind scale for land areas, plus a non-standard guide (right-hand column) to estimating wind speed in well-stocked forests

Beaufort Scale	Description	Wind speed at 10 m above ground in the open (km/h)	Specifications for estimating speed over land	Wind speed at 1.5m in the forest (km/h)
0	Calm	<1	Calm; smoke rises vertically	<1
1	Light air	1–5	Direction of wind shown by smoke drift but not by wind vanes; slender branchlets and twigs of trees move gently.	1.3–2.0
2	Light breeze	6–11	Wind felt on face, leaves rustle; ordinary vanes moved by wind; trees of pole size in the open sway gently; tops of trees in dense stands intermittently sway gently.	2.2–3.0
3	Gentle breeze	12–19	Leaves and small twigs in constant motion; wind extends light flag; trees of pole size in the open sway very noticeably; tops of trees in dense stands sway.	3.2–4.4
4	Moderate breeze	20–28	Raises dust and loose paper; small branches moved	
5	Fresh breeze	29–38	Small trees in leaf begin to sway; crested wavelets form on inland waters	
6	Strong breeze	38–49	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	
7	Near gale	50–61	Whole trees in motion; inconvenience felt when walking against the wind	
8	Gale	62–74	Twigs break off trees; generally impedes progress	
9	Strong gale	75–88	Slight structural damage (chimney pots and slates removed)	
10	Storm	89–102	Seldom experienced inland; trees uprooted; considerable structural damage	
11	Violent storm	103–117	Very rarely experienced; accompanied by widespread damage	
12	Hurricane	118 plus	Devastation	

Atmospheric stability

Atmospheric stability relates to the tendency for vertical motion to occur within the atmosphere. A stable atmosphere has a tendency to limit the vertical movement of air, or the mixing of air between the surface and higher levels, whereas an unstable atmosphere has a tendency to increase vertical mixing of air.

Atmospheric stability affects convection, and directly affects fire behaviour. Unstable atmospheric conditions promote strong convection (see Figure 27), which in turn generates strong indraught winds at ground level, leading to increased fire intensity. Atmospheric instability is also likely to be associated with gusty, erratic winds leading to unpredictable fire behaviour.

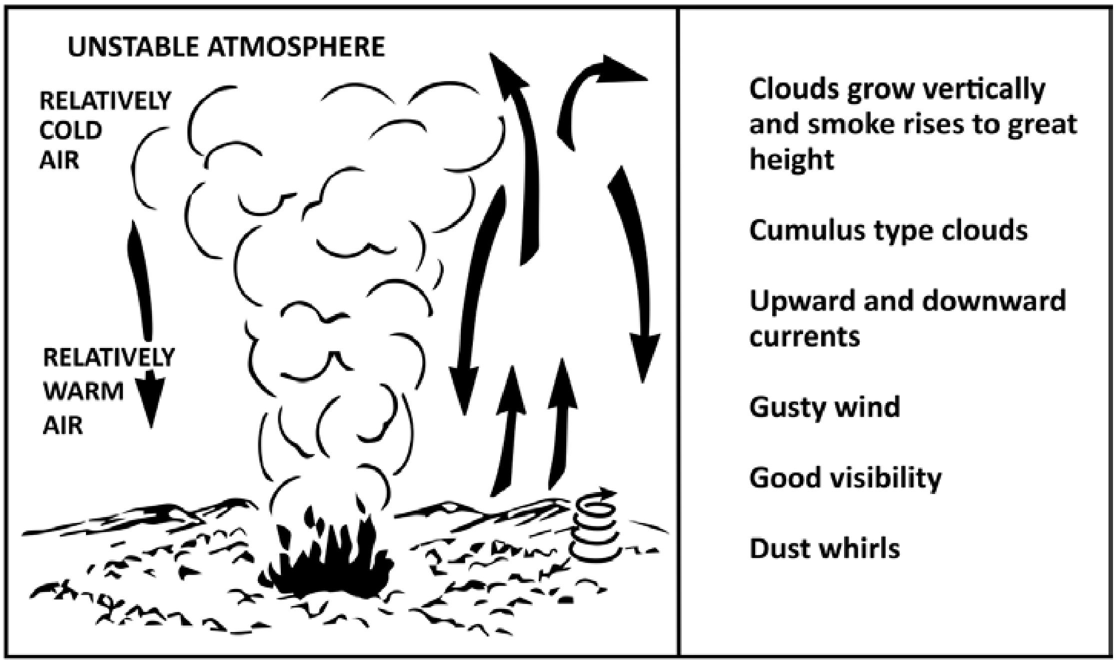


Figure 27: Unstable atmosphere and its associated effects (Source: DELWP, Vic.)

Most prescribed burning should be planned for stable atmospheric conditions. This will limit the development of strong convection, and will more likely be associated with predictable wind conditions. However, a stable atmosphere may lead to smoke being trapped and accumulating within the lower atmosphere, resulting in smoke haze and reduced visibility, especially when cold air gets trapped beneath a warmer layer, a situation known as a temperature inversion (see Figure 28).

Even where high intensity fire is desired, the powerful convection column that may develop in unstable atmospheric conditions can lead to uncontrollable fire behaviour such as fire whirls that may threaten the safety of burn personnel.

Trends in atmospheric stability can be monitored from synoptic charts in weather bulletins. Atmospheric stability is also normally predicted in detailed fire weather forecasts, and can be gauged from visible indicators such as cloud form and wind characteristics.

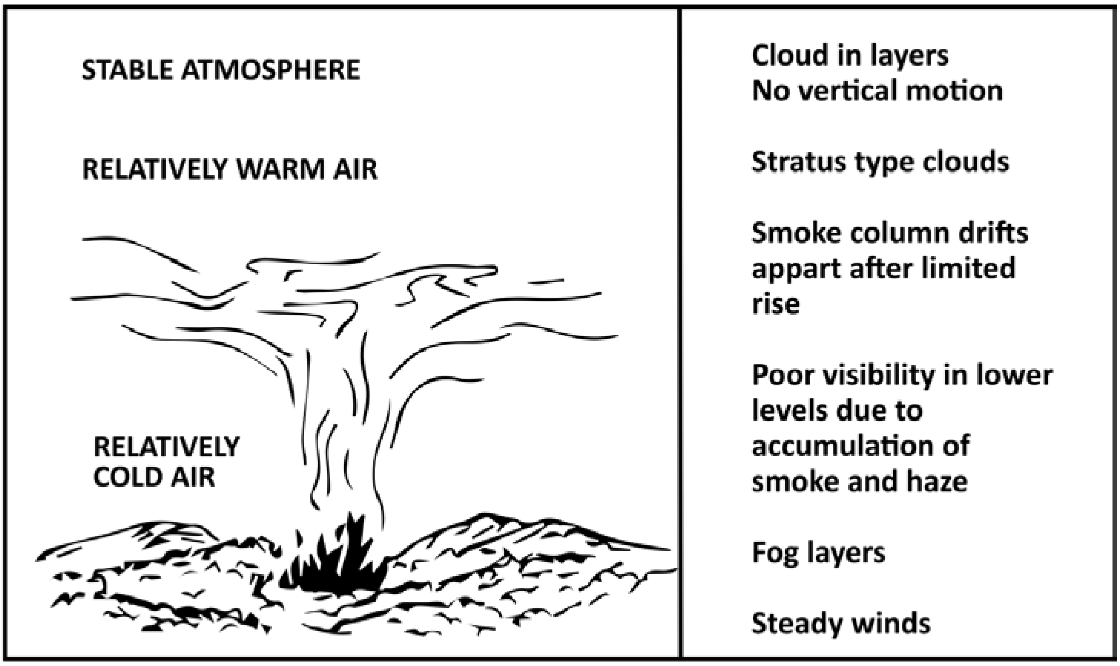


Figure 28: Stable atmosphere and its associated effects (Source: DELWP, Vic.)

> **Activity 11.1**
>
> Identify the fuel and weather characteristics critical for low and high intensity prescribed burning in your locality.

Climate and seasonal variation

Local climate, seasonal variation in temperature and humidity, and associated fuel-moisture patterns are key to determining the frequency and severity of bushfires. Across Australia, the seasonal patterns of drying vary between climate zones. Consequentially, the fire season — during which weather patterns tend to promote fast-moving, high-intensity, uncontrollable bushfires — also varies between the different climate zones. The time of year during which the fire season occurs grades from winter (dry season) in northern Australia, through spring as latitude decreases, through to summer and autumn in Australia's south (see Figure 29). In tropical northern Australia a distinct dry and wet season can be identified. Prescribed burns can be conducted in the dry season with increasing emphasis on introducing early dry season burns to reduce the extent and severity of late dry season bushfires. Southern Australia has less pronounced dry and wet seasons and prescribed burning is typically timed to avoid the high-temperature, low-humidity and high-wind periods associated with extreme fire weather (the fire season). Prescribed burning is avoided during the fire season and when it is conducted in the lead-up period to the fire season, it is often subject to enhanced safety precautions.

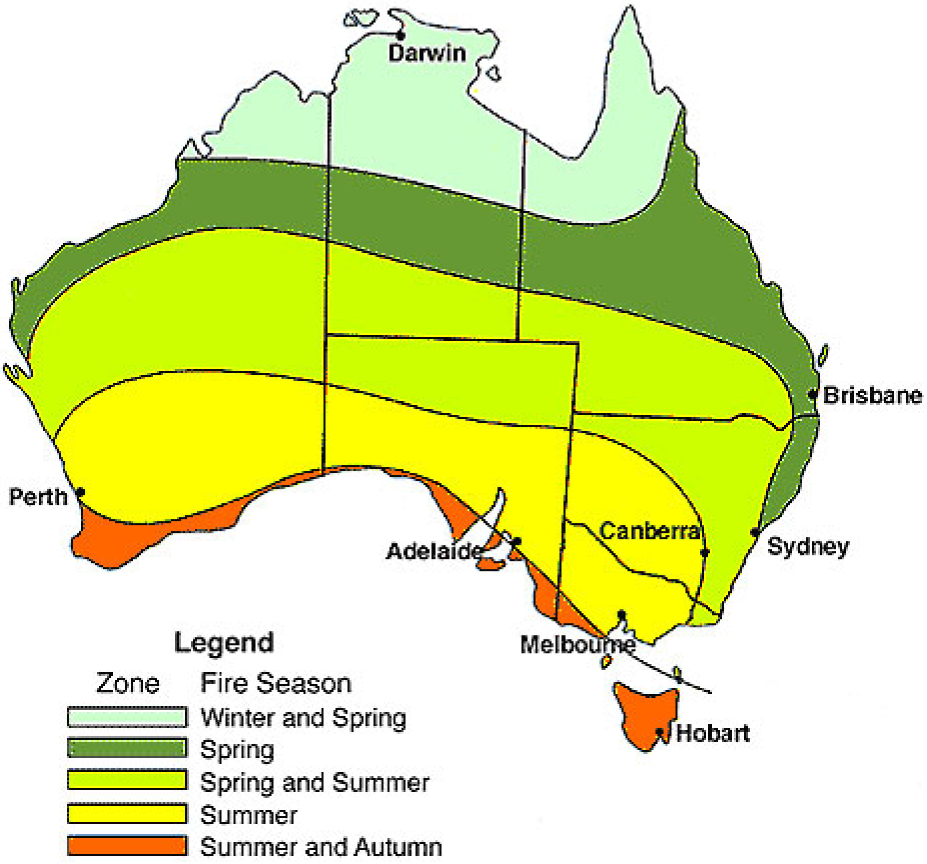


Figure 29: Pattern of season fire occurrence in Australia (Source: Luke and McArthur, 1978)

Drought Index

Drought Index, as measured by the Keetch-Byram Drought Index (KBDI) or the Soil Dryness Index (SDI), is a measure of the dryness of the soil profile. Each index maintains a daily calculation of soil moisture balance from inputs of rainfall, and losses from evapotranspiration.

Drought indices are indicators of the seasonal dryness of living vegetation, deep litter beds and coarse fuels. At high drought indices, fire intensities will be higher (because of higher overall fuel availability) and effects on vegetation (such as scorch height) will be more severe.

The KBDI has a scale of 0 to 200, where 0 represents saturated soils and 200 the maximum possible dryness. As a general rule:

- for good prescribed burning conditions, a KBDI < 100 (preferably < 80) will ensure good soil moisture and vegetation recovery
- for periods where weather conditions are deteriorating (such as the lead up to the fire season), a more cautious approach is advised and a KBDI < 30 is recommended.

Drought Factor

Drought factor is a measure of fuel availability based on drought index and recent rain on a scale between 1—10, where at ten 100 per cent of the fuel is available, and at five 50 per cent of the fuel is available.

Fire Danger Index

McArthur's Fire Danger Index (FDI) broadly summarises fuel and weather influences on fire behaviour. A maximum Fire Danger Index is commonly specified for prescribed burns because it provides an indication of the anticipated level of difficulty of fire control for the prevailing weather and fuel moisture conditions.

As a general rule, an FDI of 10 represents the upper limit for low intensity prescribed burning in forests. However this would be associated with fire behaviour at the upper end of the acceptable range, and burning with lower FDIs is often recommended.

Predicting desired fire behaviour

Successfully predicting fire behaviour galvanises the above fire-behaviour theory and fuel assessment techniques into one of the most important skills required of the fire manager in terms of planning and implementing prescribed burns.

Some guidance on predicting fire behaviour is offered below, presented as a step by step guide (drawing on the approach taken in the Queensland Planned Burn Guidelines, NPRSR 2012).

Note: the following sequence of steps was written from the perspective of preparing for a burn that is to take place within the next few days, and for which weather forecasts are available. For planning burn operations further into the future, some steps (such as Step 3: Assess on site weather conditions) cannot be done, but may need to be anticipated in the form of setting prescriptions and limitations affecting the conduct of the burn.

Step 1: Consider forecasts and seasonal conditions

It is important to gain an understanding of the pattern of weather on the proposed day of burn and on the days following. This will enable you to:

- refine your decision about which day to schedule for the burn
- be aware of potential changes in weather conditions that may pose a risk of fire escaping from the burn area.

Step 2: Gain a mental overview of your site and nearby areas

Most burn sites will contain variation in terms of terrain, fuels, moisture and will exhibit diurnal fluxes in weather conditions. As explained above, these will significantly influence fire behaviour.

Gain a mental overview by choosing a few areas that are representative of the diversity of your site. Include each fuel type present and target areas representing average condition (e.g. most of your site might be flat) as well as extremities (areas of steep slope, high fuel accumulation, wind funnel areas, etc.) if these areas are expected to create difficulties in terms of risk management (e.g. containment). Also consider areas near to the site where there may be spot overs or escapes.

Target the above areas for data collection and fire behaviour predictions in the following steps.

Step 3: Assess onsite weather conditions

Onsite weather conditions can vary significantly from forecasts, especially if the site is remote from any weather stations, or if there are topographical features or sea breezes that might introduce variation in wind speed or direction.

Use hand held meters (such as a Kestrel) to measure relative humidity, temperature and wind speed. Most fire behaviour models assume wind speeds at 10 metres above ground level, so remember to convert any readings from handheld metres as discussed earlier in this section. The Beaufort scale can also be used to estimate wind speed and has the advantage that no conversion is required for open 10 m wind speeds.

Irrespective of the method used, remember to take a number of readings over several minutes and average the result. Also, you should record peaks/gusts; electronic devices can do this automatically.

Step 4: Assess fuels

Fuel quantity, hazard and moisture content can be important inputs into fire behaviour models (in Step 5). Irrespective of this, observing the diversity of fuel conditions at your site is an important aspect of gaining an understanding of how fire might behave.

Fuel quantity

Different fire behaviour models will require different fuel parameters as inputs. For example different models may require fuel load, elevated fuel load, fuel hazard or grass curing. Ascertain which fire behaviour model or models apply to your site (see Table 10) and ascertain which fuel parameters you need to collect.

There are a wide range of techniques available to help you assess fuels depending where you are, which fuel type you are assessing and what aspects of fuel you are considering. Some are simple visual guides (e.g. to assess fuel load or grass curing) and these are probably the most practical. Seek the assistance of local experts for guidance on appropriate fuel assessment techniques in your area.

Fuel hazard

Irrespective of which fuel parameters are used by your fire behaviour models (in Step 5), it is important to consider the vertical arrangement of fuel at your site. Fire behaviour models do not always account for the three dimensional arrangement of fuel, and yet this can have a substantial influence on fire behaviour.

Observe features such as high amounts of elevated fuel, ladder fuels (i.e. fuels that provide vertical continuity between strata, and which are able to carry surface fire into the crowns of trees with relative ease) and the presence of high biomass grasses (i.e. dense, relatively dry, high carbohydrate grasses), as these may result in much higher fire intensities than predicted.

A common approach for considering fuel arrangement is using an Overall Fuel Hazard Guide (Hines *et al.* 2010; or DENR 2011).

Fuel moisture content (FMC)

Take a number of samples of fuel moisture in different locations that represent the diversity of site conditions (slope, exposed areas, different fuels types and non-target fuels).

Consider how fuel moisture is changing throughout the day, as this will influence your choice of ignition time (see Section 12 Igniting prescribed burns). It might be important to estimate fuel moisture and dew point overnight if this is being used as a strategy to limit fire spread.

FMC can be measured or monitored in a variety of ways in different jurisdictions including: predictions from temperature and RH, in-field moisture meters, fuel analogues such as hazard sticks or hazard bags, by oven-drying fuel samples, or estimates from a burning leaf test.

Step 5: Utilise appropriate fire behaviour models

Once again, it is important to make predictions of fire behaviour that represent the diversity of conditions at the site as well as different weather conditions during the day. This will provide information on the intensity of fire, how it is likely to spread and support decisions on when best to ignite a fire, ignition strategies and patrol and mop up requirements. Making predictions about fire behaviour on subsequent days and in nearby areas is also important.

When selecting a fire behaviour model, it is important to choose (where possible) a model that is fit for the type of fuel to be burned and is adapted to the purpose of prescribed burning. In 2015, CSIRO and AFAC published a comprehensive guide to fire rate of spread models containing extended commentaries on the underlying assumptions, applicability and recommended use of each (see Table 10). However, agencies may be using models that differ from those recommended below and it is important that you are familiar with those recommended in your jurisdiction.

Gain access to the models appropriate for your site and utilise them to make your predictions using the inputs you collected in previous steps. The models might be available as a booklet, a wheel, as an on-line application, automated in a spreadsheet or some other computer system. Seek advice of local practitioners.

Step 6: Compare predictions to prescriptions and objectives

Take your weather conditions and fire behaviour predictions and consider if:

- they are within the bounds of the burn plan's prescriptions/constraints
- the burn will meet the objectives specified by the burn plan
- the burn can be conducted safely and that the risks can be properly mitigated.

If not, special permission may be required to proceed with the burn, or alternatively, the burn may have to be rescheduled.

Table 10: Summary of recommended models (from Cruz *et al.* 2015)

Model	Fuel-type applicability	Geographical applicability	Targeted fire-management situation and limitations
Grasslands			
CSIRO Northern Australia meter Cheney *et al.* (1998)	Continuous grasslands, pastures and certain crops	Across Australia	Most applicable to bushfire conditions
CSIRO Northern Australia meter Cheney *et al.* (1998)	Grassy woodlands; open forest with grassy understorey	Across Australia	Most applicable to bushfire conditions
WA Spinifex model Burrows *et al.* (2009)	Spinifex grasslands	Semi-arid and arid regions of Australia	Most applicable to prescribed burning conditions in arid environments
Shrublands			
Buttongrass model Marsden-Smedley and Catchople (1995a)	Buttongrass moorlands	Tasmania	Most applicable to prescribed burning conditions; possible use in bushfire conditions (possibly applicable to some areas of Victoria, but needs validation)
Anderson *et al.* (2015)	Heaths and other temperate shrublands with height < 2.5 m	Coastal regions across Australia, New Zealand	Bushfire and prescribed burning conditions
SA Mallee-heath Cruz *et al.* (2010)	Semi-arid heaths	Southern Australia	Prescribed burning conditions
Mallee-heath Cruz *et al.*, (2013)	Semi-arid mallee-heath	Southern Australia	Prescribed burning conditions; possible use for bushfire conditions (requires careful extrapolation)
Eucalypt forests			
Leaflet 80; control burning guide McArthur (1962)	Dry eucalypt forest with litter and sparse understory vegetation	Southern Australia	Prescribed burning conditions
Red book, fire behaviour tables Sneeuwjagt and Peet (1985)	Dry and wet eucalypt forest	Southern Australia	Prescribed burning conditions
Young regrowth forest Cheney *et al.* (1992)	Young regrowth forest	Southern Australia	Prescribed burning conditions (under light wind conditions)
Dry Eucalypt Forest Fire model, Vesta model Cheney *et al.* (2012)	Dry eucalypt forest	Southern Australia	Bushfire burning conditions (assumes typical summer conditions)
Pine plantations			
Prescribed burning guide, MK 3, Byrne (1980); Hunt and Crock (1987)	Slash pine plantations with grassy understorey	Queensland Northern NSW	Prescribed burning conditions (restricted to light wind conditions)
Red book, forest fire behaviour tables Sneeuwjagt and Peet (1985)	Maritime pine plantations	Southern Australia	Prescribed burning conditions
Dry Eucalypt Forest Fire model, Vesta model Cheney *et al.* (2012)	Dry Eucalypt forest	Southern Australia	Bushfire burning conditions (assumes typical summer conditions)

Section 11 summary

- The character of any particular fire is the result of a combination of factors, including local climate, topographical influences, meteorological influences, and factors relating to fuel.
- Any fire will grow and build in intensity until its growth cannot be further promoted by the conditions under which it is burning. When it reaches this state of full development, the conditions affecting it will be in equilibrium.
- Fires lit from a single point do not usually reach their average rate of spread until 20 minutes after being lit.
- Fires lit via strip ignition, or head fires which develop from flank fires after a wind change, can reach their maximum rate of spread within 5 minutes.
- If unaffected by wind, slope or fuel variation, a fire will spread outwards in a gradually widening circle. If affected by wind, slope, the circle will elongate and the different parts will become identifiable as:
  - head fire (greatest intensity, highest flames, greatest ROS, most scorch)
  - flank fire (moderate intensity, moderate flame height, moderate ROS, some scorch)
  - back fire (lowest intensity, low flames, least ROS, no scorch).
- Low intensity fire is defined as fire that travels slowly and only burns lower storey vegetation causes little or no crown scorch, and is easily controlled. Low intensity fire includes fires with intensities no greater than 500 kW/m. However, often, low intensity fire less than 350 kW/m will be aimed at.
- High intensity fires are uncontrollable through direct attack, and typically burn with an average intensity greater than 3000 kW/m and flame heights greater than 3 m, causing complete crown scorch or possibly crown fires in forests.
- The effects of fire intensity can be analysed in various ways:
  - fire severity is related to intensity and describes the effect of fire on vegetation.
  - scorch refers to the killing of plant foliage as a result of convected and radiant heat from a fire, however he scorch height may take a week to become fully visible.
  - char height is also an expression of a fire severity, but unlike scorch it has the benefit of being visible immediately after a fire.
- The relationship between char height and scorch height tends to vary according to vegetation type and season.
- Low intensity fires in forest fuels with a well-defined fine litter layer typically have residence times 45—60 seconds.
- With the presence of heavier fuels, the difference between residence time and burn out time grows.
- Wind, atmospheric instability and high fire intensity all contribute to the likelihood and distance over which spotting will occur.
- Topography is an important consideration in planning ignition patterns, and anticipating variations in the fire behaviour of the prescribed burn. Good quality topographic maps are essential in planning (and conducting) prescribed burns.

- When two flame fronts approach one another, junction zones result in:
  - very rapid combustion
  - a significant increase in flame height and fire intensity
  - greatly increased spotting activity.
- When the distance between ignition points (or strips) is decreased, the proportion of the total area burnt by junction-zone fire increases:
  - a 60 m x 60 m grid pattern will cause approximately 20% of the total area to be burnt by junction-zone fire.
  - a 20 m x 20 m grid pattern will cause about 50% of the total area to burnt by junction-zone fire.
- Where changes to fuel moisture content within forest fuels may lag two hours behind changes in RH, the lag affecting grassland fuels is only 30 minutes.
- Fire ROS calculations are based on the speed of the wind at the base of the fire. Wind ratios for different points of a site should be worked out so that open wind speeds can be converted to ground wind speeds for those points.
- In more densely foliaged terrain, wind ratios will be higher to account for the greater difference between open and ground wind speeds.
- Most prescribed burning guides stipulate a maximum wind speed of 15 km/h at 10 m above the ground in the open, although in some specialised fuel situations, such as mallee or desert heaths, wind speeds up to 25 km/h or more may be acceptable, and in some cases are necessary to produce particular effects (such as linear burning patterns).
- Atmospheric stability affects convection, and directly affects fire behaviour. Unstable atmospheric conditions promote strong convection, which in turn generates strong indraught winds at ground level, leading to increased fire intensity. Most prescribed burning should be planned for stable atmospheric conditions. This will limit the development of strong convection, and will more likely be associated with predictable wind conditions.
- Prescribed burning is typically timed to avoid the high-temperature, low-humidity and high-wind periods associated with extreme fire weather.
- Drought indices are indicators of the seasonal dryness of living vegetation, deep litter beds and coarse fuels. At high drought indices, fire intensities will be higher and effects on vegetation will be more severe.
- McArthur's Fire Danger Index (FDI) broadly summarises fuel and weather influences on fire behaviour. Satisfactory low intensity prescribed burning can be conducted at McArthur Forest FDIs of less than five, however, in desert heaths or mallee vegetation, prescribed burning at FDIs up to 20 may be acceptable.
- Desired fire behaviour can be predicted by applying the following steps:

  (a) consider forecasts and seasonal conditions

  (b) gain a mental overview of your site and nearby areas

  (c) assess onsite weather conditions

  (d) assess fuels
    - fuel quantity
    - fuel hazard
    - fuel moisture content (FMC)

  (e) utilise appropriate fire behaviour models

  (f) compare predictions to prescriptions and objectives.

Self-assessment questions

1. Why is it recommended to postpone a post-fire assessment of scorch height until a week after the burn operation?
2. When estimating scorch height by reference to char height immediately after a burn, what other factors need to be kept in mind to ensure the assessment is more or less accurate?
3. Generally, how long does it take a fire ignited from a single spot to develop its maximum rate of spread?
4. What residence time might you expect low intensity fire burning in forest fuels with a well-defined litter layer to have?
5. How can short distance spotting affect head fire rate of speed?
6. When the distance between ignition points (or strips) is increased, does the proportion of total area burnt by junction-zone fire increase or decrease?
7. As a general rule, what is the maximum wind speed for most low intensity prescribed burning?
8. When in open country, what wind speed ratio can be used to convert ground-level wind speed (measured at a height of 1.5 m) to estimate the ‘open’ wind speed at the standard height of 10 m?
9. Why should most prescribed burning be planned for stable atmospheric conditions?
10. Why is caution required around junction zones?
11. For your agency, what are the upper limits of the Fire Danger Index (FDI) and Drought Index (KBDI or SDI) for low intensity prescribed burning?
12. What assessments are required to make fire behaviour predictions?

Section

12

Ignition

Ignition considerations are critical for controlling prescribed burning operations, with modulation of ignition time, lighting pattern and the spacing of ignition points being the principle means by which prescribed burns are controlled.

Ignition techniques

A variety of ignition techniques and tools are available for prescribed burning. These include:

- windproof/waterproof matches
- hand-held driptorches
- flame throwers (hand held and vehicle mounted)
- incendiaries 'propelled' from hand held devices
- aerial incendiaries or aerial driptorches.

The most appropriate ignition technique will depend on:

- the size of the proposed burn
- the nature of the fuels
- topographic constraints (especially slope)
- the desired fire behaviour
- other constraints such as limited access.

Matches

Matches designed to be windproof and waterproof are frequently used when igniting prescribed burns. Typically these are longer than a normal match, and have a wax-coated match-head that extends two-thirds the way down the length of the stick.

Features of wind- and water-proof matches at prescribed burns are that they:

- are cheap and easy to carry
- allow good control of ignition density (they can be rationed to crews to prevent over-lighting)
- only suit fuels which are relatively dry and will ignite easily.

For safety reasons, personnel should carry boxes of matches in a light shoulder bag, rather than in the pockets of clothing. In the unlikely event of a loose match igniting in the bag (and igniting other matches) the bag can be instantly thrown clear.

Driptorches

Features of hand held driptorches are that they:

- are relatively cheap to use (usually fuelled by a 3:1 mix of distillate and petrol, or by kerosene)
- will require 'topping-up' on long ignition lines which may be logistically awkward
- can effectively ignite relatively damp fuels at the higher end of the FMC range
- can be heavy and tiring to use, particularly in thick vegetation.

Experience has shown that unless crews using driptorches are well disciplined, they will invariably over-light an area. Application by lighting crews of the prescribed lighting pattern (size of spot ignitions, or length of lighting strips) must be constantly monitored and reinforced to crews as the operation proceeds.

Aerial driptorches

Aerial driptorches have been developed in recent years primarily as a safer and more efficient means than ground internal grid lighting for the ignition of high intensity fires in heavy fuels. They comprise a device which is slung beneath a helicopter (Figure 30), and can drop ignited globules of jellied petrol. When FMCs are relatively high, this equipment can also be used for aerial ignition of broad areas for low intensity burning.

Figure 30: Aerial driptorch slung beneath a light helicopter

Flamethrowers

Two types of flamethrowers are in common use:

- a back-pack type of about 20 litres (kerosene type fuels), connected to a hand wand incorporating a hand pump
- a vehicle mounted type of up to 120 litre capacity (distillate/petrol fuels), with fuel being electrically pumped to a hand wand, with electrical ignition.

Back pack flamethrowers are appropriate where fuels are difficult to light or discontinuous.

Vehicle mounted flamethrowers (Figure 31) are appropriate where:

- trackside lighting is required over long distances (for example, ridge top burning in remote areas)
- fuels are difficult to light or discontinuous.

Because of the nature of the flame produced, care must be taken not to use any sort of flamethrower near other personnel.

Figure 31: Vehicle-mounted flame thrower (image courtesy of DPAW, WA)

Propelled incendiaries

Incendiaries propelled from hand-held devices (generally classified as firearms) may include:

- magnesium flares fired from a 12 gauge shotgun
- match-compound incendiaries fired from a modified rifle
- aerial incendiary capsules fired from an incendiary launcher powered by a gas/air mix with electronic ignition.

The range of these types of incendiaries is up to 150m. Their use is appropriate where ignition is required:

- on steep slopes difficult to traverse on foot
- in dense vegetation where access on foot may be difficult.

For example, in burning down moderate to steep slopes from a road or track, where edge ignition is spreading very slowly, further downslope ignition could be achieved with an incendiary launcher without committing crew to a difficult and possibly dangerous situation.

