

Planned burning in Tasmania. II. Fire risk assessment and the development of a standardised Burn Risk Assessment Tool (BRAT)

J.B. Marsden-Smedley^{1*} and S. Whight²

¹School of Geography and Environmental Studies, University of Tasmania,
Hobart, Tasmania 7000

²Parks and Wildlife Service Tasmania, GPO Box 1751, Hobart, Tasmania, 7001.

*e-mail: jon.marsdensmedley@utas.edu.au (corresponding author)

Abstract

Fire risk assessment is a standardised process used to identify whether or not a planned burn will achieve its stated aims, whilst also determining the potential consequences should the fire escape. As such, it is a critical component of the planning and approval process for planned burning. Fire risk assessment can also be used to predict the impacts (positive and negative) of different fire management strategies, including changes in the amount and location of planned burns, or changes in resource level and location. An important aspect of fire risk assessment is the requirement for practitioners to explicitly consider all of the major components of the burn, and in doing so identify what part of the burn is having the greatest influence on the risk profile. The Burn Risk Assessment Tool (BRAT), originally developed by Slijepcevic et al. 2007), is used to perform this assessment and provides a standardised, objective, consistent and repeatable framework for assessing planned burn risks. The BRAT provides information on the risk of fires escaping (i.e. likelihood of impact), potential of escapes to do damage (i.e. consequence), effect of strategies used to reduce the probability of escapes, and potential for the burn to meet fire management objectives. The BRAT assesses these impacts, consequences and benefits both categorically and numerically. The BRAT also predicts fire behaviour during the planned burn along with the likely behaviour in surrounding vegetation should the fire escape.

Introduction

This paper is the second in a series reviewing the systems used for conducting planned burning in Tasmania. The first paper covers the supporting information for conducting planned burning in Tasmania and reviews the available literature (Marsden-Smedley 2011a). The current paper covers fire risk assessment for planned burning and the development of a revised Burn Risk Assessment Tool (BRAT). The third paper covers the revised guidelines for conducting the burning (Marsden-Smedley 2011b).

Land management activities always contain some level of inherent risk. These risks are the result of a wide range of factors including (but not limited to) incomplete knowledge, incomplete, uncertain or inaccurate information, inappropriate actions by practitioners, and changing conditions. As an example, weather forecasts always have a degree of uncertainty due to issues associated with forecast accuracy and the requirement to extrapolate the forecast from the site for which it is made to the fire ground. Risk assessment can provide a structured, robust and repeatable methodology for addressing these issues and, in doing so, can minimise adverse impacts whilst maximising the probability of achieving target outcomes.

The major advantage of standardised risk assessment systems is their ability to provide a consistent and repeatable framework within which the risk assessment can be performed. These systems also clarify the compromises and trade-offs (including selection of the do-nothing option) that have to be made when performing operational land management (Kerns and Ager 2007). The major disadvantages of such risk assessment systems is that they may, if they have not been resolved properly, contain errors in the way they estimate risk, and may hide or make unclear the factors controlling the level of risk.

Risk assessment has an important role in the identification and documentation of the processes used for management. In doing so, risk assessment has the potential to enhance the ability of organisations and practitioners to learn from past practices and mistakes, and incorporate such lessons into current and future management strategies (e.g. Kerns and Ager 2007; Tabara *et al.* 2003; Martin *et al.* 2007; Morehouse *et al.* 2010).

Risk is defined as the likelihood that an event will occur multiplied by its consequence. For example, if an event is rated as having a high likelihood of occurring but a very low probability of causing adverse consequences, it will be rated as low risk. Alternatively, even if an event is rated as a low likelihood, if it has a very high consequence it may be rated as moderate to high risk.

Risk assessment can also provide an important role in the training of inexperienced practitioners. By guiding practitioners through, and making explicit, the different factors that need to be considered, structured risk assessments can be an effective strategy for identifying where inexperienced practitioners have inadequate training and experience, and can demonstrate where practitioners require additional training, coaching and experience. The process of conducting risk

assessments can also assist practitioners gain higher levels of competency (Arvai *et al.* 2001; Ehrlinger *et al.* 2008; Kruger and Dunning 2009).