Ground ignition technique considerations

In planning a low intensity prescribed burn, choice of ignition technique will be largely determined by the prescribed burn objectives, size of the area and the dryness of the fuels. If the area is relatively small, usually less than 200 ha, then aerial ignition is probably not cost-effective and some form of ground ignition will be required. If fuels are likely to be quite dry (FMCs less than 12—13%) then wind proof/water proof matches may be suitable for ignition. If FMCs are higher, driptorches may be better to ensure fuels are well ignited at each spot. Table 11 summarises factors to be considered in choice of ground ignition technique.

Table 11: Ground ignition technique considerations

Ignition technique	Ignition pattern	Nature of fuel	Access considerations	Resource implications
Wind/water proof matches	Spot only	Dry continuous fuel only	Easily carried on foot	May require several experienced crew members for each lighting operation
Driptorch (hand)	Any, and flexible	Any, but tiring to carry through thick vegetation	Crews can carry anywhere but tiring and require frequent refuelling	May require several experienced crew members for each lighting operation
Flame throwers	Suit edge strip or extended spot lighting only	Any	Suit trackside lighting only	Trained accredited personnel only. Vehicle mounted equipment may not be readily available
Propelled incendiaries	Spot (with limited accuracy)	Continuous fuel only	Enable ignition of thick vegetation, steep areas	Trained accredited personnel only. Vehicle mounted equipment may not be readily available

Aerial ignition

Aerial ignition has been in use in Australia for many years. It enables:

- the ignition of large areas (up to 4000 ha per hour for low intensity burning) during favourable conditions
- ignition of areas which ground crews may not be able to reach easily.

There are two forms of aerial ignition:

- aerial driptorches (described earlier in this section under 'Driptorches')
- aerial incendiaries can be dropped by fixed-wing aircraft or by helicopters.

Aerial incendiaries are normally styrene phials or spheres containing about 4 gm of potassium permanganate. Via an automatic feed system, the incendiary machine in the aircraft (Figure 32) injects each capsule with ethylene glycol and ejects it from the aircraft. The glycol and the potassium permanganate react to produce heat which eventually, after 30—45 seconds, causes the capsule to ignite, and thus ignite the fuels on which it has landed.

The speed of the machine can be varied with the speed of the aircraft, to achieve the desired ignition spacing.

Figure 32: Aerial incendiary machine in a light helicopter

Features of fixed-wing aerial-incendiary ignition

- cheaper than helicopters, but may have much longer turnaround times on large jobs
- less accurate in incendiary placement than helicopters
- great care is required when lighting near irregular boundaries
- best suited to broad scale burning of uniform terrain.

Features of helicopter aerial-incendiary ignition

- much more costly per flying hour than fixed-wing aircraft
- best for accurate placement of incendiaries
- can achieve higher incendiary density per pass if conditions require
- can more safely light near irregular boundaries
- provides good observation of developing fire behaviour because of the ability to fly relatively 'low and slow'
- best suited for areas up to about 5,000 ha where variable fuels and irregular terrain demand careful control over fire behaviour.

Using aerial ignition in mountainous terrain

A good awareness of your prescribed burning objectives will help to inform the type of aerial ignition pattern desired. Spot ignition can be used effectively to alter the desired intensity. Aerial ignition can be used with features such as fuel moisture and landscape features such as drainage lines, moist gullies and broken rocky areas to create a mosaic. Be aware that in mountainous areas aerial incendiaries can be dropped close together along ridgelines to create fires that join before becoming too large, and then back down slopes. They can also be dropped further apart which will allow individual fires to build momentum before joining. It is usual to avoid igniting downslope areas as this creates a run of fire uphill that may ring mountain peaks with fire. But ultimately choice of ignition strategy will depend on a number of factors including (NPRSR 2013):

- prescribed burn objectives (from the burn plan)
- prescribed burn prescriptions (from the burn plan)
- fuel load and fuel moisture conditions
- prevailing weather conditions and weather conditions on subsequent days.
- a good understanding of topography and its likely effect on fire behaviour.

It is important to carefully consider the above issues to plan ignition runs and ignition patterns. Use of aerial photograph (especially stereo imaging) is useful to plan ignition runs. Plot ignition runs on a map, or take aerial photographs and upload them onto digital devices prior to aerial operations (NPRSR 2012).

Using aerial ignition in flat terrain

In flat terrain similar considerations are necessary; however different ignition techniques are employed. For example rather than targeting ridgelines with spot ignition to create backing fires downslope, it is common to use grid ignition. The spacing of spots and how soon they are extinguished by overnight conditions or otherwise join up enable those conducting the burn to control the amount of area burnt as well as control the fire intensity (see ignition patterns below).

It is important that ignition runs, lines of ignition and spot ignition density be planned, and flight runs/ lines of ignition are plotted on a map or uploaded into digital devices prior to aerial ignition operations.

Using aerial ignition for landscape mosaics and unbounded burning

Unbounded burning involves the use of fire, often in broadscale landscapes, where at least part of the burn lacks constructed fire control lines. Rather, the burn may be bounded by natural features such as streams, rocky areas, gullies or moister vegetation types (such as rainforests). Alternatively, there may be no control lines, and rather it is anticipated that the fire will self-extinguish due to overnight conditions. In some environments, strong winds are used to control the extent of fire by creating runs of head fire with very little backing or flanking fire. For these fires it is essential to understand how, when and where the head fire will be contained (AFAC 2015a).

Unbounded burning is often associated with ecological burning and often aims to create rich landscape mosaics of burnt/unburnt areas for the benefit of ecosystems, and the biodiversity of flora and fauna. However, unbounded and landscape burning comes with a number of challenges (AFAC 2015b):

- Due to the landscape scales involved, it is usual that many different types of ecosystems will present within the burn perimeter. Some of these may be due for fire while others are not (according to their recommended ecological tolerable fire intervals). However, ecosystems are usually contiguous across a landscape and therefore the ability to burn one ecosystem with limited encroachment into another requires a very nuanced understanding of the ecosystems, weather conditions, fuel moisture conditions, topography, lighting patterns and resulting effects on fire behaviour.
- Using overnight conditions, natural features such as streams and broken terrain to contain a burn requires a good knowledge of current local conditions and how these conditions will influence fire behaviour.
- Landscapes that are dissected with topography and aspect variability, and consequently substantial variability in fuel types and fuel moisture pose significant challenges to understanding fire behaviour.
- Fires may persist for weeks or longer in broadscale landscapes. Careful consideration of seasonal weather patterns is important, so that fire-weather conditions do not deteriorate with a resulting undesirable change in fire behaviour potentially leading to escapes (from the area planned to be burnt).
- Note that mountainous areas can have quite localised and changeable weather conditions that may vary considerably from weather observation stations.
- It can be difficult to successfully identify all built assets over such broad areas and GIS mapping may be incomplete.
- Be aware of the need to have well developed contingency plans and fall backs in the event that fire does not stay within the expected burn boundary.

It is important the landscape mosaic and unbounded burning is planned and carried out under the supervision of experienced prescribed burning practitioners. For best results, often aerial crews work in tandem with ground crews.

Activity 12.1

Identify the types of ignition techniques used by your agency, and the different circumstances where each are be used. List the safety factors relevant to each technique.

Ignition patterns

Ignition patterns can have a big influence on fire behaviour by affecting:

- rate of spread
- total burn out time
- incidence of junction zones, and thus
- flame height and fire intensity.

Choice of ignition pattern will be determined mostly by:

- the burn objectives
- desired fire intensity
- the dryness of the fuels
- effects of wind and slope.

Lighting should always commence on the downwind or upslope perimeter. Once a safe buffer has been established on this boundary, lighting can proceed downslope or into the wind. The choice of spot or line (strip) ignition depends on fire behaviour and the desirable fire intensity. Remember that strip ignition could increase fire intensity several fold compared to fires spreading from individual spot ignition points.

The timing of implementing the ignition pattern must be closely controlled by the burn manager, and judged from an assessment of developing fire behaviour. Good communications with ignition (lighting) crews is essential.

For complex burn operations, variations within a burn area in fuel load strata and FMC due to fuel type, location or aspect may require separate ignitions, some days or even weeks apart. Separate ignitions may be scheduled to assist burn security by edge burning hazardous fuels adjacent to control lines, or normal fuels adjacent to a critical or vulnerable control line, under milder conditions where fire intensity will be less.

In order to capture a window of milder conditions, burning may have to be planned to occur at night, or in winter in southern areas, or in summer in sub-tropical areas following initial summer rains.

Common ignition patterns

There are several common ignition patterns that can be varied to suit local conditions. These are illustrated in Figure 33 and include:

- backing fire ignition, where all fuels are burnt by fire backing into the wind, or downslope (or both)
- spot or grid ignition, where fires from separate ignition points spread substantially before influencing one another
- strip ignition, where lines of fire are successively lit from the upslope or downwind perimeter, across the slope or at right angles to the prevailing wind
- chevron (flank fire) ignition, where lines of fire are lit into the wind or downslope, resulting in the majority of the area being burnt by flank fire
- convection (centre fire) ignition, where fire is established first in the centre of the burning unit. Strong convection draws subsequent concentric lines of ignition towards the centre.

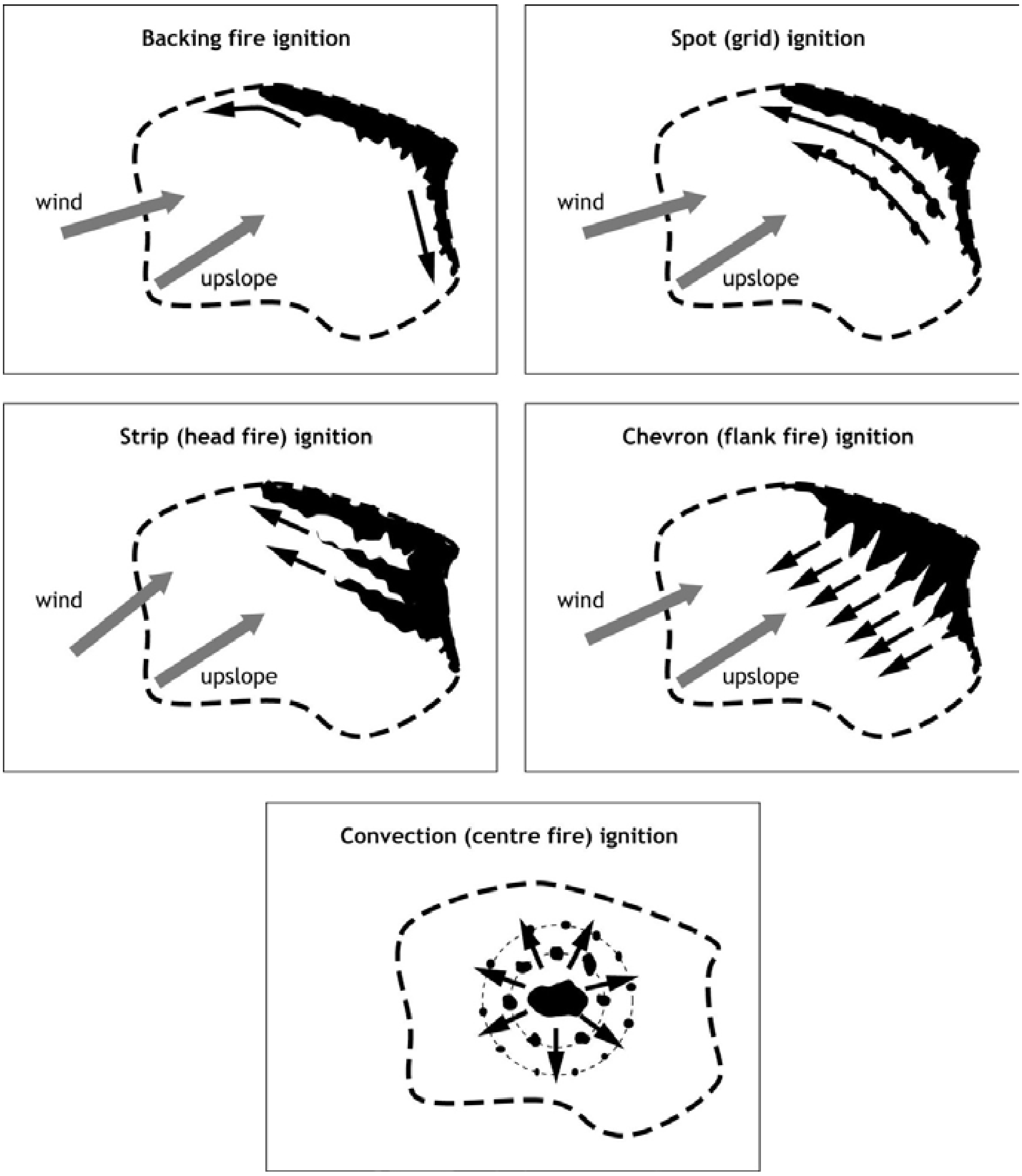


Figure 33: Common ignition patterns

Low intensity burns

For low intensity burns the level of fire behaviour (flame height, fire intensity) is critical to the burn's objective. Careful control of the ignition pattern is vital.

The fire behaviour of any prescribed burning operation will be largely determined by:

- prevailing fuel and weather conditions, and topography
- the area burnt by head fire, flank and back fire
- the area affected by junction zones.

The last two factors are determined by the choice between spot ignition and line ignition, and the spacing of spot ignition points.

Spot vs line ignition

Figure 34 shows that a fire spreading from a single ignition point will burn approximately a third of the area with head fire, and two thirds with flank and back fire. By contrast, approximately five-sixths of the area burnt by a fire spreading from a line of ignition will be burnt by head fire, and one-sixth by backfire.

Rate of fire spread for a given set of conditions is related to the width of the headfire. Under the conditions prescribed for low intensity burning, fires spreading from individual spots will remain narrow and ideally will not join up until conditions ease reducing fire behaviour and junction zone effects, or not join up at all prior to being extinguished by overnight conditions if a very patchy burn is the objective.

Conversely fires spreading from extended lines of ignition may reach their potential rate of spread very quickly.

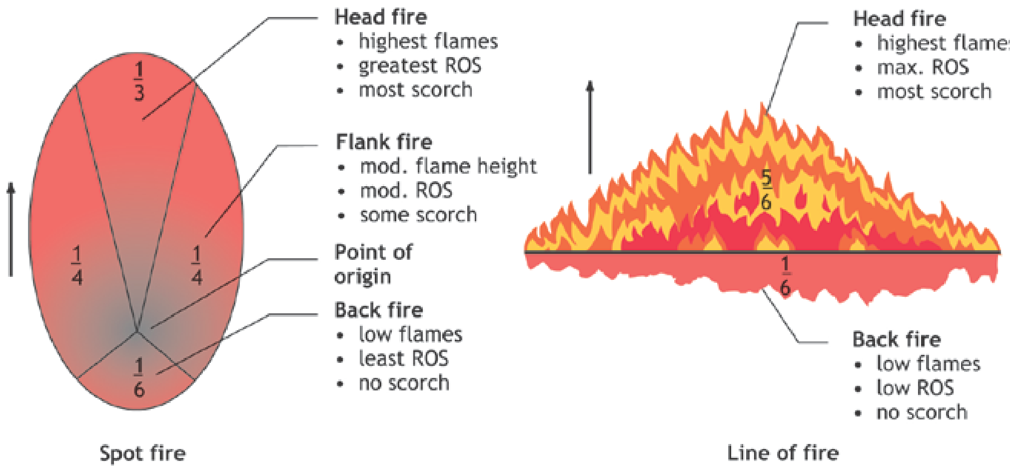


Figure 34: Spot fire versus line of fire

Similarly, wherever separate fires are lit in close proximity, some junction zone effect will occur as they burn together. Where it is essential that fire intensity be minimised, spot fire ignition is preferable to ignition with lines of fire, unless the lines are lit such that the bulk of the planned area will be burnt by the back fire (that is, a backing fire lit close to an upslope or downwind control line).

Spot (grid) ignition

Where possible a grid system of spot fires should be used. Lighting should be done along the leeward or upslope boundary first. When this boundary is burning satisfactorily against the wind or downslope, further spots can be lit along parallel strips running at right angles to the prevailing wind direction or along the contour, if the slope is significant (Figure 35).

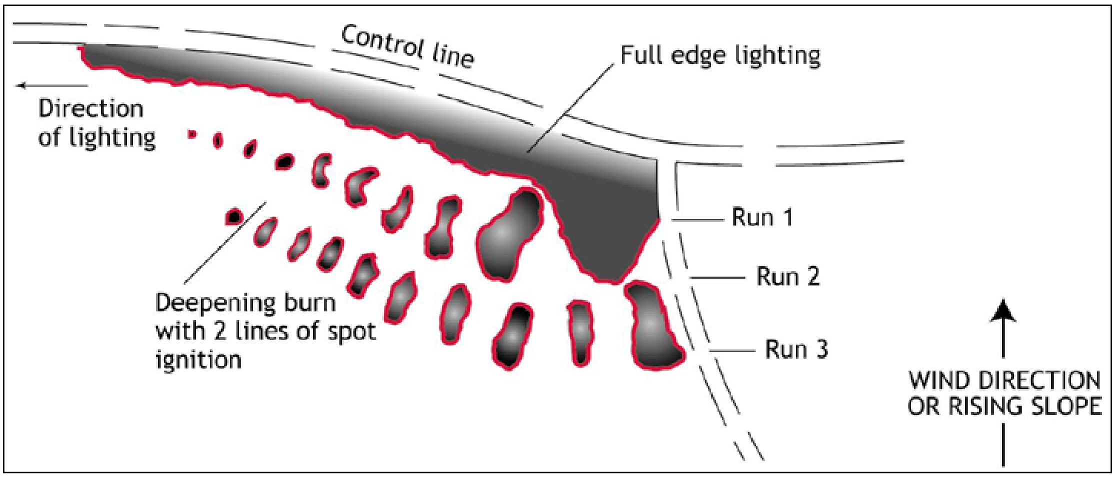


Figure 35: Lighting pattern for low intensity ground ignition by crew on foot

For hand lighting operations the crew of lighters should move in a slanted formation through the area, with the lighter on the downwind or upslope line leading the staggered crew. This ensures that each lighter is not endangered by fire from the next lighter upwind or downslope. Good communication between lighters (preferably with line of sight and voice contact) is essential to maintain this formation and ensure safety of individual lighters.

Chevron (flank fire) ignition

Chevron ignition involves extending lines of fire the wind or downslope, resulting in the majority of the area being burnt by flank fire.

High intensity burns

For high intensity burns, ignition patterns may need to be somewhat different.

To achieve the necessary high intensity fire behaviour in standing forest or heathlands, ignition patterns may need to allow individual spots or lines of fire to 'run' downwind (or upslope). Such burns will have a higher risk of escape, and fuels on the down wind or upslope boundary may have to be burned first at lower intensities to provide a buffer. Alternatively, a strong fuel-moisture differential between the area to be burnt and surrounding forests may be used.

When igniting high intensity burns it is critical that ignition crews are not trapped between lines of ignition. Continuous ignition lines and high intensity fire behaviour can make entrapment situations difficult to escape, particular when using convection ignition patterns (see Figure 37). For this reason, aerial driptorches slung under a helicopter are commonly used to light high intensity burns on small areas that have been harvested.

High intensity strip lighting of slash fuels

The fuels remaining following timber harvesting are an example of debris type (slash) fuels, comprising mainly leaves and branches of the heads of trees. Ignition patterns for slash fuels will involve either strip lighting or convection lighting.

A narrow strip of fuels along the vulnerable (upslope, downwind) edge is lit first (see Figure 36). When these fuels are burned sufficiently to provide a safe buffer, further strips are lit progressively downslope (or up wind). Strips may be allowed to widen once a safe buffer has been established. The width of the strips will depend on:

- wind speed
- slope
- distribution and arrangement of fuel.

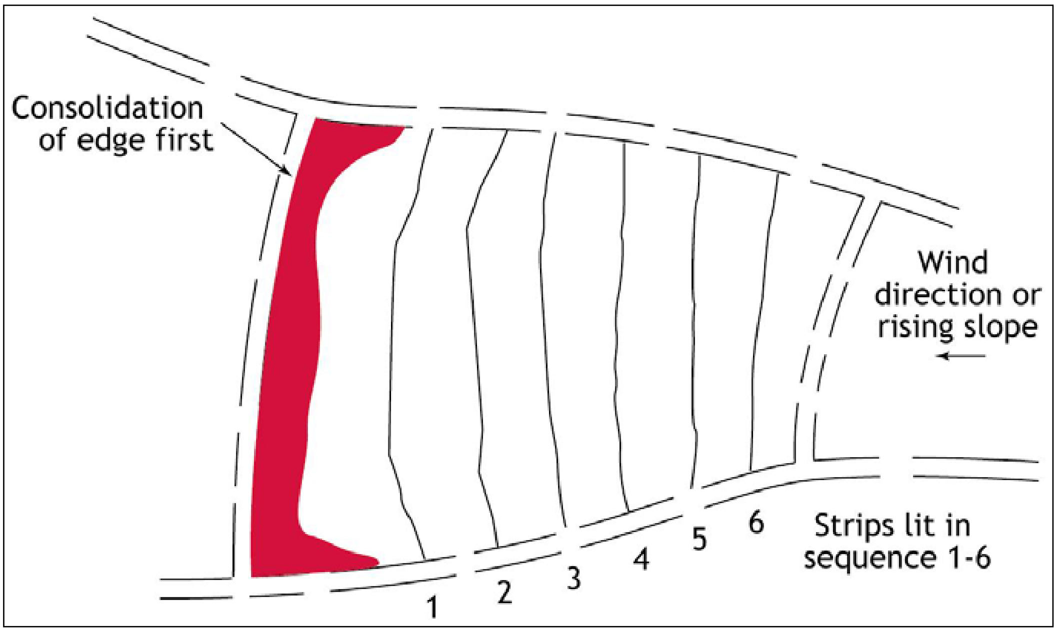


Figure 36: Strip lighting for high intensity burns

High intensity convection lighting of slash fuels.

Convection lighting or centre fire ignition (Figure 37 and 38) is used to deliberately create an initial strong convection column from burning fuels in the centre of the area, which will create indraughts around the area's entire perimeter. Fire, from subsequent ignition successively closer to the perimeter, is drawn towards the centre of the area.

Convection ignition has advantages in terms of:

- crew safety (high intensity fire drawn inwards from the perimeter)
- visibility (smoke drawn to centre of area)
- control (indraughts minimise risk of escapes over perimeter control lines).

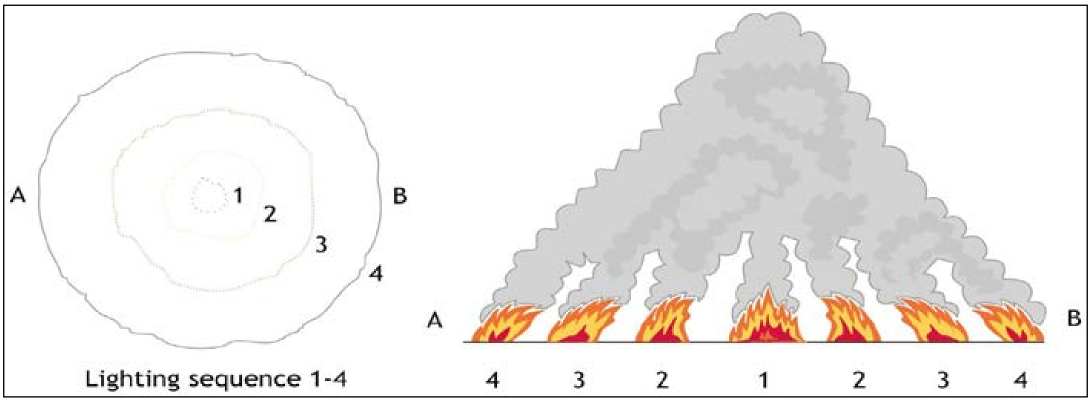


Figure 37: Convection lighting for high intensity burns

Figure 38: Convection ignition showing indraught effect

Constraints on convection lighting

Convection ignition should not be attempted where:

- slopes exceed 10°
- wind speeds exceed 15 km/h.

Steeper slopes or stronger winds may overcome the convection indraught effect and allow the column to move towards the upslope or downwind edge.

Timing is important. Once the central convection column is established, successive lighting must follow promptly before the indraught influence starts to weaken. However if perimeter lighting is commenced too early, it may draw the central fire towards it, possibly causing mass spotting over control lines.

Activity 12.2

Demonstrate how you would determine an appropriate ignition pattern for a simulated low and high intensity burn in fuels typical for your locality.

Ignition spacing

Calculations of ignition spacing can only be made once on-site conditions have been confirmed on the day of the burn; that is, information from fire behaviour models/guides as well as evidence from a test burn (where available).

First, the average rate of spread (ROS) is determined. Then, the time to be allowed for joining up of individual fires (if spot ignition is to be used) is estimated. With this information, ignition spacing can be determined. For example, if ROS is 40 m/h and available burning time is 4 hours, initial ignition spacing is 160 metres. Remember if lighting up is going to take some time, ignition spacing will have to be adjusted for the diminishing available burning time.

Ignition spacing can then be adjusted as lighting progresses during the day to adjust for diurnal patterns in fuel drying and observation of fire intensity against the burn objectives.

Activity 12.3

For a proposed prescribed burn in your locality, describe (using words and a sketch plan) the most appropriate ignition pattern, including important time sequences. List reasons justifying your choice.

Estimating spacing of lighting strips

The distance between lighting strips can be estimated as follows:

- predict the forward rate of spread (FROS) based on observations of a test fire in typical fuels, and on data from fire behaviour predictions
- estimate how much effective burning time is left. Allow for lag times and the fact that fires will burn more intensely as they draw together.

For example, if estimated FROS = 30 metres/hour and available burning time is three hours, then lighting strips should be about 100 metres apart. Successive strips are set upwind or downslope.

Individual spots along each strip should be at intervals of about half the strip width (see Figure 35). This is because flank fire spread rates will be less than half the head fire spread rates.

As described earlier in Section 11, when the distance between ignition points is decreased, the proportion of the total area burnt by junction-zone fire increases:

- If ignition points are spaced according to a 60 m x 60 m grid pattern, approximately 20% of the total area will be burnt by junction-zone fire.
- However, if the size of the ignition grid is reduced to 20 m x 20 m, the total area burnt by junction-zone fire increases to approximately 50%.

The proportion of the burn that is burnt by junction-zone fire will affect the overall intensity of the burning, as well as influencing factors such as spotting activity, and scorch height and severity.

Note that for ecological burning, it may not be desirable for individual spot fires to join prior to being extinguished by overnight conditions. This is so that a mosaic of burnt and unburnt areas is achieved. In this case the desired proportion of burnt/unburnt will influence spot spacing.

Adjust pattern if necessary

Rates of spread of individual fires should be continually monitored. Distance between strips is altered as required to give each fire maximum travel before it joins another. Be flexible and prepared to alter plans to suit changing conditions.

It is better to space spot fires too far apart than too close together. Too close a lighting pattern will cause a big increase in junction zone effect, with much higher overall fire intensity and effects such as scorch. If fires are obviously not going to meet in the available burning time, further ignition of unburnt patches can be considered, if possible, for burns that require these areas burnt out (e.g. for protection burns).

In many circumstances it will be necessary to burn out the whole perimeter and achieve a blacked out control line.

Section 12 summary

- A variety of ignition techniques and tools are available for prescribed burning. These include:
  - wind proof/water proof matches
  - hand-held driptorches
  - flame throwers (hand held and vehicle mounted)
  - incendiaries ‘propelled’ from hand held devices
  - aerial incendiaries or aerial driptorches.
- The most appropriate ignition technique will depend on:
  - the size of the proposed burn
  - the nature of the fuels
  - topographic constraints (especially slope)
  - the desired fire behaviour
  - other constraints such as limited access.
- Ignition patterns can have a big influence on fire behaviour by affecting:
  - rate of spread
  - total burn out time
  - incidence of junction zones, and thus
  - flame height and fire intensity.
- Choice of ignition pattern will be determined mostly by the:
  - desired fire intensity
  - the dryness of the fuels
  - effects of wind and slope.
- Common ignition patterns include:
  - backing-fire line ignition
  - spot or grid ignition
  - strip ignition
  - chevron (flank fire) ignition
  - convection (centre fire) ignition.
- The fire behaviour of any prescribed burning operation will be largely determined by:
  - prevailing fuel and weather conditions, and topography
  - the area burnt by head fire, flank and back fire
  - the area affected by junction zones.
- Fire spreading from a single ignition point will burn approximately a third of the area with head fire, and two thirds with flank and back fire. By contrast, approximately five- sixths of the area burnt by a fire spreading from a line of ignition will be burnt by head fire, and one-sixth by backfire.

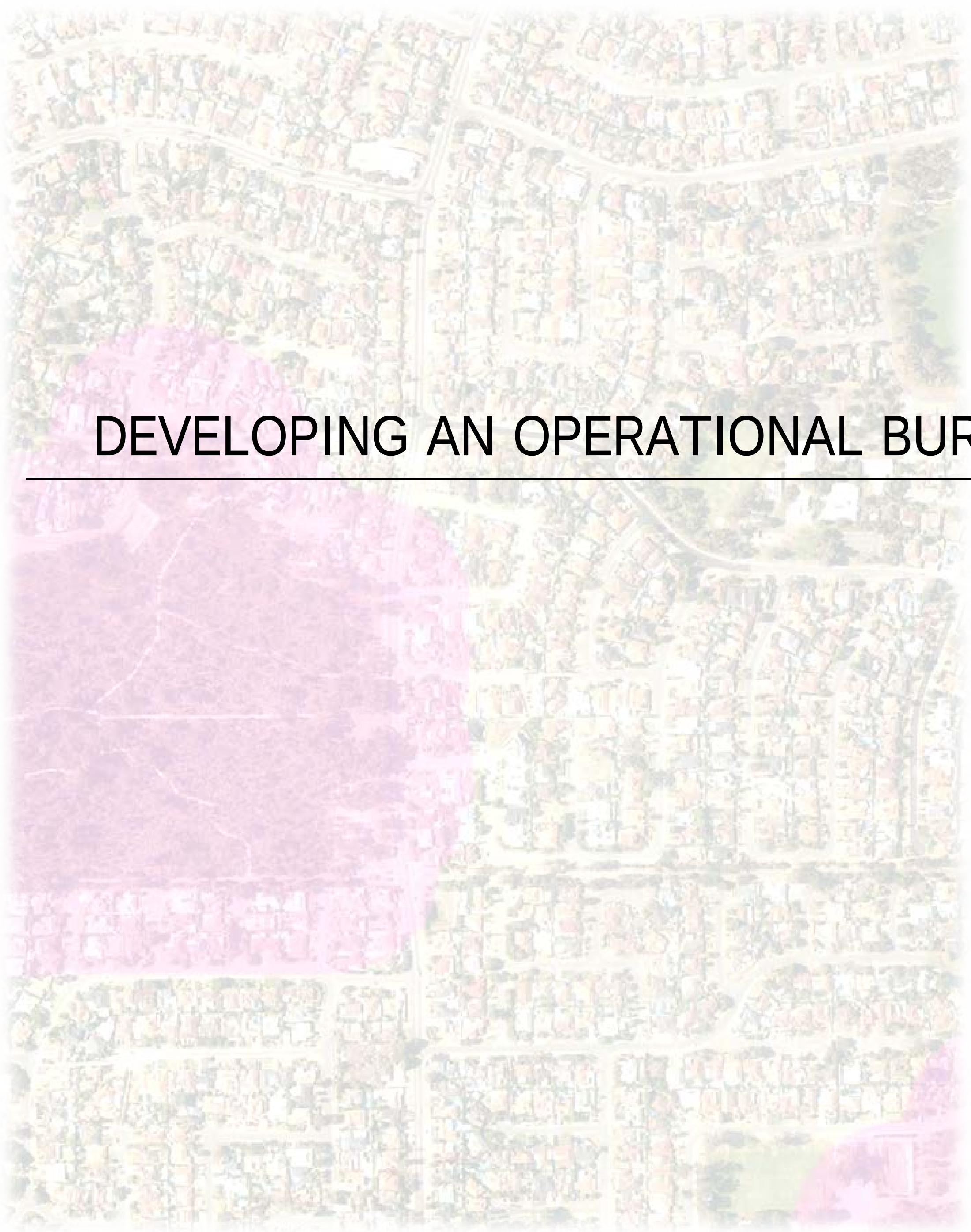
- Whether undertaking low intensity grid ignition or high intensity strip ignition, lighting should be started along the vulnerable leeward or upslope boundary first to create a buffer of burnt land abutting the control line.
- Where high intensity fire is required, convection lighting or centre fire ignition can be used to deliberately create an initial strong convection in the centre of the area, which will create indraughts around the area's entire perimeter, and draw fire from concentric points of ignition in towards the centre of the area.
- Convection ignition should not be attempted where slopes exceed 10° or when wind speeds exceed 15 km/h.
- Calculations of ignition spacing can only be made once on-site conditions have been confirmed on the day of the burn. First, the average rate of spread (ROS) is determined (in m/h), then the ROS is multiplied by the time to be allowed for the individual fires to join up (or not join up in the case of mosaic burning).
- When spot ignition is being used, the spots along each row should be spaced at half the distance of the space between rows.
- For low intensity burns it is better to space spot fires too far apart than too close together. Too close a lighting pattern will cause a big increase in junction zone effect.

Self-assessment questions

1. What are some advantages of using matches to light prescribed burns?
2. What are some disadvantages of using driptorches to light prescribed burns?
3. Why is a spot ignition pattern generally preferred to strip (or line) ignition where fire intensity must be kept low?
4. How is spacing for spot ignition determined?
5. What two aspects of the prescribed fire can be modulated by adjusting the lighting pattern?
6. What lighting patterns are appropriate for use when high intensity fire is required?

Part

C



DEVELOPING AN OPERATIONAL BURN PLAN

Outline of the operational planning process

Figure 39: The operational planning process

The operational planning process outlined in Figure 39 reflects national best practice as presented by the National Guidelines for Prescribed Burning Operations (AFAC 2016a) and is discussed on the subsequent pages. The steps may be undertaken in a slightly different order in different agencies, and some agencies may have formal procedures for all or only some of these steps with the rest undertaken informally. Irrespective of this, Figure 39 is useful as a reminder of the issues that should be considered for all complex prescribed burns.

Activity 13.1

Read through the Review Activity 1 in Part E of this resource. It presents an operational-planning scenario and a blank burn-plan template. Use this or your own local, burn-plan template and think about how you would complete it as you progress through Part C of this learner resource.

Section

13

Burn site, values assessment and consultation

This first stage of operational planning involves:

- confirming whether treating the area still aligns with the broader strategic and program objectives
- a review of the operational feasibility of conducting the proposed prescribed burn, and whether the burn objectives are achievable
- identification and assessment of potentially at-risk values and assets, both within and outside the burn area, and identification of safety hazards
- consultation with all relevant stakeholders to identify issues and requirements.

This information provides the basis for decisions regarding risk treatments and burn execution, which will be dealt with in the next section.

Aligning to strategic and program plans

An operational plan should first consider whether the proposed burn characteristics reflect relevant objectives within the strategic-level and program-level plans. In some agencies, prior planning may only have been done as part of a desktop analysis or with limited field assessment, and in practice the objectives may not be feasible, e.g. vegetation types and their condition may differ significantly from what is indicated in the available digital mapping, and this can have major implications for burn planning. Where relevant, review the fire-management zoning and check that the intent of the zoning (e.g. asset protection) is consistent with the intent of the proposed burn.

Sometimes external factors may negate the need for the burn or require a review of its timing. These factors may include:

- recent bushfires occurring within or adjacent to the burn area
- minimal fuel accumulation due to prolonged drought
- major access issues, such as track damage from flood events.

Program planning/scheduling factors are also important when considering if the burn in question is ready to proceed or needs rescheduling. These include:

- ensuring the prescribed burn meets ecological fire regime requirements
- avoiding particular times of year due to ecological or operational constraints
- utilising previously burnt areas as a secure edge for the current burn
- grouping of burns in close proximity for efficiency reasons
- availability of specialist resources.

Operational feasibility

It is important to assess the burn site to determine whether the proposed burn is feasible in practice.

Review operational history

Previous burn reports relating to the burn site can be reviewed (if available) at the beginning of the planning process. These can provide useful site-specific details about local conditions, burn boundaries, likely fire behaviour, risks and hazards, and resources required. Some agencies are moving toward identifying permanent burn units and ensuring detailed operational information is available for them (to streamline the operational-planning process). These burn units are pre-established operational areas with known, reliable boundaries for which prescribed burns are typically planned.

Review burn boundary

Seek personnel with operational experience to verify the boundaries of the burn, and determine whether it is feasible to contain the burn within this area using available control lines (e.g. roads, bare earth or slashed tracks) and/or natural features (e.g. creeks, wet gullies or exposed rocky areas). This will usually require a field assessment that considers likely fire behaviour adjacent to the control lines.

Figure 40: Build-up of fuel along a fire control line (Source: DLRM, NT)

When determining the suitability of control lines, the influence of topography and fuels on fire behaviour must be taken into account. Upslope control lines will always be under more pressure from fire behaviour than downslope areas, although appropriate lighting patterns can reduce this. Likewise, control lines that avoid areas of heavy fuel and trees with high bark hazard (or manage these hazards prior to the burn) will be more easily defended during the burn.

Preferred control line locations need to be identified at an early stage during preparations to ensure that sufficient time is available to:

- improve existing roads, tracks or fire lines to required standards
- construct new control lines where necessary
- gain approvals to undertake work on land under the tenure of others.

Be aware of any agency standards with regard to control lines. Control lines are often rated as to their effectiveness under different types of fire, and using control line standards is a very useful guide to determining suitability of proposed prescribed-burn containment.

Activity 13.2

Identify any control line standards that your agency uses. Does the rating system used for control lines relate to their suitability for burn containment?

Understanding the burn site

Burn planning must consider tenure and topography within and adjacent to the target area. GIS is commonly used for a desktop review of tenure and topography, but check that data is current.

Different land tenure will raise issues such as:

- notification requirements to neighbouring property owners or land managers
- potential cooperative arrangements to include private property or land managed by other agencies in the proposed burn (perhaps to rationalise boundaries)
- the need to locate control lines to exclude fire from areas of different land tenure
- potential cooperative arrangements to involve resources from other agencies in the conduct of the proposed burn.

Topography has a significant influence on fire behaviour through slope, aspect, elevation and landform:

- slope affects rates of fire spread (and hence fire intensity)
- aspect and elevation influence fuel types and moisture regimes
- landform can interact with weather to produce significant local effects (e.g. on wind speed and direction).

Topography within and surrounding the burn area will therefore be an important consideration in planning ignition patterns, anticipating variations in fire behaviour during the prescribed burn, and planning contingencies in the event of escape.

Identify values, risks and hazards

All values and hazards need to be identified and assessed to enable planning for risk management. The attributes of site values and hazards will contribute to the overall degree of risk. The greater the hazard, and the greater the exposure and vulnerability of the values at risk, then the greater the risk will be. Refer to the *Risk Management and Review Framework for Prescribed Burning Risks Associated with Fuel Hazards* (AFAC 2015a) for more detail. Most agencies will require an assessment of the risk level of burns and burn plans as part of the approval process.

Values

As described in Section 6, prescribed burns have the potential to impact on a range of values and assets within and adjacent to the burn area, such as:

- built assets (i.e. property, utilities and infrastructure)
- environmental values (e.g. soil conservation, ecosystem health, biodiversity maintenance)
- cultural-heritage values (e.g. public amenities, sites of historical interest)
- land-use values (e.g. water sourcing, timber production, grazing, bee keeping).

These values may be identified in strategic plans, but most agencies will utilise GIS to identify and spatially locate assets and values in or within proximity to the burn. It may also be necessary to consult with internal staff and/or external experts to help identify and assess specific values.

It needs to be understood that just because a value is at or near a burn site does not mean it is at risk from prescribed burning. For a value to be at risk it needs to be vulnerable to the radiant heat, flames or smoke produced by the prescribed burn.

Many values will be protected by burning under suitable site and weather conditions or through the presence of suitable control lines. However, there are cases where built assets, cultural sites, specific species, habitats or features need some sort of additional mitigation strategy during a prescribed burn (such as constructing a temporary control line, planning ignition to back fire away from fire-sensitive areas, or choosing conditions where fire will not penetrate beyond a moisture gradient). Such values must be highlighted on the burn plan so they are brought to the attention of the burn manager.

Fuels

For a detailed discussion see Risk Management and Review Framework for Prescribed Burning Risks Associated with Fuel Hazard (AFAC 2015a).

Fuel hazards are considered at strategic planning right through to burn implementation. At the operational planning level, fuel hazard considerations include:

- fuel type and variability within the burn area
- fuel quantity and hazard level variability within the burn area
- anticipated fuel availability (determined by fuel moisture content) within the burn area
- how slope and lighting patterns will affect fire behaviour in 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.

There are a number of field guides in use which can aid visual assessment of fuel hazard. It is important to be aware that these guides have their limitations and that interpretation of results can vary between operators. Consult with experienced operators where possible. It is recommended to assess fuel at a number of locations through the burn site and adjacent to the burn site, that account for the variability of fuel within the area, or that target particular locations where additional information is needed (e.g. next to houses, or in an area of particularly high fuel).

Some of the methods of assessment for fuel in different fuel types across Australia are presented in Table 12 below.

Table 12: Examples of assessment methods used for different Australian fuel types

Fuel type	Assessment methods
Forest	Overall Fuel Hazard Assessment Guide (Hines *et al.*, 2010) Overall Fuel Hazard Guide for South Australia (DENR, 2011) Also: • Local field guides and field surveys • LiDAR
Grassland	North Australian Grassland Fuel Guide (Johnson, 2002) Also: • Satellite imagery • Local field guides and field surveys
Buttongrass	Fire Modelling in Tasmanian Buttongrass Moorlands (Marsden-Smedley and Catchpole, 1995)
Mallee heath	Overall Fuel Hazard Guide for South Australia (DENR, 2011) Also: • Local field guides and field surveys

Field guides are generally used as a visual aid to assess fuel characteristics, variability and condition:

- across the burn area, so that appropriate ignition patterns and sequences to achieve objectives and desired fire behaviour can be planned
- in areas adjacent to the burn, so that appropriate containment-line requirements can be identified and contingency requirements planned in the event of burns escaping.

Methods of fuel assessment and using the outcomes from the fuel assessment to predict fire behaviour is covered in detailed in Sections 10 and 11.

Activity 13.3

Identify the fuel assessment system used in your area.

Conduct a fuel assessment in nearby bushland where possible.

Operational safety

For more information see Section 5. For a detailed discussion, please refer to *A Risk Framework for Operational Risks associated with Prescribed Burning* (AFAC 2016c).

Prescribed burning has inherent risks and hazards. Any prescribed burn presents some threat to the safety of:

- personnel managing and conducting the burn
- people near the burn
- assets within or near the burn
- people perhaps some distance from the burn who may be affected by heavy smoke.

A comprehensive risk assessment should be undertaken of the burn area and surrounds that may be influenced by fire, smoke and the activity of firefighting resources. Proposed means to treat the risks should be identified.

As part of the planning process, it is important to identify safety measures such as:

- suitable conditions under which to undertake the burn
- containment lines
- contingencies (for complex burns) to ensure a timely and coordinated response if an emergency occurs. Contingencies may include:
  - safety zones
  - escape routes
  - standby resources
  - first aid
  - ambulance locations
  - medevac procedures
  - communications
  - fall back control lines.

In addition to the above, it is necessary to identify potential safety hazards that are specific to the burn and burn site.

Potential hazards to burn crew safety could include:

- hazardous trees near control lines
- falling rocks from unstable slopes above control lines
- overhead powerlines within burn area
- unmapped cliffs or old mine shafts in lighting areas
- traffic hazards during ignition, patrol and mop-up.

Potential hazards to the public include:

- the public unexpectedly within the burn area
- neighbours and adjacent land/users and visitors
- road network, public transport and utilities within potential fire/smoke impact area
- smoke sensitive values, people and communities
- residual safety hazards (such as dangerous trees, re-ignition sources or unburnt escape-risk areas next to containment lines with public safety risks).

Traffic hazards may arise from the condition of tracks on the site, one-way systems, steep or slippery areas, or members of the public unexpectedly present on roads or tracks. Traffic hazards are exacerbated by smoke impacts and if crews are feeling pressured or hurried.

Where the above issues are likely to be a concern within or near the burn area under consideration, these should be identified in the burn plan.

Smoke

For a detailed discussion see *A Risk Framework — Smoke Hazards and Greenhouse Gas Emissions* (AFAC 2015b).

Smoke generated from a burn may create a substantial hazard or public nuisance under some circumstances, and may be subject to legislated requirements that must be considered when planning any burn.

Potential smoke hazards may include:

- road and transport safety
- public health, e.g. people with respiratory conditions
- ventilation facilities for transport tunnels or mines
- industries such as bee keeping and grape growing.

Wind direction requirements may need to be identified in the weather component of the burn prescription.

Smoke impacting on roads is a significant safety hazard. Several fatalities have occurred as a result of smoke from a prescribed burn causing traffic accidents. Overnight inversions during stable weather can cause smoke to settle over roads and significantly reduce visibility. Traffic control plans may be required where there is likely to be an impact on traffic.

Smoke may also impact on various forms of agriculture and industry (refer to 'Smoke' in Section 5).

Activity 13.4

Describe the risk assessment process your agency uses for operational burn planning. Identify and describe values which will require some degree of protection during a proposed prescribed burn in your area.

Burn consultation

Consultation should be undertaken with both internal and external stakeholders.

Internal

Some agencies, particularly those with land-management responsibilities, have a requirement for internal consultation with specialised staff to confirm that all values and risks have been appropriately identified and comply with specific organisational policies and procedures. This is particularly the case with regard to biodiversity and cultural heritage experts. Check if your agency has its own protocols.

External

Consultation with neighbours and external stakeholders should be undertaken during the planning process to provide opportunity to incorporate any additional issues, local knowledge or specialist insights into the burn plan. In some cases neighbours may be interested in incorporating part of their property into a burning operation, which may provide better access options and improve burn outcomes.

Identify anyone who may be potentially affected by the proposed burn including:

- neighbouring property owners or tenants
- traditional owners
- other land management agencies, e.g. local councils, main roads, environmental protection authorities
- relevant emergency services, e.g. urban and rural fire authorities
- lessees, contractors, tour operators with an interest or permit to operate in or adjacent to the burn area
- utility managers, e.g. telecommunications, electricity and water supply
- special interest groups.

Identification and contact details for property owners may need to be obtained from local government, and details of leases or permits affecting public land may need to be obtained from relevant government agencies. These processes can be time consuming and must be planned well in advance of the likely burning period.

Suggested process for consultation:

1. scope out the requirements for consultation and/or negotiation, and consider what outcomes are sought as a result of consultation
2. provide opportunity for neighbours and stakeholders to identify issues
3. document consultation outcomes and record in burn plan if relevant
4. communicate back to neighbours and stakeholders.

Most agencies have consultation policies and processes related to prescribed burning and some require the development of community engagement plans, at least for some burns. In many cases, consulting during the planning phase is far more efficient than dealing with potential conflict issues, or having to undertake hasty protection measures during the implementation phase, or resolving issues after the event.

Key decision point

Is a burn still needed at this location? Is a review of the burn intent and characteristics needed?

Decide whether the burn is operationally feasible/practical.

Decide which risks require control measures to take forward to the next stage (you may need to document your choices).

Section 13 summary

- Operational planning requires an assessment of the burn site and its values, hazard and risks to be able to make informed decisions on the burn execution and risk-treatment requirements.
- Seek personnel with operational experience to verify the burn boundaries and whether it is feasible to contain the burn within this area using available control lines.
- Topography within and surrounding the burn area is an important consideration in planning ignition patterns, anticipating variations in the fire behaviour during the prescribed burn, and contingency planning in the event of escape.
- Prescribed burns have the potential to impact on a range of values and assets within and adjacent to the burn area, such as infrastructure, cultural-heritage values, amenity values, utilities, commercial land use and biodiversity values.
- Hazard assessment should be undertaken to identify and predict potential hazards for:
  - fuel
  - burn crews
  - public safety
  - assets/values within or near the burn area
  - smoke-vulnerable values.
- Smoke from a burn may generate a substantial hazard or public nuisance under some circumstances, and may also be subject to legislated requirements that must be considered when planning any burn.
- Consultation involves identification of all relevant stakeholders who may potentially be affected by the proposed burn.
- Most agencies have consultation processes and policies related to prescribed burning.

Self-assessment questions

1. Why is it important to verify the prescribed burn boundaries?
2. What types of feature will need to be examined when examining potential burn boundaries for suitability?
3. Nominate three reasons why the identification of preferred control lines at the burn site must be undertaken at an early stage during the burn preparations.
4. Why is it important to identify different land tenure within or near the proposed burn?
5. What are the main components of a hazard assessment for prescribed burning?
6. What are three potential hazards to burn crew safety?
7. What are the possible adverse effects of smoke from prescribed burns?
8. Who should be consulted when planning a prescribed burn?

Section

14

Planning burn execution and risk-treatment requirements

The second stage of operational planning is documenting (usually in a burn plan template) the information needed by the burn manager to:

- prepare for and undertake the prescribed burn safely
- achieve the burn objectives
- minimise the risk of adverse impacts.

Predicting desired fire behaviour

It is essential that the burn planner understand the relationship between desired fire behaviour, burn objectives, prescriptions and ignition strategies. Review Section 11 on fire behaviour, and taking account of variability of fuel types, fuel characteristics, topography, any staging and timing requirements consider the type of fire behaviour desirable to meet the objectives of your burn. Following this it is recommended that the burn planner:

- Use the information gained from determining desired fire behaviour, to refine measurable burn objectives (see below).
- Use the information gained from determining desired fire behaviour, to help determine of suitable weather prescriptions (see below).
- Use the information gained from determining desirable fire behaviour to guide the development of ignition strategies that would be suitable to meet burn objectives (see below).

Smoke considerations

The operational burn plan should identify whether there are values/assets vulnerable to smoke such as airports, hospitals, major residential areas and/or roads. Some key considerations for smoke management in relation to meteorological outlooks include assessing:

- relevant smoke management prescriptions including wind direction that will direct smoke away from smoke-vulnerable values
- weather conditions to avoid (inversion layers and unstable conditions) and in some cases minimum fuel moisture thresholds
- possible ignition patterns or timing which will promote fire behaviour that may minimise smoke production
- whether smoke is likely to sink and pool at surface level overnight
- other fire activity in the area and consideration of the cumulative impacts of smoke (some jurisdictions have a maximum threshold for air quality pollutants).

BoM can assist in predicting smoke trajectories, and the Bureau has smoke models (both for plume distribution and vertical (aeronautical) temperature models that can assist in identifying inversion layers) to assist decision-making in smoke management. These are available via its registered users webpage: **reg.bom.gov.au/general/reg/smoke/index.shtml** with tabs for each state.

Be aware that use of these models assumes a certain level of understanding and skill and some training may be required.

Identifying/refining measurable objectives

Strategic objectives (sometimes expressed as fire management zones) relevant for the burn area will provide guidance as to the type of objectives required. In some agencies, nominated burn areas are assigned standard or generic objectives during the program planning stage. For any burn area, it is vital to ensure that the burn objectives are suitable, realistic and measurable. It is therefore important to identify/refine site-specific objectives after taking into consideration a detailed assessment of the values, hazards, risks, and anticipated and desired fire behaviour at the site.

It is usual for a complex burn to have more than one objective. Different objectives are sometimes identified for different purposes (e.g. mitigation, ecological) or for different vegetation types (e.g. to exclude fire from rainforest, to burn 40—60% of fire adapted vegetation). Refer to 'objectives' in Section 2. In almost all cases, defining the objective will also define the type of fire behaviour required. In operational burn planning, the objective should be measurable as in Table 13.

Activity 14.1

Find the strategic-level plan for an area that you are familiar with. Consider one of the stated objectives or fire management zones, and prepare a measurable objective suitable for use in a burn plan.

Table 13: Examples of measurable objectives matched to fire behaviour

Strategic objectives	Measurable objectives	Desired fire behaviour	
		Flame height (m)	Rate of spread (m/hr)
Protect adjoining assets from high intensity bushfire	Reduce overall fuel hazard rating to moderate or low, over ≥ 90% of the burn area, with ≤ 10% crown scorch	< 1.5	< 60
Provide a strategic corridor to substantially mitigate the spread of bushfire	Reduce overall fuel hazard rating to moderate or low over ≥ 70% of the burn area.	1.5—2.0	60—80
Maintain healthy ecosystem	A 30—60% spatial mosaic of burnt patches in the target area	< 1.5	< 60

Identifying/refining prescriptions or constraints for burning

Planning should ensure a level of fire behaviour that delivers the burn objective, while allowing the burn to remain under control.

Some of the factors which govern fire behaviour, such as topography, fuel type and fuel arrangement are fixed for any particular burn. Others, such as weather and fuel availability (as determined by moisture content), are quite variable and can be prescribed by the burn planner.

Burn prescriptions are the acceptable limits of factors that will have an important influence on fire behaviour and objectives of the burn. Factors for which limits are commonly specified for prescribed burns are:

- temperature
- relative humidity
- wind speed and direction
- Drought Index (or soil dryness index)
- Fire Danger Index on the day, and sometimes subsequent days
- fuel moisture content (of target fuels and sometimes of non-target fuels).

Standard prescriptions that stipulate upper and/or lower limits for these factors have been developed by some agencies for typical fuel types, but these will vary greatly between different climatic zones (see Table 14). Burn prescriptions can sometimes be quite broad and may require refinement to meet your objectives.

Some agencies require the burn planner to be quite specific with regard to prescriptions and ignition strategies and expect the burn planner to record their justification and thinking with regard to these. Other agencies prefer that prescriptions and ignition strategies be broad, in order to allow greater windows of opportunity for burning and also to allow the burn manager to select the best ignition strategies to suite the conditions on the day of burn. These agencies may require justification for variations from standard prescriptions.

Table 14: Examples of standard prescriptions from Victoria, Queensland and South Australia

Fuel type	FDI/GFDI (max)	Temp (°C)	RH (%)	Wind (km/hr @ 10 m in open)	KBDI	Fine Fuel Moisture Content (%)
Dry sclerophyll forest (without wiregrass) **VIC[1]**	FDI: 10 Day 2 <12	18–27	35–70	<20	<50 or <120 (if fallen ≥30 from summer max)	Fuel Reduction Burn (surface fuels): 9–16 Slash inside coup: <14 Slash outside coup: >16
Healthy tussock grass dominated eucalypt communities **QLD (Gulf Plains)[2]**	GFDI: 18	Not specified	Not specified	<23	80–100	Not specified but good soil moisture emphasised
Semi-arid mallee and mallee-heath **SA[3]**	N/A (Fuel hazard rating L or M)[4]	20–40	10–60	25–50	Not specified	5–10 Dead FMC near-surface

Figure 41: Assessing the results of a test burn (Source: DPAW, WA)

[1] DELWP 2012. *Fire Management Manual 10.1.* Melbourne, Victoria.

[2] NPRSR 2013. *Planned Burn Guidelines – Gulf Plains Bioregion of Queensland.* Department of National Parks, Recreation, Sport and Racing, Brisbane, Queensland.

[3] DENR 2011b. *Prescribed Burning in South Australia: Review of Operational Prescriptions.* Department of Environment and Natural Resources, Adelaide, South Australia.

[4] DENR 2011a. *Overall Fuel Hazard Guide for South Australia.* Department of Environment and Natural Resources, Adelaide, South Australia

Irrespective of the approach taken, there are a range of circumstances for which prescriptions may need to be refined from a nominated standard prescription. For example, there is a relationship between fuel hazard or fuel load and determining suitable weather prescriptions. If the fuel hazard or fuel load is high, it is likely that the burn planner will have to nominate milder conditions under which to ignite the burn so that the fire behaviour can stay safely within desired parameters. If the fuel hazard or fuel load is low or the fuel discontinuous, it may be necessary to specify higher wind speed, or lower humidity etc. There may be a range of other reasons why a burn planner may wish to nominate more specific prescriptions such as for rehabilitation burns, for ecological burns that aim to promote or reduce a particular species or for burns that have a high degree of risk associated with them.

Activity 14.2

For a prescribed burn in your locality, determine whether there are any standard prescriptions used by your agency, and define the parameters that are most relevant to safely meet the objective of the burn.

In addition to prescriptions, the burn plan may nominate site-specific constraints, e.g. a wind direction to be avoided. This may be important given the desired sequence of ignition, especially if topography is a significant issue or smoke hazard must be avoided. However, be aware that the more specific the conditions, the narrower the burning window (reducing opportunities to burn) and the less flexibility the burn manager will have on the day to respond to local conditions — potentially increasing the burn risk.

The timing for the burn also needs to be assessed against the expected site and seasonal conditions. Consider whether the burn area can be treated in a single event, or if the size and/or complexity of fuel types and their conditions will require a staged burning approach, e.g. targeting open grass-dominated sections first as these dry out earlier in the season; or establishing an edge burn in milder conditions prior to the main burn, in order to improve containment.

Identify and document any constraints to achieving your objectives, e.g. fuel types that may be difficult to ignite or control.

Figure 42: Mosaic burning (Source: DEWNR, SA)

Planning risk controls

It is emphasised again that the primary risk control strategies for containing burns are:

- burning under suitable conditions
- having appropriate control lines
- selecting the right lighting patterns
- resourcing the burn appropriately
- completing pre-burn risk mitigation works, where necessary, such as removal of hazardous trees.

Despite the above, there may be risks at the site that cannot be satisfactorily addressed by burning under suitable conditions with appropriate control lines. It is necessary to identify these risks in the burn plan and to identify suitable risk mitigation strategies. A number of strategies can be used to reduce risk; however, in a prescribed-burn planning situation, it is usually not possible to avoid risk altogether. Many agencies are developing risk rating tools so that the level of risk can be rigorously assessed and understood (if not totally avoided). Use of correct safety procedures and personal protection equipment form part of a successful risk management system; however, because these are usually specified as standard for all burns in agency policy it is not usually necessary to include them in individual burn plans. Rather, the burn plan should include risks peculiar to the burn site and surrounding area.

Activity 14.3

Determine whether there a prescribed burn risk rating procedure used by your agency. Obtain a prescribed burn plan or use the example in Review Activity 1 of this document, and rate the risk of the burn using your agencies risk rating procedure.

Examples of actions to reduce the level of risk to values within and surrounding the burn area are included in Table 15.

Possible actions to reduce the level of risk to fire crews operating in the burn area include identification of hazards on operational maps, using specialist staff, and amending fire behaviour prescriptions or ignition patterns to reduce fire intensity. Some examples are provided in Table 16.

Escape routes and safety zones for burn crews should also be identified and their suitability checked in the field prior to the day of the burn. Any work required to enhance them will need to be scheduled in advance of the likely burning period.

Table 15: Examples of values at risk and methods to minimise risk

Values at risk	Nature of risk	Methods to minimise the impact on values
Commercial timber production	Scorch, especially of apical tips of plants	Burn with low-intensity backing fire to promote reduction of understorey fuels while limiting scorch.
Fire-sensitive vegetation communities (e.g. dry rainforest)	Unintended encroachment of fire	Burn surrounding areas with low-intensity backing fire away from the margins of the fire-sensitive community. Burn with good soil moisture to reduce risk of encroachment.
Cultural heritage site (e.g. indigenous rock art)	Impact from flames, radiant heat or sooty smoke	Manual reduction of fuel around site, e.g. brushcutting, raking or leaf blowing. Burn away from site with low-intensity backing fire. Use a wet line around the site. Burn in conditions where smoke will be carried away from rock art.
Flammable peat soils in wetland communities	Ignition of peat	Burn adjacent fire-adapted communities when peat is waterlogged. Use ignition patterns and tactics to burn away from non-target community.
Damaging impacts to vegetation community from burning high-biomass invasive grasses	Unintentional ignition of invasive grasses leading to high fire intensities	Seek specialist advice on invasive-grass management before burning. Ensure good soil moisture to limit opening of bare ground and further encroachment of weeds. Plan for vehicle hygiene/wash-down areas at/near burn site.

Table 16: Examples of hazards to fire crews and public and methods to minimise risk

Hazards to fire crews	Methods to minimise the impact of hazards
Areas of elevated fuels	Prescribed fuel moisture content (FMC) raised. Prior ignition under very mild conditions considered. Remote ignition techniques considered.
Public present at burn site	Use of appropriate signage, notifications and checking the burn area for public presence prior to ignition
Communications black spots	Radio repeater station or radio relay point established.
Variation in aspect, slope or vegetation	Crews briefed on likely changes to fire behaviour, modify ignition pattern.
Traffic on control lines	Identify any dead-end and/or one-way tracks, location of passing bays and turn-around areas, unexpected presence of public vehicles on fire control lines.
Trees with hazardous bark adjacent to control lines	Identify sections on map that may present a spotting hazard. Brief crews on risk of spotting and sections to monitor.
Hazardous trees	Identify trees that pose a risk of falling or pose a risk of falling branches during or after prescribed burning operations.
Powerlines, gas pipelines etc.	Exclude from burn area if possible. Prescribe wind conditions to avoid smoke through powerlines. Notify utility companies.

Planning notifications, consultations and warnings

Notifications, consultations and warnings will need to be included as part of the burn plan. These are typically divided into two groups: the notifications, consultations and warnings that need to be undertaken in the days prior to a burn, and the notifications and warnings that need to be issued on the day the burn is to take place.

Days prior to burn

In some circumstances, particular notifications are required by law. Regardless of this, an essential part of planning is to identify all those persons and organisations that are relevant to the burn and arrange for timely, adequate notification. Most agencies have standard checklists for notifications and some require the preparation of notification plans.

Advanced notification of burning often occurs via media outlets (local papers), the internet, and, as the day of the burn approaches, text messaging systems or letter-box drops. This will depend on agency procedures, technologies and protocols. Community concern can often be minimised with targeted notification strategies.