In addition, planned burning typically is only one component of the duties and responsibilities of middle- and senior-level land managers. The use of structured risk assessment provides a system by which these managers can easily assess, approve and sign-off on planned burns while ensuring that all relevant factors have been included, considered and assessed.

Traditionally, risk assessments have concentrated on the likelihood of adverse outcomes, such as injury, fire escapes, property loss or adverse ecological outcomes (Tolhurst *et al.* 2008). However, the same process can equally be used to predict the likelihood of positive outcomes such as reduced fire risk or enhanced ecological outcomes (Kerns and Ager 2007).

Operational fire management is a good example of the need to balance such risks. When planned burns are conducted, practitioners almost always have to make compromises as to how the burn is going to be undertaken. However, by quantifying the relative risk of different potential outcomes and identifying which factors have the greatest influence on the level of fire risk, balanced assessments can be made. This should maximise the opportunities to complete the burn successfully, whilst minimising the risk of adverse outcomes.

In Tasmania, formalised fire risk assessment systems have been available for more than a decade (Marsden-Smedley and Chuter 1999; Slijepcevic *et al.* 2007). However, these systems have only been used to a very limited extent by fire practitioners and their utility under field conditions has been legitimately questioned. For example, feedback received by the authors from Tasmanian Parks and Wildlife Service field practitioners has shown that previous

BRAT version 2.xls [Compatibility Mode] - Microsoft Excel

Home Insert Page Layout Formulas Data Review View Developer Acrobat

Clipboard Font Alignment Number Styles

Conditional Formatting Insert Delete Sort & Filter Select Cell Styles Cell Styles Cells Editing

C7 = Butongrass moorland (Bs)

TASMANIAN PLANNED BURNING RISK ASSESSMENT TOOL		
Burn Name and Number		
		McPartian Pass
Name of person completing form		
		S Whight
Date of form completion		
		1/01/2010
Risk Factors - Likelihood. What is being burnt?		
VEGETATION TYPE		
Vegetation type	Inside burning unit	Butongrass moorland (Bs)
	Outside or adjacent to unit	Wet scrub (Ws)
FUEL CHARACTERISTICS, FUEL - HAZARD RATING AND TIME SINCE FIRE		
Time since fire	Age (years): inside burning unit	5 to <10 years
	Age (years): outside or adjacent to unit	25+ years
Butongrass moorland only	Productivity	Medium
Forest fuel hazard:	Surface hazard	Not applicable
Inside burning unit	Surface depth (mm)	Not applicable
Note: in dry scrub, heath, wet scrub and flammable weeds include values for elevated fuel height	Near-surface hazard	Not applicable
	Near-surface depth (cm)	Not applicable
	Elevated hazard	Not applicable
	Elevated fuel height (m)	Not applicable
	Bark hazard	Not applicable
Forest fuel hazard:	Surface hazard	Not applicable
outside or adjacent to burning unit	Surface depth (mm)	Not applicable
Note: in dry scrub, heath, wet scrub and flammable weeds include values for elevated fuel height	Near-surface hazard	Not applicable
	Near-surface depth (cm)	Not applicable
	Elevated hazard	Not applicable
	Elevated fuel height (m)	2 to 4 m
	Bark hazard	Not applicable
Grassland only	Degree of curing	Not applicable
Risk Factors - Likelihood. How secure are my boundaries?		
BLOCK & BOUNDARY TYPE		
Shape and size	Block shape	Regular with steep slope
	Block size	1011 to 500 ha
Slope and aspect - inside unit	Steepness of block	6 to 10 deg
	Position of block in landscape	Base of slope
	Aspect	NW to NE
Slope and aspect - adjacent to unit	Steepness of surrounds	11 to 20 deg
	Slope position	Mid-slope
	Aspect	NW to NE
Boundary	Planned boundary type	Wet scrub: 25 to 250 m wide
	Accessibility of planned boundary	Inaccessible
	Fallback boundary type	Wet forest/rainforest: 25 to 250 m wide
	Distance to fallback boundary	100 to 500 m
	Preparation works completed?	Unbounded burning
Risk Factors - Likelihood. What are the appropriate conditions to burn under?		
WEATHER PARAMETERS, FUEL MOISTURE AND FIRE DANGER RATING		
During the burn	Wind speed at 10 m (km/h)	15
	Relative humidity (%)	60
	Temperature (°C)	20
	Days since rain	4
	Amount of last rain event (mm)	5
	Season	Apr
	Soil Dryness Index	0 to 10
	Drought Factor: between 0 and 10	7
Fuel Moisture	Hazard Stick - internal	Not available
	Hazard Stick - external	Not available
	Fine fuel moisture (meter) - internal	Not available
	Fine fuel moisture (meter) - external	Not available
Atmospheric stability - Haines Index	Day of burn	L - 4
	Maximum over preceding 2 days	L - 4
Fire behaviour potential (fire danger rating)	Maximum FDR day of burn	<6
	Maximum FDR next day	6 to 10
	Maximum FDR over following 3 days	11 to 15
Risk Factors - Likelihood. What is the burning strategy?		
IGNITION STRATEGY		
	Lighting pattern	Lines or spots 100 to 300 m apart
	Lighting technique	Aerial incendiary capsule only
	Ignition duration	1 day
Risk Factors - Likelihood. What resources are required and where are they?		
	Personnel	11 to 20 people per km of boundary requiring lighting or support
	Appliances	No bushfire fighting vehicles, helicopter on-site
	Response time for additional resources	>6 hours
Potential Impact - Consequences. What are the potential negative impacts of this fire?		
Inside Burning Unit	Cultural	Rock paintings, wooden huts in good condition
	Ecological	Alpine vegetation, rare or threatened species
	Recreational	Minor visitor site or walking track
	Economic	Urban interface
Potential Impact - Consequences. What could happen if the fire escapes?		
Outside - adjacent to unit	Distance to asset	<100 m
	Cultural	Rock paintings, wooden huts in good condition
	Ecological	Native conifers and/or fagus
	Recreational	No visitor facilities or walking tracks
	Economic	Regrowth production forest
Potential Impact - Benefits. What are the positive impacts of this burn?		
	Distance to asset	<100 m
	Cultural	Rock paintings, wooden huts in good condition
	Ecological	Alpine vegetation, rare or threatened species
	Recreational	No visitor facilities or walking tracks
	Economic	Farms, mature production forest

Vegetation Select the dominant vegetation type of the block you are planning to burn

Data input form Risk output form Risk ratings Risk weightings Predicted fire

Figure 1. BRAT "Data Input Form"

systems have not dealt adequately with variations in the parameters required to burn in different vegetation types, or included appropriate assessment of fuel hazard. In fact, previous tools have largely been designed for one specific vegetation type (e.g. dry forest in the original version of BRAT: Slijepcevic *et al.* 2007).

The revised Burn Risk Assessment Tool (BRAT) presented in this paper has been designed to address these issues. It comprises a comprehensive review and updating of the previously described BRAT (Slijepcevic *et al.* 2007) and incorporates the outcomes of the recent review of planned burning in Tasmania (Marsden-Smedley 2009, 2011a, 2011b).