Day of burn

In a burn plan, it is usually necessary to highlight to the burn manager any day-of-burn notifications that need to take place. This may involve contacting neighbours and/or installing signage on and near the boundary of the burn area.

Most agencies will have a day of burn checklist, but having a pre-prepared list of contact names and phone numbers in or attached to a burn plan will ensure that all relevant persons and organisations are contacted.

Planning burn execution options

Whilst it is important to decide and document options for burn execution, there also needs to be a large degree of flexibility for the operator on the day to adjust options to suit conditions.

Ignition options

The choice of ground or aerial ignition techniques will depend on factors such as:

- size of the proposed burn
- fuel characteristics
- topography (especially slope)
- desired fire behaviour (to meet objectives)
- accessibility
- availability of resources.

Aerial ignition is best suited to large burns, burns with difficult access or for ignition of multiple burns in one day.

Ignition theory

Ignition patterns can have a big influence on fire behaviour by affecting:

- rate of spread
- total burnout time
- incidence of junction zones, and thus
- flame height and fire intensity.
- choice of lighting pattern will be determined mostly by:
- the desired fire intensity
- the dryness of the fuels
- the effects of wind and slope.

For complex burn operations, variations within a burn area in fuel-load strata and FMC due to fuel type, location or aspect may require separate ignitions a number of days, or even weeks, apart. Separate ignitions may be scheduled to assist burn security by edge-burning hazardous fuels adjacent to control lines, or normal fuels adjacent to a critical or vulnerable control line, under milder conditions where fire intensity will be less.

Further detail on ignition patterns is provided in Section 12.

Figure 43: High-biomass grasses greatly increase fire intensity (Source: Department of Land and Resource Management, NT)

Although it is usual to plan ignition strategies in advance of the burn, allowing the burn manager the flexibility to adapt ignition patterns on the day of the burn in response to the conditions on the day and site variability is essential. Such adjustments will need to be made on an ongoing basis during the burn. Nonetheless, broad ignition options can be planned, and specific strategies might be identified for certain *burns* where there are specialised outcomes sought, or particular/unusual constraints.

Planning command structure if required

When conducting complex prescribed burns, a chain of command structure using AIIMS (Australian Inter-service Incident Management System) principles is recommended by all agencies.

It may be desirable, for complex burns, to plan in advance for sectorisation of the burn, especially if different crews in different locations are required to successfully ignite and monitor the burn. Identification of sectors should be based on logical and identifiable boundaries that assist in command and control of the burn operation. Sectors assist in fireground communications by allowing for easy identification of locations for tasking, situation reports or in emergencies. They assist in maintaining the AIIMS span of control through grouping of resources.

AIIMS theory

A strong chain of command should be established at the burn to manage all resources. This may be best done by adopting a command structure consistent with the Australian Inter-service Incident Management System (AIIMS; AFAC 2013):

- Some land management agencies undertaking a program of prescribed burning may do this by appointing the burn manager to act in the role of Operations Officer, and having an Incident Controller monitoring the project of the burn from an appropriate administrative centre, also providing planning and logistical support.
- Alternatively, an agency might choose to nominate the Officer in Charge at a burn site act as the Incident Controller.

Further details are provided in *Part 2: Prescribed burn theory.*

Planning management of the public

It is often necessary to plan for specific traffic-management outcomes, and sometimes for management of the public or media, if these are expected to be an issue for the burn. Some agencies may require the preparation of traffic management or media plans to accompany, or as part of, the burn plan. Check if your agency has standard procedures or templates.

Planning resources

Burn planning must account for resources and equipment to:

- prepare for the burn, e.g. maintenance/preparation of control lines, field assessments, consultation
- ensure adequate equipment and personnel are available
- implement the burn safely (considering ignition techniques)
- implement mop up and patrol of the burn
- cater for contingencies to ensure that additional resources can be called upon in the event of worse-than-expected fire behaviour and escapes.

Planning in advance is essential for specialised or technical roles or equipment, particularly those involving aircraft, which may require staff and/or specialised equipment from outside the local area. Cooperative scheduling with other burn planners may be necessary to ensure their availability.

In the planning phase it is essential that necessary skills, competencies and accreditations be identified so that appropriate personnel are available during the burn. Planning must ensure that all personnel are competent/accredited for the roles or tasks likely to be assigned to them.

Sufficient additional resources should be identified to ensure:

- crew management including rest breaks and safety provisions, shift rotation and catering where required
- management of public safety including clearing the site prior to the burn, and controlling movement around the burn site on the day
- execution of signage and notifications
- availability of staff to monitor and report on the burn
- traffic management, including organisation of specially trained staff or traffic-control contractors where necessary.

Figure 44: Taking fuel moisture readings (Source: DEWNR, SA)

Planning post-fire evaluation

Most agencies have procedures or guidelines for post-burn evaluation, monitoring and reporting.

Evaluation and monitoring can take different forms, and many agencies make a distinction between these, as each has quite different requirements in terms of the design, effort and the rigour required. The different forms include:

- **evaluation** of individual burns (usually quick and simple techniques focused on evaluating the success of individual burn objectives)
- **monitoring** of longer-term trends and condition (usually requires photo plots or recording data over a period of years)
- **research** to answer specific (and often narrow) questions (usually scientifically designed experiments suitable for statistical analysis).

The burn plan should focus on evaluation of individual burn objectives, and many jurisdictions require some information on how the measurable objectives of a burn will be evaluated in the field.

It is necessary that those planning or implementing burns are made aware of the presence of monitoring or research sites within the burn area, as there may be consequences to monitoring or research programs, areas that need to be avoided, or opportunities that can be followed up. It may be important to notify those conducting monitoring or research of the intention to burn the area.

We will return to the topic of post-fire evaluation in Section 20.

Preparing the map

Most burn-plan templates have a checklist for map preparation which may specify essential information, such as:

1. identifying name/title of burn
2. area(s) to be burnt (including order if staged)
3. fire control lines (with labels)
4. escape routes and safety zones
5. vegetation
6. values, assets and infrastructure
7. fall-back control lines (if used).

Additional information (where relevant) may include the following items (which may be displayed on a separate operational map):

1. ignition point(s)
2. fire history information
3. neighbours
4. topography
5. reserve boundary
6. access routes (with distances)
7. crew locations
8. water points.

Key decision point

Decide on and document the burn plan in accordance with agency procedures

Activity 14.3

For a proposed prescribed burn in your area, develop a list of the resources necessary to execute the burn plan. Explain the procedures to be used in your organisation to obtain resources from outside your immediate area.

Section 14 summary

- Burn planning needs to be based on a well-considered assessment of the likely fire behaviour within the burn area and surrounding the burn area if it escapes.
- Fire behaviour at prescribed burns will be influenced by variations in fuel, weather and topography, and by choice of ignition pattern and technique.
- It is vital that the operational objectives of any proposed prescribed burn are clearly identified, since, in most cases, defining the objective will also define the type of fire behaviour required.
- Burn prescriptions are the acceptable limits of factors that will have an important influence on fire behaviour and objectives of the burn. Standard prescriptions have been developed by some agencies for typical fuel types, but these will vary greatly across different climatic zones.
- Factors commonly specified for prescribed burns are:
  - temperature
  - relative humidity
  - wind speed and direction
  - atmospheric stability
  - Drought Index
  - Fire Danger Index
  - Fuel Moisture Content.
- Burn-related risks need to be identified, analysed and evaluated. If the risk level is not acceptable, risk treatment actions need to be put in place to reduce risk to an acceptable level.
- Hazard assessment should be planned for:
  - burn personnel
  - people near the burn
  - assets within or near the burn
  - areas possibly affected by smoke.
- Escape routes and safety zones for burn personnel should be identified in advance.
- Most agencies have standard checklists or requirements for notifications of neighbours, stakeholders and the general public. Including a list of notifications within or attached to the burn plan will assist the burn manager in ensuring notification requirements are met.
- Community concern can often be minimised with targeted notification strategies.
- Choice of ignition technique or method (aerial or ground) is governed by:
  - size of burning area and topography
  - fuel and weather factors
  - funding constraints
  - availability of resources
  - the burn objective.

- Aerial ignition is suited to large burns, burns with difficult access and multiple burns in one day.
- Ignition patterns can have a big influence on fire intensity.
- Allowing the burn manager the flexibility to adapt ignition patterns on the day of the burn in response to the conditions on the day and site variability is essential.
- Map preparation should include essential information:
  - identifying name/title of burn
  - area(s) to be burnt (including order if staged)
  - fire control lines (with labels)
  - escape routes and safety zones
  - vegetation
  - values, assets and infrastructure.
- Resource planning should account for the need to prepare for, manage, ignite and control a burn, and deal with contingencies.
- Planning in advance is essential for specialist or technical roles or equipment, particularly those involving aircraft, which may require staff and/or specialised equipment from outside the local area.
- Planning should ensure that all personnel are competent/accredited for the roles or tasks likely to be assigned to them.

Self-assessment questions

1. What are the main factors that will influence fire behaviour?
2. What are burn prescriptions and what are constraints?
3. What factors commonly have parameters set in prescribed burning prescriptions?
4. Why is it important to identify the operational objective of a prescribed burn?
5. What factors can contribute to a prescribed burn escaping control lines?
6. What are some possible actions that may reduce the level of risk to fire crews operating in a prescribed burn area?
7. What information should you include in the 'day of burn' notifications to neighbours and the public?
8. What factors will influence your choice of ignition technique?
9. What information should be displayed on the map in a prescribed burn plan?
10. What are the key functional areas that need to be resourced at a prescribed burn?

Activity 14.2

Complete the Review Activity 1 in the back of this resource.

Section

15

Plan approval and post-burn activities

Preparing for approvals

Burn plans need to be assembled, checked and (preferably) peer reviewed before submission for endorsement and approval. Each agency will have unique legislative and/or organisational requirements for approving burn plans prior to implementation.

It is important to be aware of the range of organisational policies and procedures that affect burn plans, and to check for consistency and compliance with expert recommendations where required.

All material used in developing the burn plan and which does not form part of the plan document may need to be assembled and stored, so that it can be readily accessed in response to queries during the approval process.

Burn plan peer review

The person planning the burn often becomes overly familiar with the subject, so it can be beneficial to hold a local peer review and quality-control process that will review and endorse vetted plans prior to their being submitting for agency approval. In many jurisdictions this process takes the form of a review panel composed of operational personnel (who will provide advice on safety and burn feasibility) and specialist staff (who can assess the plan against risk to cultural-heritage values and ecological imperatives).

Burn plan approval

Burn plans are usually assessed in relation to a checklist or against agency procedures, and persons authorised to approve burn plans will give particular scrutiny to the stated or perceived level of risk, and the treatments (i.e. risk-mitigation) proposed to manage higher levels of risk.

The approver is usually an identified individual/role with the authority to approve the burn, require amendments to the burn plan, or not approve the burn. In some agencies, the level of approval/approver may vary depending on the identified level of risk of the burn.

Approval is endorsement of the plan, and is usually not authorisation to ignite. Authority to ignite is generally given on the day of, or day prior to, the proposed burn, after consideration at the organisational level of the burns in progress and proposed, and the medium-term weather forecast.

Activity 15.1

Describe the procedures in your agency for endorsement and approval of a burn plan.

Key decision point

Is the burn plan approved, not approved or requiring review?

Conducting burn operations

Once a burn plan is approved, advance preparations to ready the site for burning may be scheduled and undertaken. Details of these preparations and implementation of the approved burn plan are addressed in Part D: Conducting complex prescribed burns.

Post-fire activities

Even where personnel involved in planning burn operations are not directly involved in conducting burn operations, there are important post-burn activities that they might participate in, or follow up on, such as post-burn evaluations and reports.

Closing the adaptive-management loop

Adaptive management involves the incorporation of evaluation and feedback processes into planning cycles in effort to improve safety and work practices. To effectively close the adaptive-management loop (Figure 45), it is important that current burn planners and the burn manager are given feedback after the evaluation and monitoring process has been undertaken. Depending on the burn objectives, this process may occur soon after the burn, where results are already evident, but in other cases further evaluations may be required, and the process can be delayed for some months.

In any case, check whether your agency has processes/procedures in place for providing and recording feedback.

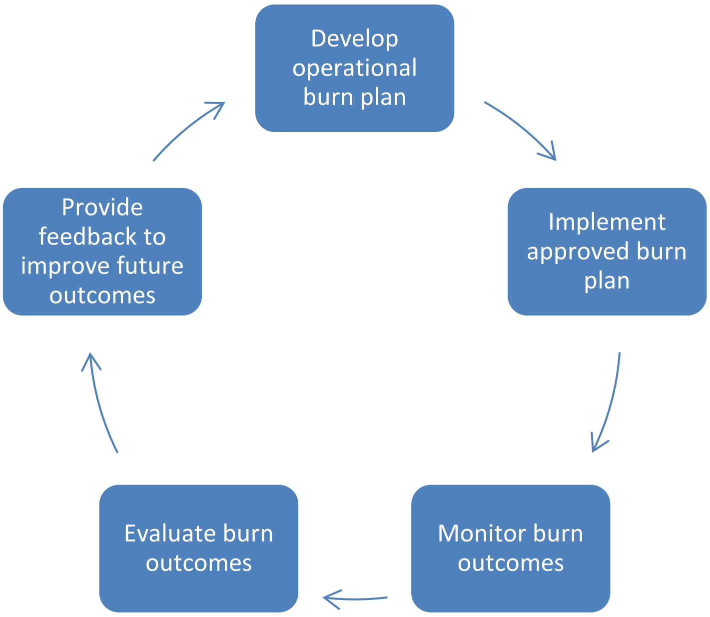


Figure 45: Adaptive-management loop for prescribed burning

Section 15 summary

- Burn plans need to be assembled, checked and (preferably) peer reviewed before submission for endorsement and approval.
- Persons authorised to approve burn plans will scrutinise them according to the stated or perceived level of risk, and the treatments proposed to manage higher levels of risk.
- Approval of a burn plan does not usually constitute authorisation to ignite a burn.
- Evaluation and assessment of burn results against objectives is necessary to determine the success of the burn, any follow-up works required, and to provide feedback for adaptive management processes.
- Collecting feedback from monitoring is important to effectively close the adaptive management loop — by informing future burn plans and burn implementation through evaluation of new knowledge gained (both positive and negative).

Self-assessment questions

1. What steps should be taken to prepare a burn plan for endorsement and approval?
2. What is the purpose of a peer-review process being undertaken within an organisation prior to the submission of a burn plan for approval?
3. What aspects of a plan generally receive most attention by the person with responsibility for approving burn plans?
4. Why is it important to collect and provide feedback on post-burn evaluations?

Activity 15.2

Download and read one of the prescribed burning case studies listed in the Appendix of this document. As you read through the case study, see how many steps you can identify from Part C of this learner resource.

Part

D

CONDUCTING COMPLEX PRESCRIBED BURNS

Outline of the prescribed burning process

Part D details the process of conducting complex prescribed burns and reflects national best practice as presented by the National Guidelines for Prescribed Burning Operations (AFAC 2016a). The steps are outlined in Figure 46 and may be undertaken in slightly different order in different jurisdictions and some jurisdictions may have formal procedures for all or only some of these, with the rest undertaken informally. Irrespective of this, Figure 46 is useful as a reminder of the issues that should be considered for all complex prescribed burns.

Activity 16.1

View the Review Activity in Appendix 1 of this document. It presents a prescribed burn implementation scenario. Think about how you would conduct this burn as you progress through Part D of this learner resource.

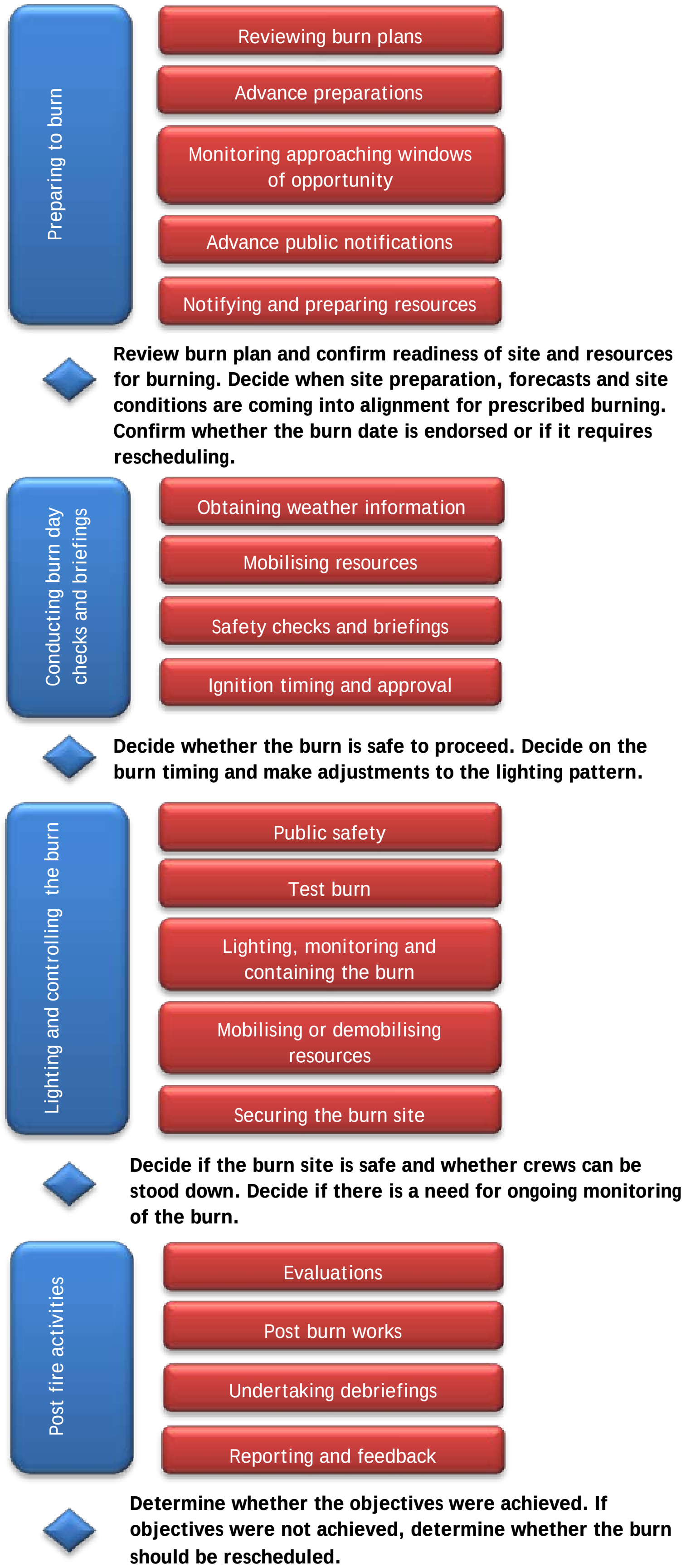


Figure 46: The prescribed burning process

Section

16

Preparing to burn

Once a burn plan is approved, advance preparations to ready the site for burning should be scheduled and undertaken. At this stage it is important to:

- review the burn plan
- complete boundary and other site preparations
- monitor approaching windows of opportunity
- make advance public notifications
- notify and prepare resources
- seek authorisation of burn date.

Reviewing burn plans

Once the development of a complex burn plan has been completed (see Part C), it should contain all the information required for a burn operator to safely and effectively conduct a complex prescribed burn operation.

The burn plan should reflect a logical thought process, and outline the key operational details. Irrespective of your agency or jurisdiction, most burn plans will contain the following elements:

- a statement of burn objectives
- a description of the area, including fuels
- a description of the values including environmental (specific species of concern, fire sensitive ecosystems, etc.), cultural (Aboriginal or European artefacts and places) and built assets/infrastructure (residences, sheds, schools, transmission lines, major roads, etc.)
- a map suitable to assist in undertaking the burn
- prescriptions or limits for fuel and forecast weather conditions
- ignition patterns and techniques
- measures for protection of assets and other values
- resourcing requirements (for ignition, mop up and patrol)

- health and safety issues (for burn personnel and the public)
- contingency planning
- risk assessment
- notifications
- post-burn evaluation requirements
- guidance on implementation.

While burn plans are typically subjected to a rigorous review and approval process, as an officer in charge of conducting a prescribed burn, it is important that you validate the burn plan for yourself and are comfortable in your own mind that:

- you are able and willing to carry out the burn based upon your experience and the difficulty of the planned operation
- the prescriptions, proposed ignition patterns and techniques, resourcing requirements and contingency planning are a correct reflection of the stated burn objectives, required fire behaviour and assessed level of risk.

Key questions you may seek to answer include:

- Has the burn plan been approved?
- Will the burn plan allow you to meet the objectives of the burn?
- Will the burn plan result in a safe operation?
- Is the planned fire behaviour containable?
- Should contingencies be in place in the event of fire escaping?
- Is the difficulty of the burn within your own skill level and that of the crews available?

Activity 13.2

Access the burn plans and post-burn reports from two or three burns previously conducted by your agency (if necessary, solicit assistance to select burns with different objectives and different operational requirements). Compare and contrast the plans, in order to familiarise yourself with the differences in objectives, operational difficulty, identified risk, and risk mitigation and resourcing requirements.

Advance preparations (to make the burn site ready)

Undertaking burn site preparations in advance will enable burning opportunities to be taken when they arise and will contribute to sound risk management. Leaving site preparations to the last minute is poor practice, as this often results in windows of burning opportunities being missed, and windows of opportunity are often quite limited.

Completing preparations for boundary and site

Ensure that the selected control lines for the proposed burn area are trafficable for fire vehicles and where necessary make any improvements, including clearing fallen trees, repairing track wash-outs, marking/establishing passing bays and turn-around areas. Where relevant, the suitability of natural boundaries should be checked to ensure they form an appropriate barrier to contain the type of fire behaviour planned and expected. This may include checking the water levels in creeks and other waterways, checking moisture levels in gullies, and reviewing likely weather conditions and soil moisture levels.

Check your agencies standards for control lines and ensure that the preparations meet the standards and/or ensure you liaise with people with sufficient operational experience.

Check the status of water points intended for use during prescribed burning operations. Check water levels in water tanks, dams and other water bodies and undertake any works to ensure that water points will be accessible during prescribed burn operations.

Figure 47: Preparing to burn (Source: Southeast Queensland Fire and Biodiversity Consortium)

Completing risk-management preparations for values

The burn plan should identify any values and assets that require special attention, and may include methods to protect them during the burn. Some precautionary measures can be made early into pre-burn preparations, such as manual reduction of fuel from around cultural heritage sites, establishing temporary control lines near assets (such as houses) and checking the condition/moisture levels of fire-sensitive vegetation communities within the burn area.

Preparing for access to adjacent properties, escape routes and safety zones

Where access to adjoining properties is required to conduct the burn, previous consultation may have been undertaken with property owners or land managers, but this could have occurred some months prior. In any case, contact should now be made to confirm any conditions of access, check for vehicle trafficability, and where necessary organise keys for locked gates and arrange for control of domestic animals and/or livestock.

Escape routes and safety zones should be checked for suitability and vehicle accessibility and any necessary improvements undertaken, e.g. removal of fallen trees and over-hanging branches.

Managing hazards

Fuel piles resulting from control line establishment or maintenance can create a hazard for the burn crew during the burn and increase the risk of the burn escaping. Such fuel piles may require redistribution or burning separately prior to the main prescribed burn. It may be necessary to identify and manage hazardous trees especially near roadways (and many jurisdictions have procedures for hazardous trees). Also it is important to identify trees with significant bark hazard that pose an escape risk over control lines. In jurisdictions that have significant bark hazard issues, burning off the bark in suitably mild conditions (“candling”) prior to the prescribed burn is common practice.

Crew and public safety are major aspects of managing a burn. For a detailed discussion on this topic refer to *Section 5: Safety*.

Potential hazards to burn crew safety could include:

- hazardous trees near control lines
- falling rocks from unstable slopes above control lines
- overhead powerlines within burn area
- unmapped cliffs or old mine shafts in lighting areas
- traffic hazards during ignition, patrol and mop-up
- areas with elevated fire-behaviour potential, where aspect, topography, fuels, weather could cause an increase in fire behaviour.

Smoke generated from a burn may also create a substantial hazard or public nuisance under some circumstances, and may be subject to legislated requirements in different jurisdictions that must be considered.

Potential hazards to the public could include smoke impacts on:

- road and transport safety
- public health, e.g. people with respiratory conditions.

Monitoring approaching windows of opportunity

To anticipate the arrival of suitable burning conditions, it is important to:

- monitor meteorological outlooks
- consider smoke management in relation to outlooks
- monitor site preparations
- monitor site fuel and moisture conditions
- monitor the fire behaviour of bushfires or prescribed burns in the area.

Monitoring meteorological outlooks

The Bureau of Meteorology (BoM) provides a national range of web-based fire weather forecast material to registered users in each state or territory through their website: **reg.bom.gov.au/reguser/** [validated 8 Sept 2016]. Local 7-day forecasts for grid locations are provided on Meteye™ **reg.bom.gov.au/australia/meteye/** [validated 8 Sept 2016].

Trends in indices such as Drought Index (or Soil Dryness Index) and Fire Danger Index (see Section 10) can be observed by daily monitoring. If Drought Index is not calculated at your work location, some idea of local values may be obtained from the BoM fire weather forecasts (the ‘fire weather estimates'), where Keetch-Byram Drought Index values are recorded for the representative forecasting stations.

As an aid in determining suitable burning weather, it is also useful to monitor broad scale synoptic trends. Synoptic situations to avoid on the day of the burn, and immediately after the burn, may include:

- frontal systems, usually accompanied by instability, abrupt wind changes, and wind gustiness
- generally unstable air masses (more likely in low pressure systems than high pressure systems) which will promote stronger convection of fires
- circumstances likely to cause major changes to wind direction and strength
- the presence of inversion layers, under which smoke may become trapped.

Smoke considerations

The operational burn plan should identify whether there are values/assets vulnerable to smoke such as airports, hospitals, major residential areas and/or roads. Some key considerations for smoke management in relation to meteorological outlooks include assessing:

- relevant smoke management prescriptions including wind direction that will direct smoke away from smoke-vulnerable values
- weather conditions to avoid (inversion layers and unstable conditions) and in some cases minimum fuel moisture thresholds
- possible ignition patterns or timing which will promote fire behaviour that may minimise smoke production
- whether smoke is likely to sink and pool at surface level overnight
- other fire activity in the area and consideration of the cumulative impacts of smoke (some jurisdictions have a maximum threshold for air quality pollutants).

Figure 48: Smoke plume (Source: Office of Bushfire Risk Management, WA)

BoM can assist in predicting smoke trajectories, and the Bureau has models (both for plume distribution and vertical (aeronautical) temperature models that can assist in identifying inversion layers) to assist decision-making in smoke management. These are available via its registered users webpage: **reg.bom.gov.au/general/reg/smoke/index.shtml** with tabs for each state.

Be aware that use of these models assumes a certain level of understanding and skill and some training may be required.

Many jurisdictions will need to liaise with their local pollution control agency with regard to smoke considerations and some jurisdictions impose limitations on burning in some conditions.
Monitoring site preparations

Favourable conditions for burning will need to coincide with completion of site preparations. Burning before preparations are complete may reduce burn security and increase risks to values and crew safety.

Monitoring site fuel moisture conditions

Trends in fine fuel moisture content are critical in anticipating suitable burning conditions.

Fire behaviour theory

Fuel moisture content (FMC) is the proportion of free and absorbed water in the fuel expressed as a percentage of the oven-dry weight of the fuel (%ODW).

FMC is fundamental to determining whether fuels burn, and if so, how rapidly (and intensely). The distribution of moisture in fuel beds also determines the proportion of fuel available to burn. Prescribed limits on fine fuel moisture content will depend on the nature of fire behaviour desired (as dictated by the burn objective), and other site factors such as the typical fuel arrangement.

FMC can be measured or monitored in a variety of ways in different jurisdictions including: predictions from temperature and RH, in-field moisture meters, fuel analogues such as hazard sticks or hazard bags, by oven-drying fuel samples, or estimates from a burning leaf test (see Figure 49).

The burning leaf test provides a simple and quick estimate of FMC from the angle at which a cured eucalypt leaf from the litter layer burns. The angle to which a burning leaf is tilted so that combustion is just sustained will depend largely on the leaf's moisture content.

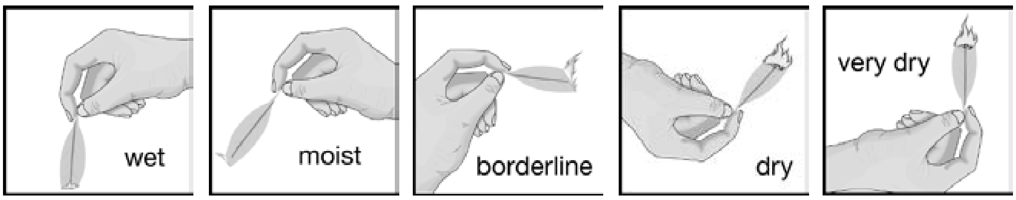


Figure 49: The burning-leaf test

Further detail is provided in Section 11: Fire behaviour, under the heading 'Fuel moisture content'.

Activity 13.3

For a proposed prescribed burn in your locality, describe how you would monitor weather and fuel conditions in the lead up to the likely burning period.

Advance public notifications

Most agencies will have standard checklists for notifications. In some circumstances, notifications will be required by law so check agency policy or protocols. Regardless of this, all those persons and organisations that have an interest in the burn area should be notified. They include those who may:

- have an interest in the area to be burned (Traditional Owners, special interest groups, management committees and researchers)
- have an interest in adjacent land to which the burn could possibly spread (private landowners, other land managers)
- have an interest in managing the consequences of the burn, (for example, fire brigades who may be called upon to assist or who may be contacted by the public, police who may be required to assist with traffic management, local government bodies who may have to field enquiries from the public, Environment Protection Authorities who may be concerned with smoke issues)
- have an interest in specific assets possibly affected by the burn, for example, utilities such as electricity providers
- be generally concerned by evidence of the burn, for example the general public alarmed by heavy smoke
- reside nearby and who need to mitigate against smoke, e.g. hospitals.

Neighbours

Notification to neighbours may be a legal requirement but regardless should be made prior to the day of burn as a matter of courtesy. Where there is a legal requirement, a written record of notifications should be made which may be as simple as a work diary entry.

Media, web, SMS

Advanced notification of burning often occurs via signage (incl. roadside electronic signs), media outlets (esp. local papers), the internet and as the day of burn approaches, text messaging systems or letter box drops. This will depend on agency procedures, technologies and protocols. Community concern can often be minimised with targeted notification strategies.

Notifying and preparing resources

Early notification as soon as favourable conditions are identified will help ensure that resources are available and ready when required.

Notify burn manager, burn crew and containment crews

In some jurisdictions there may be competition for available resources and these will be prioritised according to the importance of the burn and the level of preparedness.

If specialist or technical staff or equipment are required (e.g. aircraft, aerial incendiary operator), cooperative scheduling with other operational staff or contractor bookings may be necessary to ensure availability.

Preparing traffic and public management

Where main road traffic will be affected by the burn, permits for traffic control may be required from road management authorities, and specially trained staff or traffic control contractors will need to be arranged. Signage may need to be installed on public access roads likely to be impacted by the burn, particularly if there is likely to be traffic delays or detours on the day of burn.

Prepare contingency resources

Availability of additional resources may need to be confirmed as a contingency, in the event of worse-than-expected fire behaviour and escapes. These requirements should have been identified in the burn plan.

Authorise the burn day

Each agency will have unique legislative and/or organisational requirements for authorising burns.

Burn authorisation is usually given by an identified individual/role within each agency. This authorisation is usually to gain consent for the scheduled burn date. It is **not** usually the authority to ignite the burn. Authorisation is usually to ensure resources will be available to undertake the burn on the day proposed and that the preparations identified in checklists are complete. It is wise therefore that those seeking approval are aware of any checklists and have addressed all of the issues.

Section 16 summary

- Validating the burn plan ensures that the person in charge feels confident that they can safely deliver the burn and at the same time meet the burn objectives.
- Undertaking burn site preparations in advance will enable burning opportunities to be taken when they arise and will contribute to sound risk management. Burning before preparations are complete may reduce burn security and increase risks to values and crew safety.
- Ensure that the selected control lines for the proposed burn area are trafficable and meet agency standards where required.
- Access, escape routes and safety zones need to be prepared in advance of the burn day.
- To anticipate the arrival of suitable burning conditions, it is important to:
  - monitor meteorological outlooks
  - consider smoke management in relation to outlooks
  - monitor site fuel and moisture conditions
  - monitor site preparations.
- Regular monitoring of weather factors — such as temperature, relative humidity and wind speed and direction — at the proposed burn site in the lead up period will help to establish relationships between on-site weather and forecast weather for the nearest weather forecasting station.
- Many jurisdictions will need to liaise with their local pollution control agency with regard to smoke considerations — check whether your agency imposes limitations on burning in certain conditions.
- Monitoring of fuel moisture conditions is fundamental to determining whether fuels will burn, and if so, how rapidly (and intensely).
- Most agencies will have standard checklists, policies and procedures for notifications, however all persons and organisations that have an interest in the burn area should be notified.
- Each agency will have unique legislative and/or organisational requirements for authorising implementation of the burn on a scheduled burn date. This is not usually the authority to ignite the burn.

Self-assessment questions

1. Why is it important to check the boundaries prior to burning?
2. Where access to adjoining properties is required, what activities must the burn manager ensure are undertaken?
3. What are three potential hazards to burn crew safety?
4. What are the possible adverse effects of smoke from prescribed burns?
5. When monitoring approaching windows of opportunity, what four considerations must you keep an eye on?
6. What groups should be notified in the lead up to a prescribed burn in their area?
7. In addition to the burn crew and containment crews, what other personnel/resources might burn manager need to book?

Section

17

Conducting burn-day checks and briefings

Burn-day checks and briefings are required to ensure that the burn is ready to go, that the site is safe and that crews are appropriate tasked. This entails:

- obtaining good forecast information
- organising and tasking resources
- ensuring crew and site safety
- adjusting ignition timing.

Obtaining weather information

It is important to base your burning decisions on the most current and accurate (for your area) forecast information. In addition to obtaining the current, actual FMC for the burn as part of the burn-day checks, it is vital that you obtain weather forecasts, not only for the day(s) of the burn, but also the days following the burn (particularly with seasonal changes and the possibility of severe fire weather).

Accessing latest forecasts/outlooks

It is recommended to consult the BOM fire weather forecast for registered users in each state or territory through **reg.bom.gov.au/reguser/** for a 4-day forecast and FDI outlook as well as links to a range of other services including KBDI, satellite and smoke modelling.

Local 7-day forecasts for grid locations can be accessed through Meteye™ (**reg.bom.gov.au/australia/meteye/)** which provides detailed 3-hourly forecasts that include:

- temperature and humidity
- wind speed / direction
- dew point
- Drought Factor (dryness)
- stability (thunderstorms).

In addition, 'prescribed burn weather forecasts' can be requested in some jurisdictions. The forecast may typically take up to two hours to produce, but could be longer depending on operational requirements and meteorologist availability.

Modelling smoke

The trajectory of smoke plumes can be difficult to predict however smoke modelling may be required in some jurisdictions or for prescribed burns in smoke sensitive areas. BoM can provide a smoke dispersion forecast, or, alternatively, you can access the BoM registered users webpage for modelling (**reg.bom.gov.au/general/reg/smoke/index.shtml**), which has tabs for each state.

Activity 14.1

Identify the policy and procedures used by your organisation to predict and manage the effects of smoke. If your agency uses the Bureau of Meteorology for this purpose, outline the procedures for obtaining this assistance.

Mobilising resources

The burn manager should confirm roles for the burn and arrange an assembly point location and time for the briefing. Remember to allow sufficient travel time to the site for crew/resources from outside the area and provide clear directions and/or a map. When selecting the assembly point, consider safety of access and the number of vehicles and staff expected.

Figure 50: A prescribed burn briefing (Source: Department of Environment, Water and Natural Resources, SA)

Safety checks and briefings

After crews have mobilised to the assembly point, there are safety checks and operational briefings to undertake. These include:

- site safety checks to help determine whether the burn site is safe for crews to operate
- operational briefings to ensure that all staff involved in the prescribed burn understand what their primary task is and how it fits in with the overall objective(s) prior to deployment
- crew safety checks and site familiarisation to help ensure that crews have the knowledge and equipment to perform their designated task(s) safely.

Site safety checks

The site safety check is a final on-ground assessment of the burn site for any hazards and risks to the burn crews. This may include hazardous trees, fallen branches blocking access or trafficability issues from recent rain (or lack of rain in sandy soils) creating boggy conditions.

Some jurisdictions have formal procedures and standards for site safety checks so confirm individual agency requirements.

Figure 51: Raking fuel clear of trees (Source: Department of Environment, Water and Natural Resources, SA)

Operational briefings/tasking

Briefings are a key component of effective and safe prescribed burn operations. An important part of the briefing is allocation of tasks. Staff involved in the prescribed burn must understand what their primary task is, how it fits in with the overall objective(s), and what alternative tasks they may be required to carry out.

The prescribed burn plan can often be used as the basis for a briefing. Allow time to cover all necessary information, check for understanding and allow time for questions and clarification of any issues.

The briefing model commonly known by the acronym SMEACS, represents the key information components of an incident briefing (AFAC 2013, p.69). Refer to Section 9 for more information.

Crew safety checks and site familiarisation

Perform radio checks with all vehicles and hand-held radios. Check that all crews are wearing or have access to appropriate personal protective equipment (PPE).

Crews should be provided with an operational map(s) showing the proposed burn area with sufficient detail to enable safe navigation and operation for the duration of the burn. Depending on the size of the burn, consider driving the burn boundaries or relevant sectors for crew orientation. Crews should be familiar with the location of:

- safety zones and escape routes
- water points
- communication blackspots
- tracks (including those with dead ends).

Ignition timing and approval

Ignition timing and location should be based on well-considered knowledge of fuel moisture and current and predicted weather conditions that will result in the desired fire behaviour to achieve objectives safely within the designated time.

Ignition timing can be influenced by:

- predicted weather conditions
- FMC and predicted fire behaviour
- resource availability and skills
- completion of preparatory works.

Monitoring site conditions, weather and trends

Fuel moisture content (FMC) is a key driver of fire behaviour and understanding diurnal fuel moisture cycles will assist in planning ignition timing and location (see Figure 52). FMC will usually vary across the burn site, and under prescribed burn conditions is the principal factor affecting which fuels will burn and how rapidly (and intensely). It is therefore essential to consider actual fuel moisture conditions at the site, in conjunction with monitoring of on-site weather conditions and trends.

Monitoring site conditions and diurnal weather pattern development on the day of the burn is essential. As a minimum, record fuel moisture content, temperature, relative humidity, and wind speed and direction. Most agencies will have a checklist or template for recording observations. It is also important to review the weather forecast for the days following the burn. If deteriorating weather trends are predicted, consideration should be given to deferring the burn under circumstances where containment may be unreliable or if the burn is likely to result in large unburnt patches which may only ignite when conditions worsen.

Fire behaviour theory

Diurnal trends in temperature and relative humidity must be monitored in determining whether conditions on the day of proposed burning will stay within prescription.

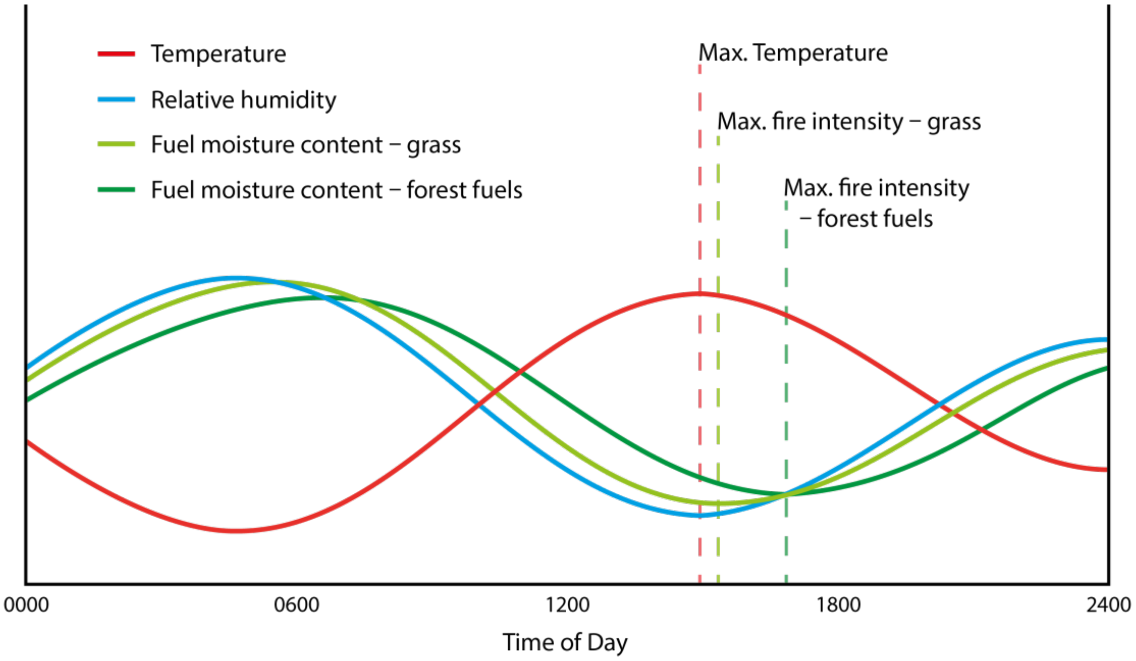


Figure 52: Variations to relative humidity and temperature throughout the day.

As we have discussed, fuel moisture content of dead fine fuels is closely related to the dryness of the air around them. As the relative humidity changes, the fuel moisture content will change after a time delay (the 'lag time'). Desorption rates are faster than adsorption rates – that is, dead fine fuels lose moisture more quickly in the morning as RH falls, than they regain it in the late afternoon or evening. Adsorption lag times could be two hours or more as humidity starts to rise in the late afternoon or evening.

Thus fuels are driest (and fire behaviour most intense) about the time of minimum RH and for some time afterwards. Refer to Section 10 for more information.

Seeking ignition approval

According to your agency procedures, seek approval to ignite test burn and/or prescribed burn using relevant checklists (if applicable). Once approval to ignite has been received, AIIMS structures may potentially apply to the prescribed burn operation in your jurisdiction (AFAC 2013, p.11).

Key decision point

Decide whether the burn is safe to proceed. Decide on the burn timing and make adjustments to the lighting pattern.

Activity 14.2

Describe the AIIMS structure you would use to manage a complex prescribed burn within your agency.

Figure 53: Using an electronic fuel moisture meter (Source: Department of Environment, Land, Water and Planning Vic.)

Section 17 summary

- Burn-day checks are required to decide whether the burn is safe to proceed.
- It is important to base your burning decisions on the most current and accurate (for your area) forecast information for the day(s) of the burn as well as the days following the burn (particularly with seasonal changes and the possibility of severe fire weather).
- The trajectory of smoke plumes can be difficult to predict however smoke modelling may be required in some jurisdictions or for prescribed burns in smoke sensitive areas.
- It is important to confirm roles for the prescribed burn and arrange an appropriate assembly point to prepare for the safety checks and briefing.
- Site safety checks are important to determine whether the burn site is safe for crews to operate.
- Operational briefings should ensure that all staff involved in the prescribed burn understands what their primary task is and how it fits in with the overall objective(s) prior to deployment.
- Crew safety checks and site familiarisation help to ensure that crews have the knowledge and equipment to perform their designated task(s) safely.
- Ignition timing and location should be based on well-considered knowledge of fuel moisture and current and predicted weather conditions that will result in the desired fire behaviour to achieve objectives safely.
- Fuel moisture content (FMC) is a key driver of fire behaviour and understanding diurnal fuel moisture cycles will assist in planning ignition timing and location.
- It is important to know your agency's procedures for obtaining approval to ignite a test burn and/or prescribed burn.

Self-assessment questions

1. Broadly speaking, the conduct of burn-day checks and briefings typically entails what four tasks?
2. How long does it typically take the BoM to produce a special 'prescribed burn weather forecast'?
3. What considerations should be considered when selecting an assembly point that is suitably close to the burn site?
4. What is a day-of-burn site safety check, and what does it involve?
5. In addition to indicating where the burn boundaries, control lines and sectors of operation are located, what three things is it important to identify the location of during a briefing to burn crews?
6. To achieve the desired fire behaviour, and in addition to a well-considered knowledge of current and predicted weather conditions, on what should the timing and location of ignition points be based?
7. When monitoring weather conditions at the burn site, what is the minimum set of parameters you should record as part of your observations?
8. Measurements of fuel moisture content are typically taken from what sort of fuel sample?

Section

18

Lighting and controlling the burn

After completing the burn-day checks and briefings, and obtaining approval to ignite, the main steps for lighting and controlling the burn involve:

- resourcing and managing public safety aspects of the burn
- conducting a test burn and assessing fire behaviour
- lighting, monitoring and containing the burn
- mobilising or demobilising resources as appropriate
- securing the burn.

Public safety

Public safety management requirements should be implemented according to the burn plan and agency procedures. Monitoring of public safety risks and the effectiveness of pre-planned risk management actions should be undertaken throughout the burn.

Implementing planned public-safety management

Ensure individuals are tasked to implement public-safety measures which may include:

- placement of temporary barriers to control/restrict public access to burn area
- placement of warning/advisory signage where it can be easily read (e.g. at entry points and intersections)
- checking the burn site to ensure no members of the public are present.

Implementing traffic control

Implement the traffic control plan if one was provided with or as part of the burn plan. If traffic control points are to be established, traffic controllers need to be deployed. They should be appropriately qualified and equipped according to agency requirements.

Day of burn notifications

Check the burn plan and agency procedures for day of burn notifications. There will usually be a day of burn checklist, but the burn plan may contain a pre-prepared list of relevant contacts with phone numbers. It may be necessary to inform your state/territory fire communications centre and fire warden (where relevant) that you are about to ignite a burn. The local police, road management authority and/or local council may also be advised where it is anticipated that the movement of traffic movement will be affected.

Test burn

A test burn can be a valuable aid in confirming fire behaviour predictions and ensuring that the actual fire behaviour will be within prescriptions or acceptable limits. The test burn will also help confirm potential rate of spread, which will be critical in determining ignition pattern.

Deciding location for test burn

The site chosen for your test burn should be representative of your prescribed burn area. Avoid road edges due to drying effects. You might also consider sites that test particular issues, such as if a fire will carry into non-target areas, such as riparian zones (vegetated areas bordering rivers and creeks).

The test burn should be lit:

- where it can be easily controlled and extinguished if necessary
- in a location generally representative of conditions across the burn area
- using line ignition (preferably of not less than 20 metres) to evaluate fire behaviour (as point ignition will produce significantly milder fire behaviour and take much longer to reach its potential flame height and rate of spread).

Monitoring test burn

Whilst the test fire is burning:

- observe and measure the distance the flame travels in metres over a pre-determined period, e.g. six minutes. Calculate the rate of spread in metres per hour (see Section 11).
- observe flame height and any spotting
- record temperature, relative humidity and wind speed
- note which factors are contributing most to fire behaviour (e.g. fuel moisture content, fuel arrangement, wind).

The test fire needs to be at its potential maximum rate of spread (ROS) for the current conditions before taking the required measurements. ROS data collected then needs to be extrapolated to the maximum for the day and checked against the burn plan parameters of desired fire behaviour.

Fire behaviour theory

Fire intensity represents the rate of heat or energy released per length of fire perimeter (expressed as kilowatts per metre kW/m). Fire intensity can be used to predict our ability to control a fire and it is a good indicator of likely post fire effects, such as scorch height and effects on vegetation. The desired fire intensity will generally be specified as part of the objectives. Flame height is a useful indication of a fire's intensity (see Figure 54) which can be assessed during the test burn.

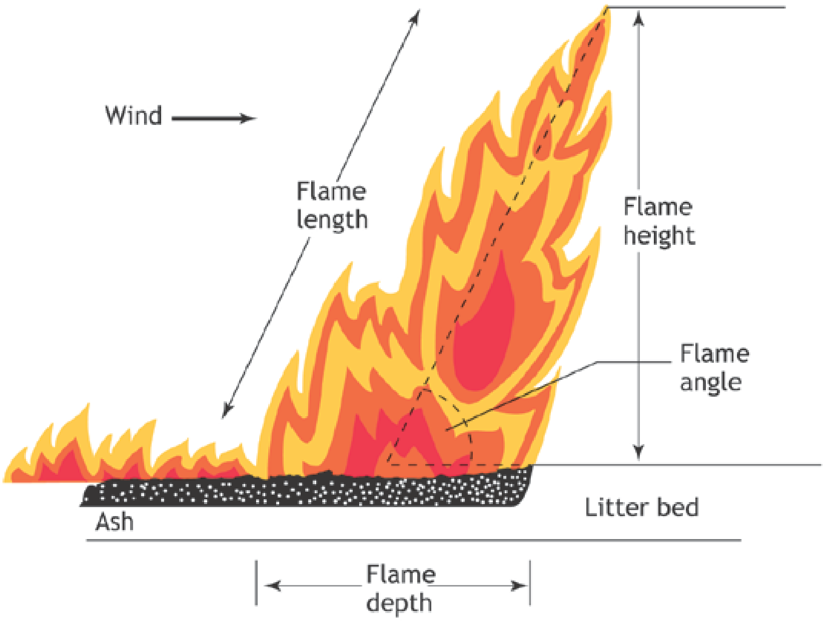


Figure 54: Flame height

Prescribed burning is often described generically as high or low intensity burning.

Low intensity burns are normally desirable where the objective is to consume some portion of surface litter and lower shrub and bark fuels, with minimum damage to middle and over-storey vegetation. They are characterised by:

- low flame height (typically less than 1.5 metres)
- slow rates of spread (less than 100m/hr)
- intensities less than 500 kW/m.

High intensity burns are normally desirable where objectives are to consume maximum fuel loads, cause significant soil heating, cause maximum death of some target species or regenerate hard seeded vegetation species that may be dying out.

Such burns are characterised by:

- tall flames (greater than 2 metres)
- rapid rates of spread, if allowed by the lighting pattern and nature of fuels
- intensities greater than 1000 kW/m. Some classifications describe fires of greater than 7000 kW/m as 'very high intensity'.

Further detail is provided in Section 11: Fire behaviour.

Evaluating results

- Calculate the rate of spread in metres per hour (the distance in metres covered in six minutes multiplied by 10).
- Confirm whether flame height or rate of spread is within the range to achieve the objectives of the burn and are safely within burn prescriptions.
- Compare observed and predicted fire behaviour, and identify the causes of any significant differences.
- Confirm that on-site weather recordings conform to the latest weather forecast for the location.
- Estimate the amount of favourable burning time available for the rest of the day.

Based on the results of the test burn, decide whether to proceed with the burn. If you. proceed, determine burn timing and make any adjustments to the lighting plan. In some jurisdictions a separate approval to ignite the prescribed burn may be required

Lighting, monitoring and containing the burn

It is important to apply good discipline in executing lighting and containment operations while retaining the flexibility to modify pre-planned techniques where conditions vary. Keep in mind the desired fire behaviour to achieve the burn objectives and monitor and adjust as necessary.

Execution of lighting plan

In order to achieve the burn objectives and comply with burn prescriptions or limits, lighting patterns which deliver the desired fire behaviour need to be implemented. Consider pre-planned ignition strategies but adjust the lighting pattern or timing where necessary if the conditions vary from original assumptions.

Activity 15.1

For a proposed prescribed burn in your locality, describe (using words and a sketch plan) the most appropriate ignition pattern, including important time sequences. Give reasons to justify your choice.

Monitoring fire behaviour, site conditions, weather and safety

Following ignition of the burn, it is necessary to monitor fire behaviour, site conditions, local weather and safety issues and make any adjustments necessary to maintain desired fire behaviour.

Ensuring containment

As the burn is progressively lit, containment arrangements and procedures need to be applied to ensure that the fire stays within defined boundaries. This will usually involve the burn manager exercising discipline over those igniting the burn, the ignition pattern deployed and suitable monitoring of conditions and containment lines.

Where, during the course of a burn, conditions change outside prescribed limits, a decision will need to be made whether to:

- alter the lighting pattern to minimise the effect of the changed conditions or
- terminate the burn at some intermediate boundary if containment cannot be ensured.

Adjusting lighting pattern (if required)

Once ignition has commenced, the only way burn crews can manipulate fire behaviour is through adjustment of lighting patterns. Monitoring of fire behaviour and adjustment of lighting patterns for the conditions will be instrumental in achieving the burn objectives.

Possible trigger points for adjusting lighting patterns could include:

- rate of spread is too slow or too fast
- overall fire intensity is too low or too severe.

Activity 15.2

Explain ways you could adjust the ignition pattern for a planned low-intensity burn (in fuels typical for your locality) where the fire intensity is becoming higher than required to meet your objectives.

Figure 55: Spot ignition spacing (Source: Fire and Landscape Strategies, Queensland)

Logging observations, taskings and incidents

Most agencies will have a template (such as a 'log') for record keeping during a prescribed burn. Details recorded may include:

- observations of weather and fuel conditions at appropriate intervals
- location of resources and tasking
- documentation of any incidents, e.g. near misses, spot-overs, damage to equipment or infrastructure.

Situation reporting

Situation reports (SITREPs) should be compiled from updates received from fireline crews or sector leaders (often via radio, a phone-in procedure or via a software form). While they are usually provided at pre-determined regular intervals, they should also be provided whenever there is a significant variation from the desired fire behaviour.

Mobilising or demobilising resources

As the burn progresses, the risk of fire behaviour escalating and or escaping will change and resourcing requirements will therefore change. Decisions about demobilising resources will be required after well-considered assessment of fire behaviour potential and level of residual risk to burn security and public safety. Often there are timing targets to consider, for example, to ensure the burn is completed in a timely manner or otherwise pulled up at a suitable control line. Such timing milestones will help inform mobilisation or demobilisation decisions.

It is important to consider how conditions may change overnight and the following day according to weather forecasts and whether the forecast conditions will contribute to fire behaviour de-escalating or even escalation and a subsequent increase in risk.

Ensure those crews remaining at the burn site understand the range and nature of remaining risk, the requirements for managing these and any triggers for considering mobilising or further demobilising resources.

Debriefing of crews may be conducted at the completion of the operation and/or prior to the release of staff at changeovers. Information gained in debriefing can provide additional intelligence to brief incoming crews on the burn progress and details of any risks encountered or identified.

Securing the burn site

Whilst any fuels remain alight the possibility exists for escapes. In the case of coarse forest fuels such as logs, stumps and hollow trees, the possibility exists for several days or sometimes weeks, and patrol measures must be taken to minimise this risk. Once burn objectives have been achieved in any part of the burn area, mopping-up/blacking-out work should commence on perimeters.

Site safety review

A site safety review will involve an assessment of any burning trees or logs that could fall or roll. The potential for falling tree or branch risks extend significantly longer than fire and smoke related risks and proper assessment of hazardous tree risks may be required before having crews re-enter under canopy for mopping up, and prior to reopening public roads and tracks around the burn site to the public. Apply agency requirements for dangerous tree identification and treatment.

Under some seasonal conditions, it may be important not to leave significant areas of unburnt fuel within control lines. These could re-ignite under more severe weather conditions on succeeding days and threaten control lines. Where such areas do exist under these conditions, a decision must be made to whether to burn them out with additional lighting.

Mopping up

Mopping up (or blacking out) is the process of extinguishing or removing burning material along or near the fire-control line, felling stags, trenching logs to prevent rolling, and whatever other activities are required to make the fire safe. Mopping up can commence as soon as burn objectives are achieved. Mopping up crews should address highest risks first progressing to lower risks areas.

The mopping up width may vary between agencies or depending on fuel types (and in some areas close to residential areas, mopping up may include the entire site, if only to minimise unwanted phone calls from concerned residents witnessing flames). Mopping up should treat any smouldering fuels near the burn perimeter which could create embers under strong winds including burning trees and logs that could fall or roll outside the burn area.

This work should continue until all burn perimeters are declared safe.

Implementing patrol/monitoring arrangements

Regular or systematic patrol of the burn perimeter must continue until it can be declared safe. Where ongoing patrols/monitoring is required, a handover or changeover to the next shift may involve:

- replacement of crews and/or the incident management structure
- debriefing outgoing crews and /briefing incoming personnel
- redistribution of equipment and/or resupply and maintenance.

Key decision point

Decide if the burn site is safe and whether crews can be stood down. Decide if there is a need for on-going monitoring of the burn or if there is residual risk.

Once the burn site is safe (even if there is ongoing monitoring required for residual risk) any AIIMS structure put into place now ends.

Agencies may have systems in place where, on days of heightened fire danger, a manager or duty officer continues to monitor all recently burnt sites within an area, and will resource them according to risk.

Figure 56: Mopping up (Source: DPAW,WA)

Section 18 summary

- Public-safety measures may include temporary barriers, signage and site checks.
- Where traffic control is required, traffic controllers should be qualified and equipped according to agency requirements.
- Day of burn notifications will normally be required according to agency checklists.
- A test burn can be a valuable aid in confirming fire-behaviour predictions and ensuring that the actual fire behaviour will be within prescriptions or acceptable limits. The test burn will also help confirm potential rate of spread, which will be critical in determining ignition pattern.
- Implementation of a lighting plan will need to deliver the desired fire behaviour to achieve burn objectives and comply with burn prescriptions or limits.
- It is important to retain the flexibility to modify a prepared lighting plan if conditions vary from original assumptions.
- Following ignition of the burn, it is necessary to monitor fire behaviour, site conditions, local weather and safety issues and make any adjustments necessary to maintain desired fire behaviour.
- As the burn is progressively lit, containment arrangements and procedures need to be applied to ensure that the fire stays within defined boundaries.
- Most agencies will have a template for record keeping during a prescribed burn to log observations, staff and resource deployments and incidents.
- Situation reports (SITREPs) should be compiled from updates received from fireline crews or sector leaders on current conditions on the fireline and fire behaviour, progress of the lighting since previous report and tasks to be undertaken.
- Situation reports are usually provided at regular, pre-determined intervals, but should also be provided whenever there is a significant variation from the desired fire behaviour.
- Decisions about demobilising resources should be based on fire behaviour predictions and the level of residual risk to burn security and public safety.
- Periodic patrol of the burn perimeter must continue until the burn area can be declared safe.

Activity 15.3

Complete the Review Activity 1 at the rear of this resources. It presents a realistic prescribed burn plan and asks you to prepare a crew briefing that includes details about how you would implement the burn.

Self-assessment questions

1. After completing the burn-day checks and briefings, and obtaining approval to ignite a test burn, what are the five main steps for lighting and controlling a burn?
2. Nominate three public-safety measures you might enact immediately prior to and for the duration of the burn.
3. For your agency, what day-of-burn notifications are required?
4. Why conduct a test burn?
5. Where should a test burn be lit?
6. What types of ignition pattern are commonly used for low intensity prescribed burning?
7. What are the trigger points that might indicate the need to adjust the lighting pattern?
8. What details need to be recorded during a burn?
9. What information should be included in a SITREP?
10. On what considerations should the decision to demobilise resources be based?
11. When should crews be debriefed?
12. How should a burn area be made safe?

Section

19

Post-fire activities

Post-fire activities include evaluating the burn results against objectives, investigating any incidents, undertaking follow-up works required, completing any necessary debriefings, and providing a record of the burn outcomes to provide feedback for adaptive management processes.

Evaluation

It is important that burn outcomes are evaluated and recorded in as much detail as appropriate. This information is useful for future planning and should form part of the documentation of the burn report. Most agencies will have a process for evaluation and documentation of burn outcomes.

Evaluate burn objectives

One of the most important post-burn activities is to determine whether a burn has achieved its objective(s). The burn objective(s) should have been based on measurable parameters which may have included:

- proportion of area burnt (patchiness)
- reduction in overall fuel hazard (e.g. from high to low)
- proportion of crown scorch
- mortality of target weed species.

For larger burns, assessment may be undertaken from helicopter by an air observer, estimated from vantage points where available or by using satellite imagery (weeks or months after the burn), particularly in remote areas. For smaller burns, ground assessment methods are mostly used, with observations often made from a number of representative locations within the burn area to determine percentages burnt and assess other parameters such as canopy scorch and residual fuel levels (using an appropriate fuel hazard guide).

Depending on the burn objectives, an evaluation of the degree to which the burn has been successful may be possible immediately post burn (e.g. whether fuel hazard parameters been modified to the extent required). In some cases, an assessment of the success of the burn may not be apparent until many months later (e.g. where a burn objective was to promote favourable conditions for regeneration of a grassy understorey).

Investigating incidents

Incidents associated with prescribed burns may include:

- significant escapes of fire beyond containment lines
- damage to assets within or outside burn boundaries (environmental values, infrastructure, equipment or other property)
- injuries to burn personnel or others
- significant numbers of complaints about the conduct of the burn or its consequences (for example, the effects of smoke).

It is important to follow agency guidelines for reporting and investigating incidents, as these are often associated with strict timeframes.

Figure 57: The results of mosaic burning (Source: Queensland Parks and Wildlife Service)

Post-burn works

The prescribed burn may have required construction of temporary control lines, turn-around areas, safety zones, helipads or other mechanically disturbed areas. Where such works were implemented solely for the burn and are not needed after the burn has been declared safe, activities to rehabilitate disturbed flora and to restore habitat requirements for native fauna may be needed.

During the course of the burn, there may also have been damage to values within or outside burn boundaries, such as burnt fence-posts, gates and signage, or encroachment of fire into sensitive vegetation. This may require a more formal incident investigation, but any restoration activities required should form part of the assessment for post-burn works.