Burn Risk Assessment Tool

BRAT structure

The BRAT has been set up on an Excel workbook (Microsoft Corporation 2006) which contains a number of named worksheets. The first worksheet is version control, detailing when the BRAT was last updated and where, if required, the latest version can be obtained. Using the “Data Input Form” in a separate worksheet (Figure 1), the operator will select from a series of dropdown lists to input the parameters of the burn. The risk levels associated with the different parameters are then presented in the “Risk Output Form” on another worksheet (Figure 2). The BRAT also includes a number of worksheets that perform the large number

TASMANIAN PLANNED BURNING RISK ASSESSMENT TOOL			
Burn Name and Number		McPartlan Pass	
Name of Person Completing Form		S Whight	
Date of Risk Assessment		1/01/2010	
RISK FACTORS		Category	% rating
Fuel	Inside block	High	12.5
	Adjacent to block	Extreme	10.0
Weather	FDI: day of the burn	Low	0.9
	FDI: next day	Moderate	0.5
	FDI: following 3 days	High	0.3
	Stability: day of the burn	Moderate	0.5
	Stability: max over preceding 2 days	Moderate	0.3
	Fuel moisture	Extreme	7.7
Site factors	Inside block	Significant	2.6
	Adjacent to block	High	1.0
	Boundary factors	Extreme	7.8
Ignition strategy	Lighting pattern, technique and duration	High	2.8
Resources	Personnel and equipment	Extreme	7.5
	Response time for additional resources	Extreme	2.5
	Preparation works completed prior to burn ignition	High	5.0
BURN OVERALL RISK RATING		HIGH	61.7
CONSEQUENCES		Category	Rating
Inside	Cultural	Extreme	100
	Ecological	Extreme	90
	Recreational	High	50
	Economic	Low	0
Outside	Cultural	Significant	33
	Ecological	Moderate	24.75
	Recreational	Moderate	16.5
	Economic	Moderate	16.5
POTENTIAL BENEFITS FROM PERFORMING THE BURN		Category	Rating
	Cultural	Significant	33
	Ecological	Low	0
	Recreational	Moderate	16.5
	Economic	Moderate	16.5

PREDICTED FIRE BEHAVIOUR DURING THE BURN			
Inside burn block		Values	
Vegetation type inside burning block		Buttongrass moorland (Bs)	
Rate of fire spread	head fire	m/min	9.7
	flank fire	m/min	3.9
	back fire	m/min	1.0
Flame height	head fire	m	4.1
	flank fire	m	2.5
	back fire	m	2.1
Fire intensity	head fire	kW/m	3818
	flank fire	kW/m	1527
	back fire	kW/m	382
Fire Danger rating	dimensionless		7
Adjacent to burn block if fire escapes		Values	
Vegetation adjacent to burning block		Wet scrub (Ws)	
Rate of fire spread	head fire	m/min	51.7
	flank fire	m/min	20.7
	back fire	m/min	5.2
Flame height	head fire	m	4.1
	flank fire	m	2.5
	back fire	m	2.1
Fire intensity	head fire	kW/m	29907
	flank fire	kW/m	11963
	back fire	kW/m	2991
Fire Danger rating	dimensionless		11

Figure 2. BRAT “Risk Output Form”.

Table 1. Risk matrix used to guide the allocation of risk categories in the BRAT.

	Likelihood					
	1	2	3	4	5	6
Consequences	Practically impossible	Conceivable	Remotely possible	Unusual but possible	Quite possible	Almost certain
1 Noticeable	Low	Low	Low	Moderate	Moderate	Significant
2 Important	Low	Low	Moderate	Moderate	Significant	High
3 Serious	Low	Moderate	Significant	High	High	High
4 Very Serious	Moderate	Significant	High	High	Extreme	Extreme
5 Disaster	Significant	High	High	Extreme	Extreme	Extreme
6 Catastrophic	High	High	Extreme	Extreme	Extreme	Extreme

Derived from Australian and New Zealand risk management standard AS/NZS 2009.

of calculations required to estimate the risk profile of the burn.

The revised BRAT uses the Australian and New Zealand risk management standard (AS/NZS 2009) as its basis, and estimates the likelihood of adverse outcomes from conducting the burn. The BRAT provides information on the risk of fires escaping (i.e. likelihood of impact), potential of escapes to do damage (i.e. consequence), effects of strategies used to reduce the probability of escapes, and the potential for the burn to meet fire management objectives. These impacts, consequences and outcomes are assessed categorically (i.e. as being very low, low, moderate, high, very high or extreme) and numerically (i.e. between 0 and 100%). The benefits arising from a burn will relate to the management aims of the organisation performing the burn, and may include fuel hazard removal, ecological management and cultural management.