This may require earthen or log barriers, and perhaps placement of vegetative material/debris at least at the start of the track to make it less obvious. In most cases natural regeneration will occur but occasionally extra stabilisation measures such as direct seeding may be required.

Undertake any repairs on permanent tracks such as reforming drainage or mechanically moving felled trees from fireline edges or stabilising creek banks due to damage from fireline traffic.

Where practicable, undertake as much of the post-burn works as possible before burn resources leave the site. However in many cases the need for access for on-going patrolling until the burn is declared safe may require machinery to be brought back to the burn site days or weeks later.

Undertaking debriefings

All personnel involved in a prescribed burn should be debriefed. This is best done near the end of the operation or day of burning when most crews are still present. However because some crews may be committed to patrol until late in the day (or overnight) more than one debriefing may be necessary.

Refer to Section 8: Burn management, for details concerning how to undertake debriefings.

Reporting

Most agencies will have standard procedures and templates for prescribed burn reporting.

Reporting burn outcomes

As a minimum, burn reports should include:

- measurable objectives and whether fully achieved, partially achieved or not achieved
- percentage of area burnt (preferably mapped using GIS)
- details of deviations or unexpected results from the burn
- details of any incidents that occurred during the burn.

Report follow-up or site rehabilitation works required

It may not be possible to implement all post-burn works immediately. Report any follow-up works or rehabilitation required. Also check burn plans for any pest animal and/or weed management requirements in follow-up works as the burn may have increased exposure of vulnerable or threatened wildlife to feral predators or in some cases exacerbated weed issues e.g. areas of high biomass grasses.

Follow-up works may also include details of any formal or informal monitoring required.

Key decision point

Determine whether the objectives were achieved and if any follow-up or site rehabilitation works are required. If objectives were not achieved, determine whether another burn should be scheduled.

Evaluation feedback

Fire management is an ever-evolving science reliant on a continuous learning process. Providing feedback from monitoring is important to:

- effectively close the **adaptive management loop** — by informing future burn plans and burn implementation through the results of monitoring and evaluation of new knowledge gained (both positive and negative)
- enable staff involved with **community engagement** and public education to proactively promote the positive benefits of prescribed burning programs

Closing the adaptive management loop

To effectively close the adaptive management loop (Figure 58), it is important that current burn planners and burn operators are given feedback after the evaluation and monitoring process has been undertaken. Depending on the burn objectives, this process may occur soon after the burn where results are already evident but in other cases further monitoring may be required and the process can be delayed for some months.

In any case, check whether your agency has processes/procedures in place for providing and recording feedback.

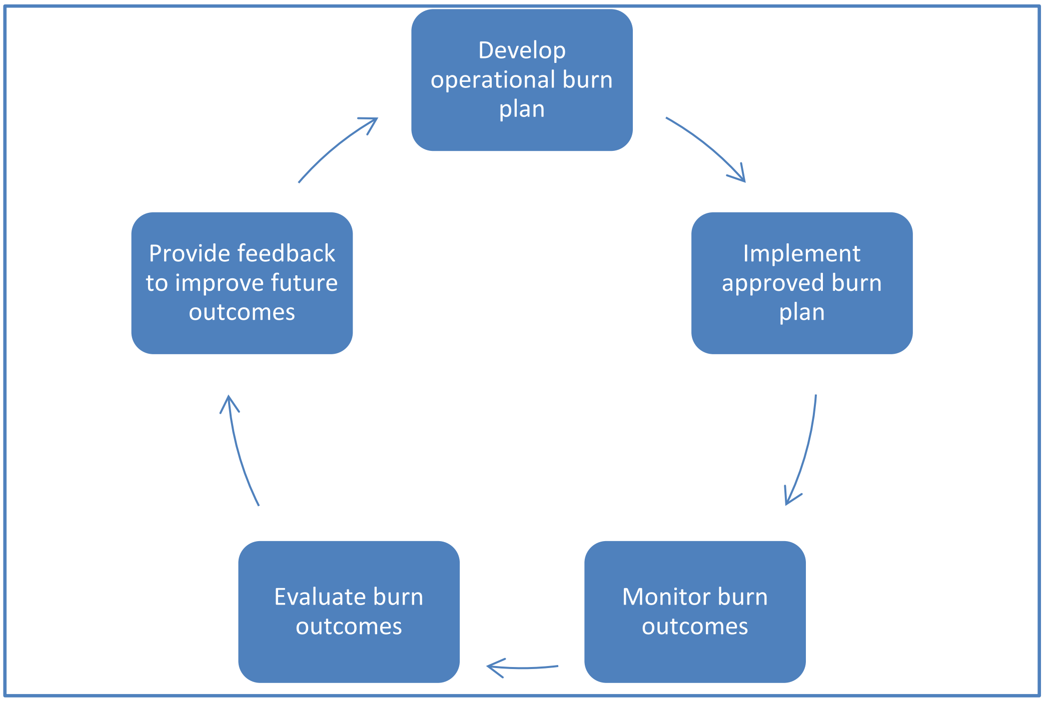


Figure 58: Adaptive management loop for prescribed burning

Community engagement

An often forgotten part of the feedback process is trying to improve community engagement and understanding of the importance of prescribed burning in the Australian environment. Providing the community with positive feedback on the results of prescribed burning can help to counteract some of the negative but mostly short-term impacts created such as smoke pollution, temporary changes to visual amenity and access restrictions.

Figure 59: Monitoring (Source: DEWNR, SA)

Section 19 summary

- Evaluation and assessment of burn results against objectives is necessary to determine the success of the burn, any follow-up works required and to provide feedback for adaptive management processes.
- Post-burn works may include repairs to tracks, rehabilitation of areas disturbed solely for burn operations and repairs/restoration to any values damaged during the burn.
- All personnel involved in a prescribed burn should be debriefed to identify factors or information about the conduct of the burn that may be relevant to operational procedure, safety and logistical issues.
- Any incidents which occurred during the burn should be investigated and reported according to agency guidelines.
- Burn reports should include:
  - measurable objectives and whether fully achieved, partially achieved or not achieved
  - percentage of area burnt (preferably mapped using GIS)
  - details of deviations or unexpected results from the burn
  - details of any incidents that occurred during the burn.
- Providing feedback from monitoring is important to:
  - effectively close the adaptive management loop — by informing future burn plans and burn implementation through the results of monitoring and evaluation of new knowledge gained (both positive and negative)
  - enable staff involved with community engagement and public education to proactively promote the positive benefits of prescribed burning programs.

Self-assessment questions

1. Why is it important to evaluate the results of a prescribed burn?
2. What sort of things, created for the purposes of conducting a burn, will require removal during the course of environmental restoration and rehabilitation activities?
3. While natural regeneration will usually be sufficient for restoring temporary vehicular tracks or other areas cleared of vegetation, what actions will often need to be undertaken to create the right conditions for natural regeneration to occur?
4. What is the purpose of debriefing after a prescribed burn?
5. What are two examples of variations from a burn plan that should be reported?
6. What incidents at a prescribed burn would require immediate reporting, and follow-up investigation?
7. What details should be recorded in a prescribed burn report?

Activity 16.1

Download and read one of the prescribed burning case studies from Appendix 2 of this document. As you read through the case study, see how many steps you can identify from Part 2 of this learner resource.

Part E

Answers
References
Glossary
Review Activities
Appendix

Self-assessment answers

Section 1

1. Fuel modification by prescribed burning can assist subsequent bushfire suppression operations by reducing fuel load and modifying its arrangement (through the removal of elevated fine fuels), thereby reducing the intensity of a potential bushfire.
2. In most parts of Australia, public land managers and private property owners have a statutory requirement to ensure fire hazards are minimised on their land.
3. The key factor that distinguishes a simple prescribed burn from a complex prescribed burn is risk, with simple prescribed burns being low in risk and of low potential impact on (natural and man-made) assets. While simple prescribed burns are of low fire intensity and conducted over small areas, complex prescribed burns may range from low to high intensity and cover medium to large areas. Many burns undertaken for ecological purposes will typically be of low fire intensity and may present a low risk of escape, yet will nonetheless qualify as complex due to the need for precise control of fire intensity to manage the risk to desirable species.
4. The different types of objectives that can be achieved by prescribed burning include:
   - reduction of fine fuel loads
   - the modification of other fuel properties in key areas to reduce the likelihood of dangerous fire behaviour in a subsequent bushfire
   - removal of debris and creation of desirable seed-bed conditions following timber-harvesting operations
   - control of target species invading vegetation communities
   - maintenance or restoration of ecosystems, habitats or species populations
   - promoting the greatest possible diversity of habitats and representation of successional stages of vegetation
   - for production purposes, such to encourage pasture or for protection of silvicultural assets.
5. Prescribed burning may be restricted at particular times of the year when general prohibitions are in force or when specific authorisations must be applied for. Burning during critical lead ups to periods of high fire danger may also require enhanced safety precautions.

Section 2

1. A long-term, landscape-level planning approach, providing aims and objectives for the fire management of a geographical area is done within the strategic level of prescribed burn planning.
2. The main purpose of operational planning is to develop burn plans for each area scheduled for treatment in the annual burning program. Burn plans should ensure safety requirements are met, have measurable objectives and reflect strategic plan goals, while at the same time comply with the policies, preferences and/or objectives of the land owner or manager. Each burn plan should specify the safety requirements, tactics to be used and tasks to be undertaken on the day of the prescribed burn. The burn plans should also set out the requirements for the assessment of the outcome of the burn.
3. The key elements in a complex prescribed-burn plan include:
   - a statement of burn objectives
   - a description of the area, including fuels
   - a description of the values, including environmental (specific species of concern, fire sensitive ecosystems, etc.), cultural (Aboriginal or European artefacts and places), and built assets/infrastructure (residences, sheds, schools, transmission lines, major roads, etc.)
   - a map suitable to assist in undertaking the burn
   - prescriptions or limits for fuel and forecast weather conditions
   - ignition patterns and techniques
   - measures for protection of assets and other values
   - resourcing requirements (for ignition, mop up and patrol)
   - health and safety issues (for burn personnel and the public)
   - contingency planning
   - risk assessment
   - notifications
   - post-burn evaluation requirements
   - guidance on implementation.

Section 3

1. Objectives for ecological or environmental management outcomes may be quite diverse and depend on the ecosystems, populations and species involved. Some operational objectives that might be applied at an ecological prescribed burn include achievement of:
   - a 30—60% spatial mosaic of burnt patches in the target area
   - less than 10% of the canopy scorched
   - more than 90% of clumping-grass bases remain as stubble
   - more than 90% of fallen logs (with a diameter ≥ 10 cm) retained
   - stimulation of native seed bank germination over 50% of the burn area
   - zero soil erosion within the prescribed-burn area.

2. Examples of an operational objective for a protection prescribed burn include:
    - reducing the overall fuel hazard to below moderate over 90% of the target area
    - reducing fuel load to less than 5 tonnes per hectare over 90% of the target area
    - burning 90—100% of understorey fuels in the target area.
3. Examples of an operational objective for a mitigation prescribed burn include:
    - reducing the overall fuel hazard to below moderate over 70% of the target area
    - reducing fuel load to less than 5 tonnes per hectare over 70% of the target area.
4. Examples of operational objectives that might be applied at a land-management prescribed burning include:
    - stimulate regrowth of grasses over >90% of the target area
    - reduce slashing trash by 90%
    - reduce woody weed (e.g. lantana) abundance by 75%.

Section 4

1. Five dimensions of prescribed burn risk include:
    - risk of not fulfilling the **burn objectives**
    - risk of not ensuring **burn containment**
    - risks to crew safety
    - risks to public safety
    - risk of environmental damage.
2. Static risk is constant or tends to be consistent in nature over a given timeframe, whereas dynamic risk arises from causes that are open to change, and which may vary in likelihood and/or potential consequence over a given timeframe.
3. The process of managing risks should ideally occur in stages, whereby:
4. the values are identified
    (a) the risks to those values are assessed to determine if they require mitigation
    (b) the risks requiring mitigation are treated to eliminate or reduce the risk level
    (c) these risk-treatments are monitored to ensure their effectiveness
    (d) the success of the risk-management process is reviewed with a view to its improvement.

Section 5

1. While the nature and dimension of prescribed-burn control lines will be based on consideration of land tenure, vegetation type and changes in fuel type or structure, the availability of control lines that will allow fire to be confined to the target area will ultimately determine the boundaries of a prescribed burn. For this reason the nature of control lines and their width will be dictated by likely fire behaviour adjacent to them, both on the day of the proposed burn and potentially on subsequent days when conditions may be more severe.
2. It is important to plan control lines well before the proposed burn to ensure that sufficient time is available to improve existing roads, tracks or firebreaks to the standard necessary for the burn, construct new control lines where necessary, and to gain approvals to undertake work on other agency's or property owners land.
3. Some of possible site-safety hazards at a burn site include vehicle movement, localised steep slopes or rocky ground, wind funnel areas, localised areas of high fuel, vegetation with flash fuels, areas of elevated fuels, communications blackspots, changes in aspect, slope or vegetation, mine shafts, cliffs, dead standing trees, and powerlines or gas pipelines.
4. The use of personal protection equipment important since there will always be a residual degree of risk affecting prescribed-burning and fire-suppression work after the various identifiable risk factors have been assessed and treated. For this reason PPE forms a vital layer within a broader risk-management approach.
5. Adverse effects of smoke are possible at prescribed burns and include:
   - reduced visibility, creating road and transport safety issues
   - respiratory complaints affecting both crews and the wider public
   - damage to smoke-sensitive forms of agriculture, including grape growing and bee keeping.
6. Where smoke may affect traffic on public roads, traffic-control plans could be required.
7. Areas nominated as safety zones should be low-fuel zones (on the probably upwind side of the burn) large enough to cater for all burn personnel, and able to be easily reached from the burn perimeter. Large burns or burns with difficult terrain or limited access may require more than one safety zone.

Section 6

1. Values and assets potentially affected by prescribed burning include:
   - Property and infrastructure
     - residential homes, sheds, barns, fences and other residential structures
     - schools, halls, hospitals and other community buildings
     - factories, warehouses and other types of industrial site
     - park and forestry structures, such as benches, walkways and mills
     - community infrastructure, such as powerlines, power substations and pipelines
   - Ecological and environmental values
     - ecological communities that are fire sensitive
     - rare, vulnerable, endangered or regionally/locally significant species
     - habitats that require protection for these species
     - environments at risk from erosion, pollution and weed spread

- Cultural heritage values
  - middens
  - rock-art sites
  - stone tools, wrapped bundles and burial sites`
  - engravings on trees and rock faces
  - arrangements of stones or raised earth patterns,
  - scarred or carved trees
  - natural features with cultural significance
  - historic building and fence remains
  - quarries and mine sites
  - forestry artefacts such as marked trees and forestry equipment
  - military artefacts
  - survey and trig points
  - markers from early European exploration
- Land-use values
  - grazing resources
  - silviculture resources
  - apiary resources
  - agricultural.

2. When identifying assets and values that may be impacted by prescribed burning, strategic-level planning documents are a good place to start, and most agencies will have GIS resources that identify the location of many built assets and ecological values. However, to properly identify and assess built assets, it is necessary to visit the site of the burn and nearby areas. And similarly to be sure you've identified, and properly assessed and understand how to protect significant ecological values, it may also be necessary to consult with internal staff and/or external experts.
3. Whenever the values identified during operational planning require additional mitigation strategies beyond burning in appropriate conditions, they should be specified in the burn plan. These may include:
   - ensuring fire control lines are sufficient to contain burns
   - establishing temporary control lines which may include slashed lines, rakehoe lines, wet lines or areas cleared of all fuel
   - ignition strategies to back fire away from built assets
   - weed hygiene and erosion controls around ecological values
   - burning under conditions when fire will not penetrate beyond a moisture gradient, thereby protecting the moister, fire-sensitive ecosystem
   - burning with appropriate winds so that embers, smoke and flames are directed away from built assets
   - preliminary burns in areas adjacent to built assets under very mild conditions to establish a burnt buffer prior to conducting the main prescribed burn
   - notification of owners of the built assets so that they are aware and may potentially assist by preparing their property
   - notification of additional resources (and local brigades) so that they can be ready to respond, or so that they can be in attendance with suitable appliances to assist in protecting built assets.
4. Cultural-heritage items potentially impacted by prescribed burns may be damaged through mechanical disturbance (vehicles, rakehoe lines, tractors), direct contact from fire, by radiant heat from fire, and by smoke (especially sooty smoke effecting rock-art sites).

Section 7

1. A 'classic' urban—rural interface is typically found on the edges of cities and towns where development has extended into the surrounding natural landscape. There is a distinct border between vegetation and residential or industrial development.
2. Important considerations when planning or implementing prescribed burns in the urban—rural interface include:
   - **fuel variation**, which can change significantly over small areas in urban—rural interface zones
   - **smoke impact** to roads, residences, hospitals, nursing homes, schools, etc.
   - **increased risk of entrapment to residents** if the efficacy of fire-control lines is the overestimated and relocation of residents is delayed in the event of escape
   - public education and awareness-raising
   - the need for **timely and well-worded public notifications** prior to prescribed burning is important to gaining community trust and support
   - **traffic management**, which is likely to require careful planning
   - **media presence**, which may be more likely
   - a potential need to **black-out larger areas than usual** to minimise calls to brigades or other government authorities from residents concerned about visible flames after operations are complete.
3. Burning in appropriate conditions is the key strategy to ensuring life and property are protected, however other important strategies used when undertaking prescribed burning in the urban—rural interface include:
   - ensuring values at risk are clearly identified and assessed for their vulnerability
   - having a good public-notification plan and a list of contacts for notification purposes, to ensure residents and local brigades are aware of prescribed burning activities
   - a traffic management plan and qualified traffic contractors
   - ensuring fire control lines are sufficient to contain burns
   - establishing temporary control lines which may include slashed lines, rakehoe lines, wet lines or areas cleared of all fuel
   - using appropriate ignition strategies to back fire away from built assets
   - burning with appropriate winds, so that embers, smoke and flames are directed away from built assets
   - being aware of smoke plume dynamics and being mindful of where smoke is likely to pool, even after prescribed burning operations are complete, including overnight
   - conducting preliminary burns in areas adjacent to assets under very mild conditions to establish a burnt buffer area prior to conducting the main prescribed burn
   - notification of owners of the built assets so that they can be aware and potentially assist by preparing their property
   - notification of additional resources (and local brigades), so that they can be in attendance or ready to respond with appliances suitable for assisting in the protection of built assets.

Section 8

1. Burn mosaic and fire patchiness are related concepts. Fire patchiness describes the variation between burnt and unburnt areas created after a single burn. A burn mosaic describes the manner in which different areas within an ecosystem exhibit different states of recovery from fire. Deliberately burning in a patchy manner allows a richer burn mosaics to be created over time, leading to greater diversity of habitats and greater ecosystem health and resilience.
2. The concept of fire regime describes the general pattern of fires that has occurred, or is desirable to occur, in an ecosystem over space and time. This includes both planned fires and bushfire. A fire regime includes consideration of fire frequency, fire extent, fire season, fire intensity, fire patchiness, and the ongoing combination of these factors.
3. When determining the minimum tolerable fire intervals for particular ecosystems, the maturation cycles of (1) obligate seeder species, (2) resprouting species and (3) fire-sensitive species need to be considered.
4. Medium or high intensity fire might occasionally be desirable in an ecosystems adapted to low intensity fire if:
   - certain tree species have become over abundant
   - if certain weed species require removal
   - if certain species that are present require sufficient heat to stimulate seed germination.
5. ‘Reading’ an ecosystem’s condition through visual indicators might assist you to alter a planned burn treatment when:
   - an area is recorded as being due for fire, but is still in a healthy or prime state, and so does not yet require fire
   - an area is recorded as not yet due for fire, but is showing signs of senescing, such that fire may in fact be beneficial
   - a particular species is flowering and this is known to be a sign that the area is ready for burning
   - there are signs of drought, and therefore burning at this time may stress the system
   - there are signs of tree die-back, and a different style of burning is required to rehabilitate the area
   - there is an overabundance of a particular tree species colonising the area, and an altered approach is required to thin the tree species
   - there are signs of weed infestation, and introducing fire at this time might provide a competitive advantage to the weed
   - there are signs of weed infestation, and introducing a more intense fire than recommended might help control the weed
   - there are signs of invasive grass infestation, and introducing fire at this time might cause more intense fire behaviour than expected, causing damage to native vegetation.

Section 9

1. Situational awareness is a dynamic awareness of the on-going situation. At a prescribed burn It not only includes understanding of the burn, its progress and the changing weather and fuel conditions as the day wears on, but also what is occurring for your teammates and for yourself.
2. The key elements of a briefing, as captured by the acronym SMEACS, are Situation, Mission, Execution, Administration, Command and Communications and Safety. It is also important to include time for questions.
3. When articulating the 'mission' at pre-burn briefings, in addition to informing crews what the burn is to achieve, it is important to tell them why and by when, since crews will take greater ownership of an operation if they understand the 'big picture'.
4. The three types of debriefing most relevant to prescribed burning are hot debriefs, shift debriefs, and after-action reviews.
5. Conducted with personnel during a shift, immediately after a significant event or a near-miss situation to determine:
   - how it occurred
   - who was affected
   - whether there is any on-going risk to personnel
   - how the risk might be eliminated or mitigated.
6. The five role types that need to be resourced at a prescribed burn are:
   - burn manager
   - lighting personnel and equipment
   - patrol/control/mop-up personnel and equipment
   - technical support personnel and equipment
   - logistical support personnel and equipment.

Section 10

1. The fuel conditions should you consider as part of a fuel assessment for a low intensity prescribed burn are:
   - fuel hazard (which comprises
     - fuel type
     - available fuel quantity
     - fuel arrangement)
   - fuel distribution
   - fuel moisture content.
2. The vertical structure of fuel affects their aeration. Well aerated elevated fuels will promote taller flames, greater fire intensities and more rapid rates of spread.
3. A simple method for estimating fuel moisture content is to use the leaf burn test, which uses the angle at which the combustion of a cured eucalypt leaf from the litter layer is just sustained to indicate fuel moisture content.
4. Knowing fuel moisture content is important to determining whether fuels burn, and if so, how rapidly (and intensely). The distribution of moisture in fuel beds also determines the

proportion of fuel available to burn. A good knowledge of FMC is essential to predict likely fire behaviour, and related things such as smoke properties and difficulty of fire control.

5. An increasingly common method for estimating fuel hazard is through the use of visual field guides that permit visual assessment of elevated fire fuels and surface fuels.

Section 11

1. It is recommended that a post-fire assessment of scorch height not be made until a week after the burn operation in order to allow time for scorched foliage to turn brown and thereby make the scorch height clearly visible.
2. When estimating scorch height by reference to char height immediately after a burn, you need to take into account the vegetation type and season if the estimation is to be accurate.
3. Generally, it takes 20 minutes for a fire ignited from a single spot to develop its maximum rate of spread. For strip ignited fire, this time may be less than five minutes.
4. A fairly typical low intensity fire burning in forest fuels with a well-defined fine litter layer will have a residence time of approximately 45—60 seconds, however residence times for 'flashy' and elevated fuels may be shorter.
5. Short distance spotting may increase head fire ROS if spot fires are drawn back by convection-column indraughts and gradually overtaken by the advancing flame front. This creates a junction zone effect and increases head fire intensity.
6. When the distance between ignition points (or strips) is increased, the proportion of the total area burnt by junction-zone fire decreases.
7. Most Prescribed burning guides suggest a maximum, unobstructed wind speed of exceed 10—15 km at 10 m above the ground in open country, however this figure is open to variation based on fuel type, the density of the forest's canopy, and on the objectives one aims to achieve through the burn.
8. A ratio of 1:1.25 can be used to convert ground-level wind speed (measured at a height of 1.5 m) to estimate the 'open' wind speed at the standard height of 10 m. The ratio in foliaged areas can be as high as 1:9.
9. Most prescribed burning should be planned for stable atmospheric conditions, because this will limit the development of strong convection, and will more likely be associated with predictable wind conditions.
10. Caution is required around junction zones, because they are areas where flame height and fire intensity will increase greatly and which will generate increased spotting activity.
11. Depending upon the fuel type to be burnt, the upper limits of the Fire Danger Index and Drought Index (KBDI or SDI) for low intensity prescribed burning will vary. You will need to check your own agency's guidelines. However, as a general rule, an FDI of 10 represents the upper limit for low intensity prescribed burning in forests. Yet this would be associated with fire behaviour at the upper end of the acceptable range, and normally is acceptable only in tall forest (for example, with canopy height > 40 m).

    In desert heaths or mallee vegetation, prescribed burning at FDIs up to 20 may be acceptable (because higher wind speeds are utilised in these areas).

12. Making fire behaviour predictions requires the following assessments:
13. consideration of forecasts and seasonal conditions
    (a) gaining a mental overview of your site and nearby areas and their variability

(b) assessment of onsite weather conditions

(c) assessment of fuels in each fuel type at representative locations and in areas of potential concern (such next to assets), including

- fuel quantity
- fuel hazard
- fuel moisture content (FMC)

(d) utilisation of appropriate fire behaviour models

(e) comparison of predictions to prescriptions and objectives.

Section 12

1. Some advantages of using matches to light prescribed are that they:

   (a) are cheap, easy to carry

   (b) allow good control of ignition density (they can be rationed to crews to prevent over-lighting)

   (c) only suit fuels which are relatively dry and will ignite easily.

2. Driptorches will require 'topping-up' on long ignition lines which may be logistically awkward. They can become heavy and tiring to use, particularly in thick vegetation. Experience has shown that unless crews using driptorches are well disciplined, they will invariably over-light an area.

3. A spot ignition pattern is generally preferred to strip (or line) ignition when fire intensity must be kept low because the head fire progressing from a spot will only burn 1/3rd of the total area burnt, whereas head fire progressing in a strip will burn 5/6^{ths} of the total area burnt. Also, due to fire increases in fire intensity that occur at junction zones, intensity of burning can be managed by modulating the spacing of ignition points, spacing them further apart to minimise the overall area subject to junction zone effect.

4. Spacing for spot ignition may be determined by determining average rate of spread (ROS) and multiplying by the total burn time remaining (e.g. 40 m/hr **x** 4 hours **=** 160 m)

5. The two aspects of prescribed fire that can be modulated by adjusting the lighting pattern are fire intensity and convective indraughts, which a both associated with the junction zone effect.

6. Appropriate lighting patterns for situations that require high intensity fire are line ignition and convection ignition.

Section 13

1. It important to verify the prescribed burn boundaries to determine whether it is feasible to contain the burn within this area using available control lines. This will usually require a field assessment with consideration of likely fire behaviour adjacent to the control lines.

2. When determining the possibility of containing a burn, prescribed burning personnel will need to examine available control lines, such as roads, bare earth or slashed tracks, and/or natural features, like creeks, wet gullies or exposed rocky areas.

3. Identification of preferred control lines must be undertaken at an early stage during burn preparations to ensure sufficient time:

   — to improve existing roads, tracks or fire control lines to required standards

— to construct new control lines where necessary

— to gain approvals to undertake work on land under the tenure or other individuals or organisations.

4. It is important to identify different land tenure within or near the proposed burn, since tenure will raise issues such as:

— notification requirements to neighbouring property owners or land managers

— potential co-operative arrangements to include private property or other agency land in the proposed burn (perhaps to rationalise boundaries)

— the need to locate control lines to exclude fire from areas of different land tenure

— potential co-operative arrangements to involve resources from other agencies in the conduct of the proposed burn.

5. Some of the main components of a hazard assessment for prescribed burning include fuel attributes, and risks to burn crew and public safety are important components of this assessment

6. Potential hazards to burn crew safety could include:

— hazardous trees near control lines

— falling rocks from unstable slopes above control lines

— overhead powerlines within burn area

— unmapped cliffs or old mine shafts in lighting areas

— traffic hazards during ignition, patrol and mop-up.

7. The possible adverse effects of smoke from prescribed burns include reduced vision along road and other transport routes, and its potential to directly affect people’s health, especially those with existing respiratory conditions.

8. Those who should be consulted when planning a prescribed burn include both internal and external stakeholders. Internal stakeholders within agencies may include specialist personnel tasked with confirming that all values and risks have been appropriately identified and comply with specific organisational policies and procedures. External stakeholders may include:

— neighbouring property owners/tenants

— traditional owners

— other land management agencies, e.g. local councils, main roads, environmental protection authorities

— relevant emergency services, e.g. urban and rural fire authorities

— lessees/contractors/tour operators with an interest/permit to operate in or adjacent to the burn area

— utility managers, e.g. telecommunications, electricity and water supply

— special interest groups

— general public.

Section 14

1. The main factors that will influence fire behaviour are fuel type, fuel arrangement and topography (which are fixed factors for any particular burn), and weather and fuel moisture content (which are quite variable and can therefore be prescribed by the burn manager).
2. Burn prescriptions are the acceptable limits for factors that will have an important influence on fire behaviour and the achievement of the burn objectives. Constraints may be nominated when particular conditions are required for specific risk management reasons, such as nominating a wind direction to keep smoke away from a major road.
3. The parameters for which prescriptions are often set for prescribed burning operations are:
   - temperature
   - relative humidity
   - wind speed and direction
   - Drought Index (or soil dryness index)
   - Fire Danger Index on the day, and sometimes subsequent days
   - fuel moisture content (of target fuels and sometimes of non-target fuels).
4. It important to identify the operational objective of a prescribed burn because this will determine the type of fire behaviour required.
5. Factors that can contribute to a prescribed burn escaping control lines include:
   - fire behaviour greatly exceeding expectations
   - un-forecast weather altering fire behaviour
   - inadequate control/patrol resources
   - inadequate control lines.
6. In addition to the creation of escape routes and safety zones for burn crews, actions that may reduce the level of risk to fire crews operating in a prescribed burn area include identification of hazards on operational maps, using specialist staff, amending fire behaviour prescriptions or ignition patterns to reduce fire intensity. (A list of other actions that may reduce the risks presented by specific hazards is summarised in Table 16.)
7. The information comprised in the 'day of burn' notifications to neighbours and the public should include:
   - who is conducting the burn
   - when and where the burn is proposed
   - the purpose of the burn
   - potential impacts of the burn (smoke, access restrictions)
   - contact details for further information.

8. Your choice of ignition technique may be influenced by a number of factors including:
   - size of the proposed burn
   - fuel characteristics
   - topography (especially slope)
   - desired fire behaviour (to meet objectives)
   - accessibility
   - availability of resources.

9. In a prescribed burn plan, the map should display:
   - identifying name/title of burn
   - area(s) to be burnt (including order if staged)
   - fire control lines — labelled
   - escape routes and safety zones
   - vegetation
   - values, assets and infrastructure.

   Additional information, where relevant, may include the following (or be displayed on a separate operational map):
   - ignition point(s)
   - fire history information
   - neighbours
   - topography
   - reserve boundary
   - access routes (with distances)
   - crew locations
   - water points.

10. Key functional areas that need to be resourced at a prescribed burn include:
    - safe ignition and control of the burn
    - crew management including rest breaks and safety provisions, shift rotation and catering where required
    - management of public safety including clearing the site prior to the burn, and controlling movement around the burn site on the day
    - execution of signage and notifications
    - availability of staff to monitor and report on the burn
    - traffic management, including organisation of specially trained staff or traffic control contractors where necessary.

Section 15

1. Before a burn plan is submitted for endorsement and approval, it needs to be assembled, checked and, preferably, peer reviewed.
2. The purpose of a peer review process prior to the approval of a burn plan is to solicit fresh insight to ensure plans are comprehensive, complete and appropriately pitched to balance program objectives, operational feasibility, safety considerations, and local botanical, zoological, and cultural-heritage values.
3. The person with responsibility for approving burn plans will give particular scrutiny to the stated or perceived level of risk, and the treatments proposed to manage higher levels of risk.
4. It is important to conduct post-burn evaluations and provide the results as feedback to operational planners, since this is will close the adaptive-management loop and assist them to improve the safety and work practice considerations that go into the drafting of future burn plans.

Section 16

1. It is important to check the boundaries prior to burning to ensure that they are appropriate to contain the type of fire behaviour planned and expected. This may include checking the water levels in creeks and other waterways, checking moisture levels in gullies, and reviewing likely weather conditions and soil moisture levels.
2. Where access to adjoining properties is required contact should be made to confirm any conditions of access, check for vehicle trafficability, and where necessary organise keys for locked gates and arrange for control of domestic animals and/or livestock.
3. Potential hazards to burn crew safety could include:
   - hazardous trees near control lines
   - falling rocks from unstable slopes above control lines
   - overhead powerlines within burn area
   - unmapped cliffs or old mine shafts in lighting areas
   - traffic hazards during ignition, patrol and mop-up.
4. The possible adverse effects of smoke from prescribed burns include reduced vision along road and other transport routes, and its potential to directly affect people's health, especially those with existing respiratory conditions.
5. When monitoring approaching windows of opportunity, it is important to:
   - monitor meteorological outlooks
   - consider smoke management in relation to outlooks
   - monitor site fuel and moisture conditions
   - monitor site preparations.

6. All those persons and organisations that have an interest in the burn area should be notified in the lead up to burning. They include those who may:
   — have an interest in the area to be burned (Traditional Owners, special interest groups, management committees and researchers)
   — have an interest in adjacent land to which the burn could possibly spread (private landowners, other land managers)
   — have an interest in managing the consequences of the burn, (for example, fire brigades who may be called upon to assist or who may be contacted by the public, police who may be required to assist with traffic management, local government bodies who may have to field enquiries from the public, Environment Protection Authorities who may be concerned with smoke issues)
   — have an interest in specific assets possibly affected by the burn, for example, utilities such as electricity providers
   — be generally concerned by evidence of the burn, for example the general public alarmed by heavy smoke.
7. In addition to the burn crew and containment crews, a burn manager may need to book:
   — specialist or technical staff or equipment (e.g. aircraft, aerial incendiary operator)
   — road traffic management staff
   — potential contingency resources.

Section 17

1. Broadly speaking, the conduct of burn-day checks and briefings entails:
   — obtaining good forecast information
   — organising and tasking resources
   — ensuring crew and site safety
   — adjusting ignition timing.
2. It typically takes the BoM up to two hours to produce a special 'prescribed burn weather forecast', but could be longer depending on operational requirements and the availability of meteorologists.
3. When selecting an assembly point that is suitably close to the burn site is important to consider safety of access and the number of vehicles and staff expected.
4. A day-of-burn site safety check is a final on-ground assessment of the burn site for any hazards and risks to the burn crews. This may include checking for hazardous trees, fallen branches blocking access, or trafficability issues from recent rain (or lack of rain in sandy soils) creating boggy conditions.
5. In addition to indicating where the burn boundaries, control lines and sectors of operation are located, when briefing burn crews it important identify the locations of:
   — safety zones and escape routes
   — water points
   — communication blackspots.

6. To achieve the desired fire behaviour, and in addition to a well-considered knowledge of current and predicted weather conditions, the timing and location of ignition points should be based on an understanding of fuel moisture across the site.
7. When monitoring weather conditions at the burn site, the minimum set of parameters you should record as part of your observations is temperature, relative humidity, wind direction and wind speed.
8. Measurements of fuel moisture content are typically taken from samples of fine, dead surface fuel (i.e. the upper 10 mm of litter bed).

Section 18

1. After completing the burn-day checks and briefings, and obtaining approval to ignite a test burn, the main steps for lighting and controlling the burn involve:
   - resourcing and managing public safety aspects of the burn
   - conducting the test burn and assessing fire behaviour
   - lighting, monitoring and containing the burn (following approval to ignite)
   - mobilising or demobilising resources as appropriate
   - securing the burn.
2. Three public-safety measures you might enact immediately prior to and for the duration of the burn are:
   - placement of temporary barriers to control/restrict public access to burn area
   - placement of warning/advisory signage where it can be easily read (e.g. at entry points and intersections).
   - checking the burn site to ensure no members of the public are present.
3. Neighbours and stakeholders should be notified. Required day-of-burn notification might also include contacting your state/territory fire communications centre and fire warden (where relevant) that you are about to ignite a burn. The local police, road management authority and/or local council may also be advised where it is anticipated that traffic movement may be affected. While each agency will typically have a set-list of contacts to which day-of-burn notifications should be issued, the burn-plan may also contain a pre-prepared list of relevant contacts.
4. A test burn can be a valuable aid in confirming fire behaviour predictions and ensuring that the actual fire behaviour will be within prescriptions or acceptable limits. The test burn will also help confirm potential rate of spread, which will be critical in determining ignition pattern.
5. The site chosen for your test burn should be representative of your prescribed burn area. Avoid road edges due to drying effects. You might also consider sites that test particular issues, such as if a fire will carry into a non-target areas, such as riparian zones (vegetated areas bordering rivers and creeks).

   The test burn should be lit:
   - where it can be easily controlled and extinguished if necessary
   - in a location generally representative of conditions across the burn area
   - using line ignition (preferably not less than 20 metres wide) to evaluate fire behaviour (point ignition will produce significantly milder fire behaviour).

6. The types of ignition pattern commonly used for low intensity prescribed burning are backing fire ignition (where all fuels are burnt by fire backing into the wind, or downslope, or both), and spot (or 'grid') ignition.
7. Possible trigger points for adjusting lighting patterns could include:
   — rate of spread is too slow or too fast
   — overall fire intensity is too low or too severe.
8. Details agencies typically require to be recorded during prescribed burn operations include:
   — observations of weather and fuel conditions at appropriate intervals
   — location of resources and tasking
   — documentation of any incidents, e.g. near misses, spot-overs, damage to equipment or infrastructure.
9. A SITREP should include current conditions on the fireline and observations of fire behaviour, the progress of the lighting since the previous report, and tasks to be undertaken.
10. Decisions about demobilising resources require after well-considered assessment of fire behaviour potential and level of residual risk to burn security and public safety. It is important to consider how conditions may change overnight and the following day according to weather forecasts and whether the forecast conditions will contribute to fire behaviour escalation and a subsequent increase in risk.
11. Debriefing of crews should be conducted at the completion of the operation and/or prior to the release of staff at changeovers.
12. A burn area should be made secure by:
    — conducting a **site safety review** to detect and assess any burning trees or logs that could fall or roll, and to determine whether there are any unburnt areas that might contribute to risk of escape should re-ignition occur
    — **mopping up/blacking out** work undertaken to treat any smouldering fuels (including burning trees) tackling areas of highest risk first, such as near the burn perimeter
    — the establishment of periodic **patrol** of the burn perimeter until it can be declared safe.

Section 19

1. It important to evaluate the results of a prescribed burn because this information is useful for future planning.
2. The sort of things, created for the purposes of conducting a burn, that require removal during the course of environmental restoration and rehabilitation activities include temporary control lines, turn-around areas, safety zones, helipads and other mechanically disturbed areas.
3. While natural regeneration will usually be sufficient for restoring areas cleared of vegetation, those areas should be closed to further use by appropriate means. This may require earthen or log barriers, and perhaps placement of vegetative material/debris at least at the start of the track to make it less obvious to people passing through the area.

4. The purpose of debriefing after a prescribed burn is to identify factors or information about the conduct of the burn that may be relevant to operational procedure, safety and logistical issues. Points for discussion may include:
   - what the objectives were
   - what actually happened (were the objectives achieved)
   - why it happened
   - what could be done better.

5. Two examples of variations from a burn plan that should be reported are:
   - details of deviations or unexpected results from the burn
   - details of any incidents that occurred during the burn.

6. Incidents at a prescribed burn would require immediate reporting, and follow-up investigation include:
   - significant escapes of fire beyond containment lines
   - damage to assets within or outside burn boundaries (environmental values, infrastructure, equipment or other property)
   - injuries to burn personnel or others
   - significant numbers of complaints about the conduct of the burn or its consequences (for example, the effects of smoke).

7. A prescribed-burn report should record the following details:
   - measurable objectives and whether fully achieved, partially achieved or not achieved
   - percentage of area burnt (preferably mapped using GIS)
   - details of deviations or unexpected results from the burn
   - details of any incidents that occurred during the burn.

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Glossary

(Adapted from AFAC 2012.)

Adsorption	The taking in of water vapour from the air by dead plant material.
Aerial ignition	Ignition of fuels by dropping incendiary devices or materials from aircraft.
Aspect	The direction towards which a slope faces.
Atmospheric stability	The degree to which the atmosphere resists turbulence and vertical motion.
Available fuel	The portion of the total fuel that would actually burn under various environmental conditions.
Available resources	The resources at an incident and available for allocation at short notice. (AIIMS)
Backburn	A fire started intentionally along the inner edge of a fireline during indirect attack operations to consume fuel in the path of a bushfire (Australia). A counterfire commenced from within continuous fuel for the purpose of fighting a fire (New Zealand).
Backing fire	The part of a fire which is burning back against the wind or down slope, where the flame height and rate of spread are reduced.
Bark fuel	The flammable bark on tree trunks and upper branches.
Blacking-out (or mopping up)	The process of extinguishing or removing burning material along or near the fireline, felling stags, trenching logs to prevent rolling and the like, in order to make the fire safe.
Burning out	To intentionally light fires to consume islands of unburned fuel inside the fire perimeter.
Burn over	A section of fire that overruns personnel and/or equipment
Burn perimeter	The containment perimeter of a burn as defined by its fire control lines.
Burn plan	The plan which is approved for the conduct of prescribed burning. It contains a map identifying the area to be burnt and incorporates the specifications and conditions under which the operation is to be conducted.
Bushfire (or wildfire)	Unplanned vegetation fire. A generic term which includes grass fires, forest fires and scrub fires both with and without a suppression objective.

Candle (candling)	A tree (or small clump of trees) is said to candle when its foliage ignites and flares up, usually from the bottom to the top.
Canopy	The crowns of the tallest plants in a forest — the overstorey cover.
Coarse fuels (or heavy fuels)	Dead woody material, greater than 25mm in diameter, in contact with the soil surface (fallen trees and branches). Some researchers categorise forest fuels as: fine <6 mm diameter; twigs 6-25 mm diameter; coarse >25 mm diameter.
Combustion	Rapid oxidation of fuels producing heat, and often light.
Control line	See: **Fireline**.
Convection	1. As applied in meteorology, atmospheric motions that are predominantly vertical, resulting in vertical transport and mixing of atmospheric properties; distinguished from advection. 2. As applied in thermodynamics is a mechanism of heat transfer occurring because of the bulk movement of fluids.
Convection column	The rising column of smoke, ash, burning embers and other particle matter generated by a fire.
Control line	See: **Fire-control line**.
Crown scorch	Browning of the needles or leaves and spreading from crown to crown.
Dead fuel	Fuels with no living tissue in which moisture content is governed almost entirely by absorption or evaporation of atmospheric moisture (relative humidity and precipitation).
Desorption	The loss of moisture to the atmosphere from dead plant material.
Direct attack	A method of fire attack where wet or dry firefighting techniques are used. It involves suppression action right on the fire edge which then becomes the fireline.
Diurnal fuel moisture cycle	The pattern of increase or decrease in fuel moisture content of fuel over a period of a day.
Drought index	(Also see Keetch-Byram Drought Index, Soil Dryness Index). A numerical value reflecting the dryness of soils, deep forest litter, logs and living vegetation.
Ecological burning	A form of prescribed burning. Treatment with fire of vegetation in nominated areas to achieve specified ecological objectives.
Ecotone	A transition zone between two ecological communities.
Elevated fuel	The standing and supported combustibles not in direct contact with the ground and consisting mainly of foliage, twigs, branches, stems, bark and creepers.
Elevated fuel	The standing and supported combustibles not in direct contact with the ground and consisting mainly of foliage, twigs, branches, stems, bark and creepers.
Escape route	A planned route away from danger areas at a fire.

Fall-back control line	Any fireline which is at a distance from the fire perimeter, and is the second control line at which the fire perimeter may be stopped should it cross the first fire control line. Also known as 'fallback line'.
Fine fuel	Fuel such as grass, leaves, bark and twigs less than 6mm in diameter that ignite readily and are burnt rapidly when dry.
Fire behaviour	The manner in which a fire reacts to the variables of fuel, weather and topography.
Fire control	See Fire suppression.
Fire-control line	A natural or constructed barrier, or treated fire edge, used in fire suppression and prescribed burning to limit the spread of fire.
Fire danger	Sum of constant danger and variable danger factors affecting the inception, spread, and resistance to control, and subsequent fire damage; often expressed as an index.
Fire Danger Index (FDI)	A relative number denoting the potential rates of spread, or suppression difficulty for specific combinations of temperature, relative humidity, drought effects and wind speed.
Fireground	The area in the vicinity of a fire suppression operations, and the area immediately threatened by the fire. It includes burning and burnt areas; constructed and proposed fire lines; the area where firefighters, vehicles, machinery and equipment are located when deployed; roads and access points under traffic management control; tracks and facilities in the area surrounding the actual fire; and may extend to adjoining area directly threatened by the fire.
Fire hazard	A fuel complex, defined by volume, type condition, arrangement, and location, that determines the degree of ease of ignition and of resistance to control.
Fire intensity	The rate of energy release per unit length of fire front usually expressed in kilowatts per metre (Kw/m). The rate of energy release per unit length of fire front, defined by the equation **I = Hwr**, where, I = fireline intensity (kW/m) H = heat yield of fuel (kJ/kg)-16,000 kJ/kg w = dry weight of fuel consumed (kg/m2) (mean total less mean unburnt) r = forward rate of spread (m/s). The equation can be simplified to **I = wr/2**, where, I = fireline intensity (kW/m) w = dry weight of fuel consumed (tonnes/ha) r = forward rate of spread (m/hr).
Fireline	See: **Fire-control line**.
Fireline intensity	See **Fire intensity**.
Fire management	All activities associated with the management of fire prone land, including the use of fire to meet land management goals and objectives.
Fire suppression (or fire control)	The activities connected with restricting the spread of a fire following its detection and before making it safe.

Fire weather	Weather conditions which influence fire ignition, behaviour, and suppression.
Fire weather forecast	A weather prediction specifically prepared for use in wildland fire operations and prescribed fire.
Flame angle	The angle of the flame in relation to the ground, caused by wind direction or the effect of slope.
Flame depth	The depth of the zone within which continuous flaming occurs behind the fire edge.
Flame height	The average maximum vertical extension of flames at the leading edge of the fire front. Occasional flashes that rise above the general level of flames are not considered. This distance is less than the flame length if flames are tilted due to wind or slope.
Flame length	The distance between the flame tip and the midpoint of the flame depth at the base of the flame (generally the ground surface), an indicator of fire intensity.
Flammability	The ease with which a substance is set on fire.
Flanks of a fire	Those parts of a fire's perimeter that are roughly parallel to the main direction of spread.
Foam solution	The mixture of water and foam concentrate.
Fuel	Any material such as grass, leaf litter and live vegetation which can be ignited and sustains a fire. Fuel is usually measured in tonnes per hectare. Related Terms: Available fuel, Coarse fuel, Dead fuel, Elevated dead fuel, Fine fuel, Ladder fuels, Surface fuels, and Total fine fuel.
Fuel arrangement	A general term referring to the spatial distribution and orientation of fuel particles or pieces.
Fuel load (or fuel quantity)	The oven dry weight of fuel per unit area. Commonly expressed as tonnes per hectare. (Also known as fuel loading)
Fuel moisture content	The water content of a fuel particle expressed as a percentage of the oven dry weight of the fuel particle. (%ODW).
Fuel quantity	See **Fuel load**.
Fuel reduction burning (or Hazard reduction burning)	The planned application of fire to reduce hazardous fuel quantities; undertaken in prescribed environmental conditions within defined boundaries.
Fuel type	An identifiable association of fuel elements of distinctive species, form, size, arrangement, or other characteristics that will cause predictable rate of spread or difficulty of control under specified weather conditions. (AFAC)
Grid ignition	A method of lighting prescribed fires where ignition points are set individually at a predetermined spacing through an area.
Ground fuel	All combustible materials below the surface litter, including duff, roots, peat and saw dust dumps that normally support a glowing or smouldering combustion without flame.
Habitat	The local environment of conditions in which an animal or plant lives.

Hazard reduction burning	See: **Fuel reduction burning**.
Hazardous tree	A hazardous tree exhibits characteristics that may lead to falling branches or the entire tree falling and posing a risk to humans.
Heat transfer	The transfer of thermal energy from one physical system to another by conduction, convection or thermal radiation.
Heavy fuels	See: Coarse fuels.
High fire danger	The second lowest fire danger rating as determined by fire agencies and generally with a Forest fire danger index between 25 and 49 or a Grassland fire danger index between 25 and 49.
High intensity fire	Fires with an average intensity greater than 3000 kW.m-1 and flame heights greater than 3 m, causing complete crown scorch or possibly crown fires in forests. Uncontrollable by direct attack. The term is also applied to stationary fires burning in very high fuel loads (such as logging slash).
Ignition pattern	The manner in which a prescribed burn, backburn, or burnout is set, determined by weather, fuel, ignition system, topographic and other factors having an influence on fire behaviour and the objective of the burn.
Ignition spacing	The spaces between spot ignition points as used in prescribed burning. The rate of spread of fire and the distance between ignition points determines when spot ignition fires will juncture.
Incendiary	A chemical compound (sometimes contained in a capsule) used to produce intense heat or flame.
Incendiary device	Device designed and used to start a fire.
Incident Action Plan (IAP)	The plan used to describe the incident objectives, strategies, resources and other information relevant to the control of an incident. (AIIMS)
Incident Controller	The individual responsible for the management of all incident control activities across a whole incident (AIIMS).
Incident management	The process of controlling the incident and coordinating resources.
Incident objectives	An incident objective is a goal statement indicating the desired outcome of the incident. Incident objectives guide the development of the Incident Action Plan and must reflect the policies and needs of the control authority and supporting agencies. All factors affecting the incident and its potential impact must be considered before determining the objective. (AIIMS)
Instability	The tendency for air parcels to accelerate when they are displaced from their original position; especially, the tendency to accelerate upward after being lifted. Instability is a prerequisite for severe weather — the greater the instability, the greater the potential for severe thunderstorms.
Inversion	A layer of the atmosphere in which temperature increases with increasing elevation. A condition of strong atmospheric stability.

Junction zone	An area of greatly increased fire intensity caused by two fire fronts (or flanks) burning towards one another.
Junction zone effect	The effect whereby fire intensity increases where two fire fronts junction.
Keetch-Byram Drought Index (KBDI)	A numerical value reflecting the dryness of soils, deep forest litter, logs and living vegetation, and expressed as a scale from 0—200 where the number represents the amounts of rainfall (mm) to return the soil to saturation.
Ladder fuels	Fuels which provide vertical continuity between strata. Fire is able to carry from surface fuels into the crowns with relative ease.
Lag time	The time delay in fuel moisture content responding to changing environmental conditions (for example, relative humidity). Technically, it is the time necessary for a fuel particle to lose approximately 63% of the difference between its initial moisture content and its equilibrium moisture content.
Litter	The top layer of the forest floor composed of loose debris of dead sticks, branches, twigs and recently fallen leaves and needles, little altered in structure by decomposition. (The litter layer of the forest floor).
Litter bed fuel	Dead fine fuel, including surface fuel and fuel lower in the fuel profile.
Local winds	Winds which are generated over a comparatively small area by local terrain and weather. They differ from those which would be appropriate to the general pressure pattern.
Low-intensity fire	A fire which travels slowly and only burns lower storey vegetation, like grass and lower tree branches, with an average intensity of less than 500 kW/m and flame height less than 1.5 m. Usually causes little or no crown scorch and is easily controlled.
Mineral earth	When used in the context of fire control refers to a non-flammable surface (either natural or prepared) which provides a break in understorey, litter and humus fuels and hence a barrier (of varied effectiveness depending, amongst other things, on its width and the intensity of the approaching fire) to fire travelling on or near the ground surface.
Mopping up	See **Blacking out**.
Near surface fuel	Live and dead fuel, including suspended leaves, bark or twigs, effectively in touch with the ground but not lying on it, with a mixture of vertical and horizontal orientation.
Parallel attack	A method of suppression in which fireline is constructed approximately parallel to, and just far enough from the fire edge to enable workers and equipment to work effectively, though the fireline may be shortened by cutting across unburned bays. The intervening strip of unburned fuel is normally burned out as the control line proceeds, but may be allowed to burn out unassisted where this occurs without undue delay or threat to the fireline.

Patrol	1. To travel over a given route to prevent, detect, and suppress fires. Includes interaction with the public for wildland fire prevention and educational purposes. 2. To go back and forth vigilantly over a length of control line during and/or after construction to prevent breakaways, suppress spot fires, and extinguish overlooked hot spots. 3. A person or group of persons who carry out patrol actions.
Permit burn	A burn carried out under permit from a Fire Authority.
Personal protective equipment (PPE)	The equipment and clothing designed to mitigate the risk of injury from the chemical, physical and thermal hazards that may be encountered at an incident.
Prescription	A written statement defining the objectives to be attained during prescribed burning.
Prescribed burning	The controlled application of fire under specified environmental conditions to a predetermined area and at the time, intensity and rate of spread required to attain planned resource management objectives.
Prescribed fire	Any fire ignited by management actions to meet specific objectives. A written, approved burn plan must exist, and approving agency requirements (where applicable) must be met, prior to ignition.
Rate of spread (ROS)	The speed with which a fire moves in a horizontal direction across the landscape at a specified part of the fire perimeter. See also **Forward rate of spread**.
Response	Actions taken in anticipation of, during, and immediately after an incident to ensure that its effects are minimised, and that people affected are given immediate relief and support.
Resprouters	Those plant species that recover after fire from epicormic or basal shoots.
Safe	The stage of bushfire suppression or prescribed burning when it is considered that no further suppression action or patrols are necessary.
Safety zone	An area cleared of flammable materials used for escape if the line is outflanked or in case a spot fire outside the control line renders the line unsafe. In fire operations, crews progress so as to maintain a safety zone close at hand, allowing the fuels inside the control line to be consumed before going ahead. Safety zones may also be constructed as integral parts of fuel breaks. They are greatly enlarged areas which can be used with relative safety by fire fighters and their equipment in the event of a blow up in the vicinity.
Scorch height	1. The height above ground level up to which foliage has been browned by a fire. 2. A measurement for determining the acceptable height of flame during prescribed burning.
Scrub	Vegetation such as heath, wiregrass and shrubs, which grows either as an understorey or by itself in the absence of a tree canopy.

Situation report (SITREP)	A report on the progress of the fire and the efforts to control it. It confirms the location of the fire, its status and potential and the number, nature and effectiveness of resources deployed. Situation reports are normally provided at regular times until the fire is declared safe.
Slope	The angle the ground surface makes with the horizontal, and is normally expressed as a gradient. A gradient of 1:10 means that in a horizontal distance of 10 units, the ground rises or falls 1 unit.
Smoke management	Used by land managers and meteorologists planning a prescribed bur, to ensure that smoke does not cause problems downwind of the burn.
Smoke plumes	The column of smoke that rises form a fire. (See also Convection column')
Soil Dryness Index (SDI)	A form of Drought Index, usually with slightly more detailed inputs than the Keetch-Byram Drought Index. May be on a scale of 0-200 like the KBDI, but some versions have different scales (for example, Western Australia: 0 - 2000, Tasmania (Mount SDI) 0 - open-ended).
Spot fire	1. Isolated fire started ahead of the main fire by sparks, embers or other ignited material, sometimes to a distance of several kilometres. 2. A very small fire that requires little time or effort to extinguish.
Spot ignition	An ignition pattern using a series of spaced points of ignition.
Spotting	Behaviour of a fire producing sparks or embers that are carried by the wind and start new fires beyond the zone of direct ignition by the main fire.
Strip burning	See **Strip ignition**.
Strip ignition (or strip ignition)	1. An ignition pattern using lines of continuous fire. 2. In hazard reduction, burning narrow strips of fuel and leaving the rest of the area untreated by fire.
Surface fire	Fire that burns loose debris on the surface, which includes dead branches, leaves, and low vegetation.
Surface fuel	Litter fuels made up of leaves, twigs, bark and other fine fuel lying on the ground, predominately horizontal in orientation.
Understorey	The lowest stratum of a multi-storeyed forest.
Values	The natural resources or improvements that may be jeopardised if a fire occurs.
Water point	Any natural or constructed supply of water that is readily available for fire control operations.
Wind speed	The rate of horizontal motion of the air past a given point expressed in terms of distance per unit of time. Wind speed is measured at the standard height of 10 metres in the open, averaged over a 10-minute interval and in kilometres per hour.

Review Activity 1: Developing a burn plan

Read the below scenario describing a prescribed burn area and then study the maps provided. Based on the scenario and maps and any other information you think relevant, complete the blank **burn plan** template provided or alternatively, use your own agency's burn plan template.

This is an activity to assist in consolidating your learning and you are expected to review various sections of this learner resource (especially Part C, but also some areas of Parts A and B) in order to complete it successfully. The purpose of this activity is to demonstrate acquired knowledge in the development of a complex burn plan. Instructions for completing the burn plan include:

1. Identify the burn location, agency and nominate a person responsible for conducting the burn.
2. Identify the purpose of the burn by identifying which fire management zone(s) are targeted. For each vegetation type within each zone (e.g. Bushfire Mitigation Zone/Open Forest) complete the information requested. Some of this information is provided in the scenario, the rest can be derived from reviewing parts of this document. Identify at least one measurable objective for each zone/vegetation type.
3. Complete the section on prescriptions and constraints. You are encouraged to make a number of fire behaviour predictions based on likely weather and fuel scenarios (see the fire behaviour theory section of this learner resource) to help refine prescriptions and planning decisions.
4. Use a highlighted or marker pen to update the map with any additional information required. Complete the map checklist in the burn plan template.
5. Document operational strategies required to successfully undertake the burn including any pre-ignition works, ignition strategies, patrols, post-fire rehabilitation works and contingency strategies. Do not be too prescriptive, it is advisable to leave flexibility for the burn manager to choose ignition strategies based on conditions on the day.
6. Identify risks that are specific to the burn or burn site and that require mitigation.
7. Estimate the resources required to undertake the burn.
8. Record any additional notifications required.

Note that while particular fire management zones are referred to in this activity, different jurisdictions use different terms and you may need to mentally adjust the terms as suited.

Once finished, you can check your thinking by referring to the completed plan within Review Activity 2.

Scenario

You are assigned the job of developing a **burn plan** for an area in Bauple State Forest, 53 km north of Gympie in Queensland, scheduled to be burnt within this year's **burn program**. The area is managed by the Queensland Parks and Wildlife Service's (QPWS) Gympie Operations Unit. It was last burnt 10 years ago.

A detailed operations map (called Bauple State Forest Map) of the burn area is provided, as well as a general location map produced using Google Maps. The prescribed burn is 1834 hectares in area and is marked on the map as '**Planned Burn 1834ha**' (being the area bounded by the orange and green highlighted unsealed roads).

Areas recently burnt are marked on the map; all of these areas were successfully burnt and have very low fuel loads. However, one adjacent block marked 'Long Unbrunt' has high fuel loads.

Resources available include:

- The Gympie Operations Unit which has four two-person crews each with a 4WD mounted fire unit.
- The Rural Fire Brigade can offer two two-person volunteer crews, also a 4WD mounted fire units, and a high capacity water tanker with one driver.

The next closest resources are stationed in Maryborough (100 km away) with an equal number of resources as the Gympie Operations Unit.

The Gympie Operations Unit has a standard notification list of neighbours, local brigades, police and stakeholders, but if you have additional (non-standard) notifications, add them to the burn plan.

A quick review of the Fire Strategy reveals that there are two Fire Management Zones in the burn area. The main zone under consideration is a **Bushfire Mitigation Zone** that was established to re-enforce the Protection Zone (burnt last year) adjacent to the housing estate. The Bushfire Mitigation Zone takes up 70% of the burn area and is bounded by the unsealed roads highlighted in orange. The remaining area is a **Conservation Zone** and is bounded by the unsealed road highlighted in green.

The map indicates that the burn site consists of the vegetation type **'Open Forest'** and in this area you have been advised that the understorey is predominantly grassy verging into shrubby areas in gullies. Though not mapped, the Gympie Operations Unit has indicated that the vegetation type **'Melaleuca Woodlands'** occurs in depressions in the Bushfire Mitigation Zone and makes up about 10% of the burn area. GIS analysis reveals that it is an endangered ecosystem. GIS analysis also reveals the presence of the vulnerable Powerful Owl nesting in the area. The zoologist advises to avoid burning near Powerful Owl nesting sites during late winter and spring.

Fuel loads across the site are estimated to be 12 t/ha, with 18 t/ha in some locations near gullies. Areas west of the burn site have not been burnt for some time and have fuels loads of about 24 t/ha. There are some trees close to the fire control line at point 'L' and 'H' on the map that pose a spotting risk due to high bark hazard.

The area contains long term monitoring sites maintained by the environment department (contact 07 #### ####). The nearby plantation is a multi-million dollar silviculture resource and the Gympie Operations Unit has reinforced the need to keep fire away from the plantation.

Generic burn prescriptions for hazard reduction and the different vegetation types are provided below:

Open Forest

- **Fire intensity:** Low to moderate.
- **Mosaic:** 40—80 per cent burnt.
- **Fire frequency:** Between three to six years for grassy understorey and seven to twenty-five years for shrubby understorey.
- **Season:** January to August. Late summer and autumn will generally provide better regenerative conditions for plants and animals. Use caution if burning in August as strong dry westerly winds are common during this period, increasing the risk of re-ignition.
- **FFDI:** < 11 (7 is optimal to promote a grassy ground stratum)
- **DI (KBDI):** < 120 (good soil moisture is the critical factor)
- **Wind speed:** < 15 km/hr.