In some situations, for example unbounded burning in buttongrass moorland in south-west Tasmania, the likelihood of escape beyond planned burn boundaries is very high but the consequences of such an escape are very low (the sole consequence being that more of the target vegetation type is burnt) and a very low risk of adverse ecological outcomes. In such situations, the land management agency needs to determine if they are willing to accept the

risk of undertaking the planned burning operation. BRAT provides guidance, but the decision is a management decision.

Risk is analysed in two ways. Firstly, there is the inherent risk of the burn causing adverse outcomes. Secondly, there is an overall risk profile based on a matrix of the magnitude of adverse outcomes versus their likelihood (Table 1). By identifying where problems are likely to be encountered during planned burning, practitioners can take steps to minimise the factors causing these enhanced levels of risk, and hence reduce the risk of adverse outcomes.

Numerical weightings have been used in the BRAT for assessing likelihood. These weightings have been developed using expert opinion, with extreme values being assigned a weighting of 100%, very high ratings 90%, high ratings 75%, moderate ratings 50%, low ratings 25% and very low ratings 10%. To generate the overall risk profile of a burn, the scales of likelihood and consequence are used as described in Table 1.

The "Data Input Form" has seven sections: vegetation type; fuel characteristics; block and boundary types; weather parameters; ignition strategy and resources; potential impacts (consequence); and potential benefits arising from the burn. Where appropriate, within some of the sections there will be a series of vegetation-specific

sub-factors. Therefore, not all of the input parameters are used for all vegetation types, and the weightings vary between vegetation types.

The BRAT "Risk Output Form" reflects the structure of the "Data Input Form". An important aspect of the risk output is the prediction of fire risk and behaviour, both within and adjacent to the planned burning block. The BRAT not only predicts the risk associated with undertaking the burn, it simultaneously predicts the potential rate of fire spread, flame height, Byram's intensity (Byram 1959) and fire danger rating if the burn takes place with the weather and fuel parameters defined at input. The BRAT also predicts the potential fire rate of spread, flame height and Byram's intensity in surrounding vegetation should the fire escape.

Fire behaviour predictions are based on the following models:

- dry and damp forest and woodland: Vesta fire model (Gould *et al.* 2007a, 2007b);
- dry scrub and heathland: Heathland fire model (Anon 1998; Catchpole *et al.* 1998, 1999);
- wet scrub, flammable weeds and bracken: Scrub Fire Danger prediction system (Marsden-Smedley 2002);
- buttongrass moorland: Buttongrass moorland fire prediction model (Marsden-Smedley *et al.* 1999); and,
- native grasslands: CSIRO grassland fire prediction model (Cheney *et al.* 1993).

Look-up tables are used in the BRAT in order to ensure appropriate inputs are utilised. Other boxes on the form will require free text to input burn-specific information (e.g. the burn name, the person undertaking the risk assessment, how much rain last fell on the site etc.). When data are entered but the practitioner does not have information for a certain input, and selects "Unknown", then the BRAT will assume the worst-case scenario and use the highest risk level values for that parameter. For example, if fuel moisture is entered as "Unknown",

the BRAT will assume the fuel moisture is in the driest category (less than 10%).

A critical aspect of conducting planned burning is the balancing of different parameters for weather, site and ignition techniques. If a burn is conducted with the majority of its parameters at high levels, the risk of an adverse outcome will be very high. Conversely, if a burn is conducted with the majority of its parameters at low levels, it is probable that the burn will have insufficient intensity and coverage of the block to achieve the objectives of the burn. By including fire behaviour predictions on the "Risk Output Form", practitioners can calculate the likely burn-out time of their block, and assess the likelihood of the burn meeting their objectives.