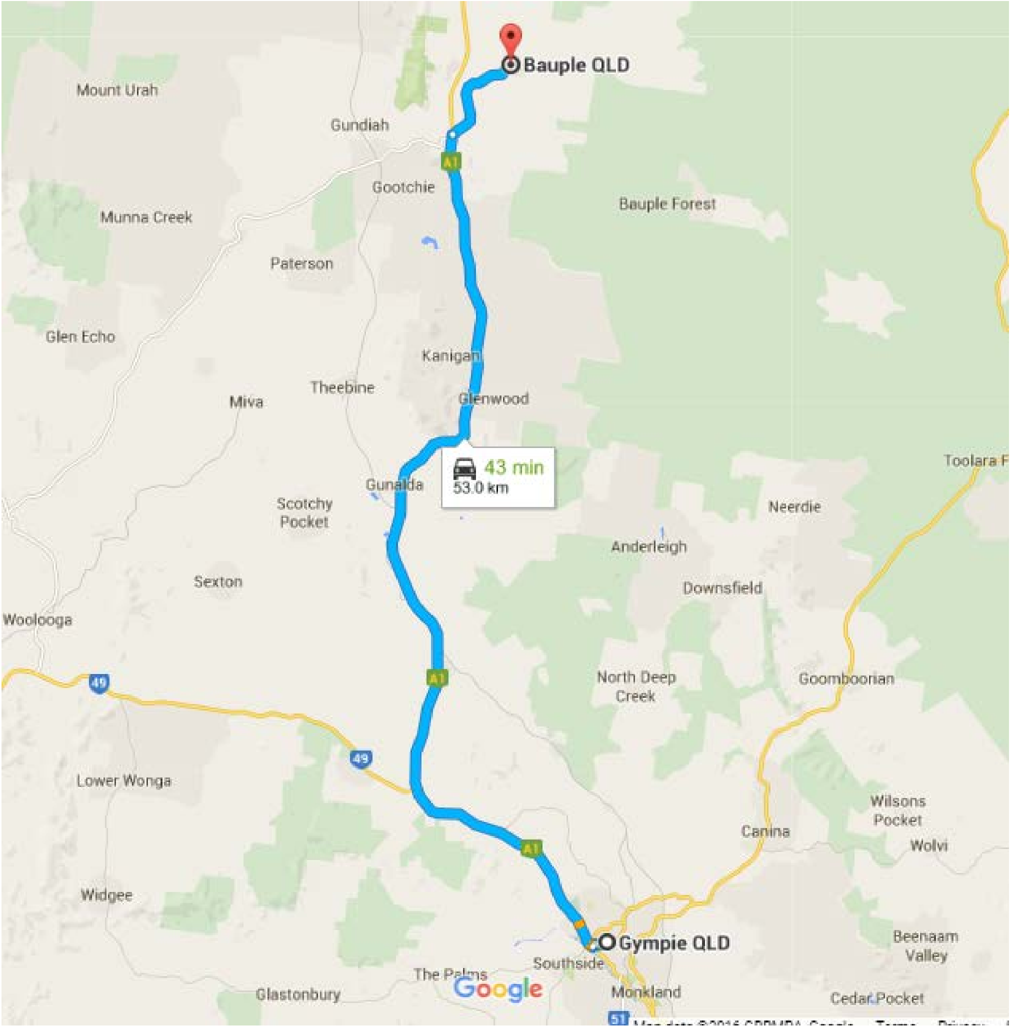
Melaleuca

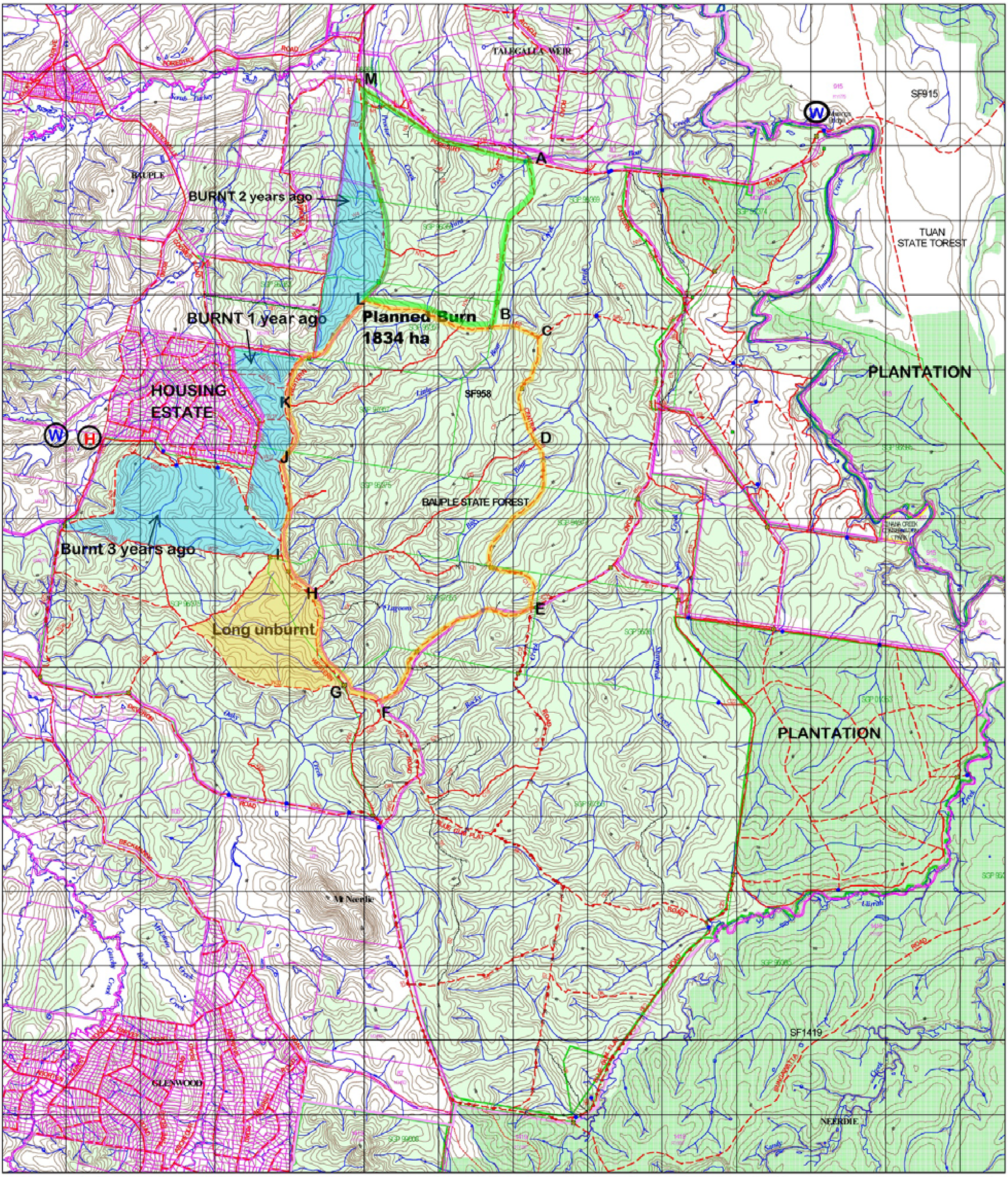
- **Fire intensity:** Low to moderate (Melaleuca open grassy/ferny woodland)
- **Fire frequency:** Fire interval range of six to twenty years
- **Season:** January to July
- **FFDI:** < 11
- **DI (KBDI):** Ideally 60—80, but < 100
- **Wind speed:** < 15 km/hr.

Hazard reduction burning for mitigation

- **Fire intensity:** Low and occasionally moderate.
- **Mosaic:** 70—80 per cent burnt.
- **Season:** January—August. Avoid periods of increasing fire danger.
- **FFDI:** < 12
- **DI (KBDI):** < 120
- **Wind speed:** < 15 km/hr.

Maps


Bauple QLD
Mount Urah
Gundiah
Gootchie
Munna Creek
Bauple Forest
Paterson
Glen Echo
Kanigan
Theebine
Miva
Glenwood
43 min
53.0 km
Gunalda
Toolara F
Scotchy Pocket
Neerdie
Anderleigh
Sexton
Downsfield
Woolooga
North Deep Creek
Goomboorian
Lower Wonga
Wilsons Pocket
Canina
Wolvi
Widgee
Gympie QLD
Beenaam Valley
Southside
The Palms
Glastonbury
Google
Monkland
Cedar Pocket



NOTES

Source .
Queensland Parks and Wildlife Service data sets.
Cadastral data compiled from DCDB.
Topographic data courtesy AUSLIG.

Projection
UTM (MGA zone 56)
Datum : GDA 94

ACCURACY STATEMENT
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MAP PRODUCTION
Forest Management
Queensland Parks and Wildlife Service
Environmental Protection Agency
Maryborough.

VEGETATION

Accuracy - Enlarged from 1:100,000 scale mapping.
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Compiled from EPA Regional Ecosystem (Version 3)

- Open Forest
- Rainforest
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- Cleared
- Plantation
- Water

CADASTRAL INFORMATION

- Cadastral Boundaries
- Forest Reserve Boundary
- State Forest Boundary
- FPQ area Boundary
- National Park Boundary
- Dedicated Road
- Stock Grazing Permit Boundary

GPS Controlled
ROADS and FIREBREAKS

- Highway
- Sealed
- Unsealed (Class 1,2 and 3)
- 4WD Track or Firebreak (Class 4)
- Untrafficable (Class 5)

GPS Controlled POINTS

- Bridge, Causeway
- Gate
- Grid
- Pipe
- Quarry
- Ramp
- Yards
- Water Point

TOPOGRAPHIC INFORMATION

- Rivers and Creeks
- Contours - 5 meter interval - AHD

CADASTRAL INFORMATION

- SGP 01/053 Stock Grazing Permit Number
- 12 Real Property Description

SCALE 1: 25 000

EDITION July 2007

N

Queensland Government
Queensland Parks and Wildlife Service

GDA

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Burn plan template

1. GENERAL INFORMATION

Burn plan prepared by:

Burn to be conducted by (agency):

Burn to be conducted by (person responsible):

Reserve name:

Area of burn (total ha):

What year do you hope to do the burn?:

Burn season/month:

2. OBJECTIVES OF BURN

Fire management zones included:

Measurable objectives for each vegetation type with fire management zones:

Zone/ vegetation type	% of the proposal area	Fuel loads	FMC desired	Fire intensity desired	Measurable objectives and/or indicators

3. PRESCRIPTIONS

Burn prescriptions and constrains (complete as applicable):

Season (if applicable)	Wind speed km/h (approx/range)	Wind direction (range)	Temp. °C (range)	Rel.hum.% (range)	Ignition time (approx/range)	Drought Index	Forest FDR / FDI	Grass % curing (approx/range)	Grassland FDR / FDI	Other (e.g. soil moisture, dewpoint, fuel load)
Day of burn										
Days following burn										

4. MAP

Attach a burn map
(tick items included,
note: items in **bold** are essential):

- ☐ **Proposal number**
- ☐ **Area(s) to be burnt**
- ☐ **Preliminary burns (if any)**
- ☐ **Fire control lines — labelled**
- ☐ ignition point(s)
- ☐ relevant fire history information
- ☐ neighbours (if relevant)
- ☐ monitoring plots (if any)
- ☐ topography
- ☐ safety refuge areas (if relevant)
- ☐ important crew locations
- ☐ **Vegetation (basic)**
- ☐ reserve boundary
- ☐ **Infrastructure**
- ☐ access routes (with distances)
- ☐ water points

5. BURN OPERATIONS

Details of operational strategies for the burn (relate to "burn map"):

Pre-ignition preparatory works required:	
Ignition strategies:	
Crew movements and patrols:	
Post-fire rehab required:	
Contingency fall back lines (identify on map) and strategies:	

6. RISKS

Analysis of specific risks:

Risk	Nature of risk	Minimised by
Personnel involved in the burn (Only trained staff may attend fires and they must have correct PPE)		
Public and users of reserve		
Neighbouring life & property		
Natural & cultural values		
Park infrastructure		
Smoke hazard		

7. RESOURCES

Resources required for the burn (complete as applicable):

Item		Source (location)	Type	Quantity (e.g. unit of measure)	Days required	Hours required
Personnel	Preparation stage					
	Ignition and mop up					
	Patrol					
	Rehabilitation					
Vehicles	Preparation stage					
	Ignition and mop up					
	Patrol					
	Rehabilitation					
Plant and equipment	Preparation stage					
	Ignition and mop up					
	Patrol					
	Rehabilitation					
Traffic control						
Contingency						
Aircraft hire						

8. NOTIFICATIONS

List notifications required:

Contact	Address/organisation	Phone

Review Activity 2: Pre-burn briefing

Read the below scenario and study the burn plan and map provided. Based on the scenario, burn plan and map, and any other information you think relevant, complete a written briefing to be delivered to your crews.

The briefing should be in a SMEACS format and should include the operational details (including a detailed ignition plan) of how you would implement the burn based on the scenario provided. You should calculate FFDI (using a McArthur Meter) and make fire behaviour predictions (using a suitable fire behaviour model) based on the information provided, and let this help inform your implementation strategy. Reviewing Part D of this learner resource will assist in completing this activity. It is recommended the following information be included in your briefing.

Situation – the current and predicted situation, including:

- the burn site and reason(s) for the burn
- current and expected weather
- at-risk values to be protected
- a summary of resources deployed.

Mission – the statement of the specific objectives set for the burn.

Execution – how the mission will be accomplished; that is:

- strategies and tactics
- constraints
- task and resource allocation
- access around the burn site
- ignition times, ignition plan
- immediate tasks after briefing
- contingency plans.

Administration – Logistics for the operation including:

- key support locations and roles
- burn staging area
- catering
- supply
- ground/medical support.

Command and Communications – Burn Management Structure including:

- sectorisation
- reporting relationships and times
- the Communications Plan
- contact numbers, radio channels.

Safety – Identification of known or likely hazards including:

- weather
- ‘Watch-out’ situations
- safety equipment required and protective clothing standards
- welfare, hydration and first aid.

Burn plan

Note: There is more than one possible solution appropriate for this scenario, only one of which is offered below.

1. GENERAL INFORMATION

Burn plan prepared by: Jonie Joe

Burn to be conducted by (agency): Queensland Parks and Wildlife Service

Burn to be conducted by (person responsible): Joe Bloe

Reserve name: Bauple State Forest

Area of burn (total ha): 1834

What year do you hope to do the burn?: 2016

2. OBJECTIVES OF BURN

Fire management zones included:

Bushfire Mitigation Zone

Conservation Zone

Measurable objectives for each vegetation type with fire management zones:

Zone/ Vegetation Type	% of the proposal area	Fuel loads	FMC desired	Fire intensity desired	Measurable objectives and/or indicators
Bushfire Mitigation Zone/ Open Forest	60	12-18	9-16	Low to mod	Reduce the overall fuel hazard to below moderate over 70% of the target area (use Victorian Overall Fuel Hazard Guide)
Bushfire Mitigation Zone/ Melaleuca woodland	10	12-18	13-16	Low	Less than 30% of ecosystem burnt. Do not specifically target but some fire encroachment is ok.
Conservation Zone/ Open Forest	30	12-18	9-16	Low to mod	40 — 80% mosaic burnt (with grassy areas more extensively burnt then shrubby areas) 90 % of clumping grass bases remain as stubble in grassy areas

3. PRESCRIPTIONS

Burn prescriptions and constrains (complete as applicable):

Season (if applicable)	Wind speed km/h (approx/range)	Wind direction (range)	Temp. °C (range)	Rel.hum. % (range)	Ignition time (approx/range)	Drought Index	Forest FDR / FDI	Grass % curing (approx/range)	Grassland FDR / FDI	Other (*e.g.* soil moisture, dewpoint, fuel load)
Day of burn										
January til July	<15	Easterly	Not specified	Not specified	Afternoon most likely, depends on diurnal conditions	<100	<11 but <8 ideal	NA	NA	
Days following burn										
	<15					<100	<11			

4. Map

Attach a burn map
(tick items included,
note: items in **bold** are essential):

- [x] **Proposal Number**
- [x] **Area(s) to be burnt**
- [ ] **Preliminary burns (if any)**
- [x] **Fire control lines — labelled**
- [ ] ignition point(s)
- [x] relevant fire history information
- [x] neighbours (if relevant)
- [ ] monitoring plots (if any)
- [x] topography
- [x] safety refuge areas (if relevant)
- [x] important crew locations
- [x] **Vegetation (basic)**
- [x] reserve boundary
- [x] **Infrastructure**
- [x] access routes (with distances)
- [x] water points

5. BURN OPERATIONS

Details of operational strategies for the burn (relate to "burn map"):

Pre-ignition preparatory works required:	Preparation and improvement of all fire control lines and contingency fall back lines ensuring they are to agency standard. Site safety checks including for hazardous trees. Check and clear any hazards on road edges that pose spotting risk. Mark trees at point 'L' and 'H' that pose a spotting risk and clear litter from around trees just prior to ignition.
Ignition strategies:	Ignite boundary from Point F to Point M forming a secure edge on the western boundary of the burn. Spot ignite using suitably spaced spot ignition, the interior of the burn site, light from ridges preferred. Once burn is well established, ignite from Point M through to Point F in order to consolidate the northern, eastern and southern burn boundary.
Crew movements and patrols:	Note that a sea breeze is common in this area at about 3pm, and though it will not impact on preferred wind direction, it may increase fire behaviour. Patrolling the area between Points 'G' and 'I' on the map is a priority as the area east of this is long unburnt. Be aware that any unexpected wind direction change could have consequences for fuels and plantations to the west, and therefore a contingency plan has been put into place (see below). Be aware of the need to monitoring conditions closely and be prepared to move crews to monitor the western boundary.
Post-fire rehab required:	Rehabilitate any temporary lines or track damage prior to leaving site.
Contingency fall back lines (identify on map) and strategies:	In the event of fire escaping into high fuels areas east of the burn site, and then getting out of control, ignition from fall back control lines may be necessary to create a new safe edge. Two fall back control areas have been highlighted in orange on the map east of the burn block. Ensure plantation owners are available to unlock any locked gates. Check for presence of public. Two further fallback areas have been identified south and southwest of the burn in the event that fire escapes into the long unburnt area or areas south. Also, ensure three fire crews from the Maryborough Operations Unit are available at short notice to support contingency operations if required.

6. RISKS

Analysis of specific risks:

Risk to:	Nature of risk	Minimised by:
Personnel involved in the burn (Only trained staff may attend fires & they must have correct PPE)	Safety zone and escape in the event of worse than expected fire behaviour	The area west of points J and K on the map have been identified as safety zone, as this is a Protection Zone that was recently burnt and still contains very low fuel loads. From point J, an escape route has been marked on the map in black highlight.
Public and users of reserve	Presence of public.	Signage should be erected on roads and at the edges of the burn site, advising of the burn. Check for users prior to burning.
Neighbouring life & property	The Plantation is a multi-million dollar silviculture resource. Nil Burn area with high fuels	Advise plantation owners and see contingency plan. There is an area that has not been burnt for a long time adjacent to the Western Boundary marked 'Nil Burn' on the map. Ensure a crew is patrolling the area between points G and I as the fire progresses, until conditions reduce fire behaviour to safe levels.
Natural & cultural values	The melaleuca woodland is an endangered ecosystem. Powerful Owl	It is within the vegetation type's fire regime to burn about 30% of this ecosystem at this time. It is downslope so should only be affected by backing fire and if FDI is less than 8, it would burn very patchily due to higher fuel moisture content in this ecosystem. Check fuel moisture on site. Avoid burning in late winter and spring.
Park infrastructure	Nil	
Smoke hazard	Smoke effecting housing estates west of the burn site. Smoke effecting local roads.	Letterbox drop week prior to burn. Erect signage advising of burn along roads. Use flashing lights on vehicles. Have traffic control resources on standby.

7. RESOURCES

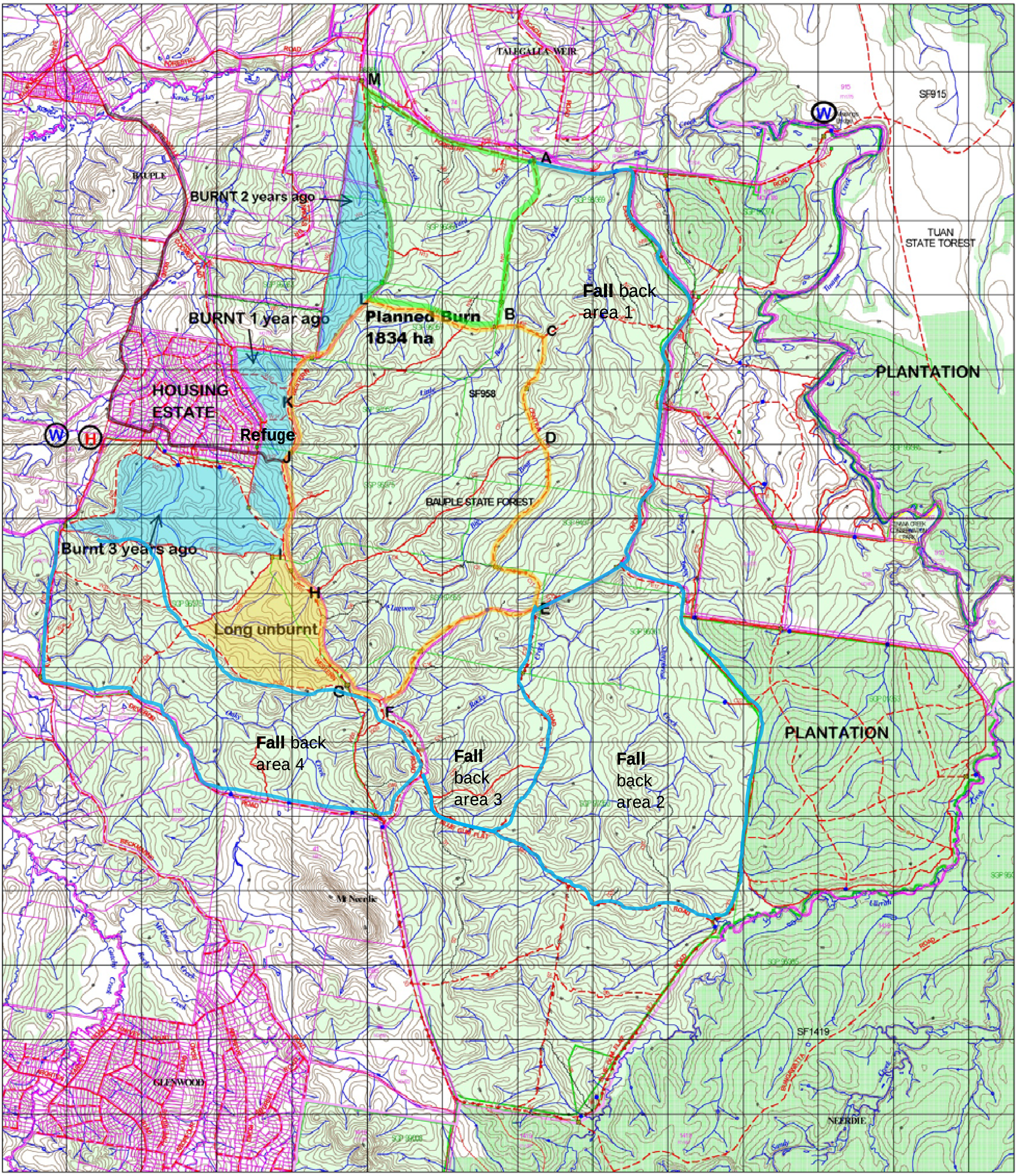
Resources required for the burn (complete as applicable):

Item		Source (location)	Type	Quantity (e.g. unit of measure)	Days required	Hours required
Agency Personnel	Preparation stage	Gympie		1		2
	Ignition and mop up	Gympie		8	1	8
		Rural Fires	4WD unit	4	1	8
	Patrol	Gympie		2	1	8
	Rehabilitation					
Vehicles	Preparation stage	Gympie	Any	1		2
	Ignition and mop up	Gympie	4WD unit	4	1	8
		Rural Fires	4WD unit	2	1	8
	Patrol	Gympie	4WD unit	1	3	24
	Rehabilitation					
Plant and equipment	Preparation stage	Hired tractor	Grader	1	1	8
	Ignition and mop up					
	Patrol					
	Rehabilitation					
Traffic control		Contractor	Personnel	1	1	6
Contingency		Maryborough	4WD unit and crew	3	1	6
Aircraft hire						

8. NOTIFICATIONS

List notifications required:

Contact	Address/Organisation	Phone
Charles Brown	DAF	07 #### ####
Operations Manager	Plantations Queensland	07 #### ####
Other standard contacts	See standard list.	



NOTES

Source:
Queensland Parks and Wildlife Service data sets
Cadastral data compiled from DCDB.
Topographic data courtesy AUSLIG.

Projection
UTM (MGA zone 56)
Datum : GDA 94

(C) The State of Queensland
Queensland Parks and Wildlife Service
January 2002

ACCURACY STATEMENT
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Forest Management
Queensland Parks and Wildlife Service
Environmental Protection Agency
Maryborough.

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Accuracy - Enlarged from 1:100,000 scale mapping. Suitable for Departmental use only.

Compiled from EPA Regional Ecosystem (Version 3)

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- Rainforest
- Open Forest / Rainforest mix
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- Plantation
- Water

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- FPQ area Boundary
- National Park Boundary
- Dedicated Road
- Stock Grazing Permit Boundary

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- Highway
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- Untrafficable (Class 5)

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- Bridge, Causeway
- Gate
- Grid
- Pipe
- Quarry
- Ramp
- Yards
- Water Point

TOPOGRAPHIC INFORMATION

- Rivers and Creeks
- Contours - 5 meter interval - AHD

CADASTRAL INFORMATION

- SGP 01/353 Stock Grazing Permit Number
- 12 Real Property Description

SCALE 1: 25 000

EDITION July 2007

GDA

N

Queensland Government
Queensland Parks and Wildlife Service

BAUPLE STATE FOREST

FTY1782

SF958

Scenario

You have been assigned the task of implementing a burn that is scheduled for today. You must prepare a crew briefing.

You have previously reviewed the burn plan and found it satisfactory. Site preparations and advance public notifications are complete. Public notifications and letterbox drops are complete. You have notified the necessary resources that are soon to gather at Point ‘J’ as indicated on the map for a briefing.

A site safety survey has just been conducted and three hazardous trees (with potential for branch drop) have been identified and marked. The site safety survey has also identified a mine shaft near Little Boar Creek close to Point ‘B’ on the map.

Your own inspection of the site has revealed steep slopes with shrubby fuels east of the fire control line between point I and G that are likely to present fire behaviour higher than predicted in the burn plan. There is also a small area of fuel build up next to the road at Point ‘D’ with an overall fuel hazard of ‘very high’ that was not previously picked up. Also, the road section between L and B is only trafficable to one vehicle width, which wasn’t indicated on the burn plan map.

You have checked weather predictions and had someone record current site conditions. These are still within prescription and are:

10 AM on site	• Wind direction: SE • Wind speed (km/hr 10 m in open): 10 average, 15 peak • FMC: 10% • Temp : 21 degrees • Humidity: 60%
Weather forecast for today	• Clear skies • Wind direction: SE, trending to east with 3pm sea breeze. • Wind speed (km/hr 10 m in open): 12 • Temp : 23 degrees • Humidity: 55% • KBDI: 70
Weather forecast for tomorrow	• Cloudy • Wind direction: NE, trending to east with 3pm sea breeze. • Wind speed (km/hr 10 m in open): 10 • Temp : 26 degrees • Humidity: 50%
Weather forecast for day after tomorrow	• Clear skies • Wind direction: SE, trending to east with 3pm sea breeze. • Wind speed (km/hr 10 m in open): 20 • Temp : 21 degrees • Humidity: 50%.

Appendix: Case Studies

Planning and implementing prescribed burns is a complex process and to do it well takes considerable practical knowledge. One way to quickly improve practical knowledge is to consider case studies. A list of case studies is provided below (sourced from AFAC 2016a) together with a brief synopsis of each. The reader is encouraged to follow the link to the full version of the case study online. These case studies are quite detailed and cover a range of iconic Australian ecosystems and prescribed burning situations.

Full case studies available at: **www.afac.com.au/initiative/burning**.

Case study 1: Bush-urban interface burning in the Blue Mountains of NSW

This case study incorporates burn operations planning and implementation practice information as well as the relevant fire science on which current procedures have been founded. It focuses on prescribed burning in public land managed by NSW National Parks and Wildlife Service.

Case study 2: Burning young silvertop ash regrowth forests in NSW

Young regrowth forests being managed for timber production and other values can suffer significant damage, timber value degrade, and productivity loss from fires of sufficient intensity to cause excessive stem or crown damage. Therefore, forestry organisations may seek to reduce the risk of future tree crop damage by bushfire, through conducting fuel reduction burning in regrowth forests that are suitably resilient to low intensity fire.

Case study 3: Low intensity burning in tall moist karri forests in Western Australia

This case study incorporates relevant fuel assessment fire behaviour prediction components from the Forest Fire Behaviour Tables for WA — commonly called the 'Red Book' and planning practice from the Department of Parks and Wildlife's Prescribed Fire Manual 2013.

Case study 4: Multi-year landscape mosaic burning in forested mountain terrain using natural boundaries in Victoria

This case study integrates knowledge and operational practice information from a range of sources including DELWP's Landscape Mosaic Burning Planning Guidelines, and burn planning information for the Lake Dartmouth Landscape Mosaic Burn Unit. It focuses on the Lake Dartmouth Landscape Mosaic Burn Unit in order to illustrate broadscale, unbounded mosaic burning.

Case study 5: Semi-arid mallee and mallee-heath burning in SA

This case study is a synthesis of semi-arid mallee and mallee-heath fuels, fire behaviour and burning information documented in reports from SA, Vic and WA. It incorporates burn operations planning and implementation practice information as well as the relevant fire science on which current procedures are founded.

Case study 6: Buttongrass moorland burning in Tasmania

This case study is a synthesis of buttongrass burning information documented in Buttongrass Moorland Fire-Behaviour Prediction and Management, Prescribed burning in Tasmania I, II, and III, and Parks and Wildlife Service Fire Planning Policy P- 055. It incorporates burning operations planning and implementation practice information as well as the relevant fire science on which current procedures are founded.

Case study 7: Burning for greenhouse gas abatement in northern Australia

This case study synthesises information from Russell-Smith *et al.*, with general procedural information about planning and implementing savannah burning.

Case study 8: Burning of spinifex grasslands in the arid interior of Western Australia

This case study synthesises information from Department of Parks and Wildlife's Prescribed Fire Manual, WA's Spinifex Grassland Fire Behaviour Guide — Mk 2, DPAW's Lorna Glen/Earaheedy Fire Management Plan 2011—2015, and annual operations implementation reports.

Case study 9: Burning for eucalypt forest health southeast Queensland/northern NSW

This case study summarises how a Vegetation Condition Assessment Framework is applied as part of the Burning Block Analysis Phase (Principles 1 and 2) to south-east Queensland conservation reserves.