Vegetation type

The vegetation associations used in the BRAT are based on the fire-attributes vegetation types published in Pyrke and Marsden-Smedley (2005), with the vegetation types inside and surrounding the planned burning block being selected using drop-down tables (Table 2). The look-up table for vegetation types within the burning unit is limited to those types suitable for planned burning.

Fuel hazard and time since fire

For effective planned burning, there needs to be a good understanding of what is being burnt, and how much fuel is present. All burning units need to be assessed for fuel hazard (structure and arrangement of fuels) and fuel age (time since fire). This information can only be gathered by undertaking a proper site-based fuel-hazard assessment, and looking at fire history records for an area.

The system for estimating fuel-hazard is detailed in Marsden-Smedley (2009, 2011a) and Hines *et al.* (2010). Information required will include surface fuel hazard, surface fuel depth (mm), near-surface hazard, near-surface fuel depth (cm), elevated fuel

Table 2. Vegetation types used in the BRAT.

Fire-attributes vegetation type		Suitability for planned burning ¹
Ac	alpine & subalpine heath with conifers and/or fagus	N
As	alpine & subalpine heath without conifers or fagus	N
Ag	alpine & subalpine sedge and/or grass without conifers or fagus	N
Sp	Sphagnum	N
Df, Dd	dry eucalypt forest and woodland	Y
Ds, Hh	dry scrub and heathland	Y
Dp	damp sclerophyll forest	Y
Wf, Wd	wet sclerophyll forest and woodland	N
Mf	mixed forest	N
Rc	rainforest with conifers	N
Rf	rainforest without conifers	N
Bs	buttongrass moorland	Y
Ws	wet scrub	Y
Wl	swamp and wetland	N
G	native grassland	Y
Sr	plantation	N
Ub	urban areas	N
We	flammable weeds (mainly gorse) and bracken	Y
Pt, Wt, Zz	other: agricultural land, water, non-vegetated	N

¹N, Not suitable. Y, Suitable

hazard, elevated fuel height (m) (for dry scrub, heathland and wet scrub), and the fuel hazard created by bark (in forested vegetation types).

When buttongrass moorland is present either within the burning unit or in the surrounding area, the site productivity (low or medium) and the time since the previous fire (i.e. fire age) are required. The methodology for determining these are detailed in Marsden-Smedley *et al.* (1999) and Marsden-Smedley (2009, 2011b). Site productivity and time since fire are not required for other vegetation types.

Burning block and boundary types

The shape, size and slope of the burning block are important influences on fire risk.

In general, more regular block shapes lead to lower fire risks, largely as irregularly shaped blocks have a greater boundary length to area ratio than regularly shaped blocks. In contrast, small blocks will generally have a lower fire risk profile due to their having a lower potential to support fast-moving fires and the shorter time period required to burn out the block. Block steepness has a major influence on fire risk due to the potential for fires to rapidly increase their rates of spread, intensity and spotting potential on steep slopes (McArthur 1967; see also Marsden-Smedley 2009).

The location of a block in the landscape has an important influence on its risk profile due to the potential for fires to run up-slope. Blocks located at the base of slopes, or mid-slope, have the potential to run up-hill should they escape. This is especially likely if they are

lit too intensely, lit under too high a fire danger, or if conditions change during the burn. In addition, if fires burn rapidly up hill, there is an increased risk of spot fires when the fire reaches the ridge crest, slows down and its convection column collapses.

Aspect has an important influence on fuel moisture through its influence on the amount of solar radiation reaching the ground surface (Nunez 1983). This is particularly an issue in Tasmania due to its latitude being between about 42° and 43° S. For example, Marsden-Smedley and Catchpole (2001) found that in buttongrass moorlands there was a gradient with aspect in fine fuel moisture and hence fire risk, with north-west aspects having the lowest fuel moistures and the highest fire risks, while south-east aspects had higher fuel moistures and lower fire risks.

Boundary type and accessibility also influence fire risk. Where burns are conducted with highly secure boundaries, the risk of escape will be greatly reduced. In contrast, where burns are conducted with low-security boundaries and preparation is incomplete, the risk profile will be greatly enhanced.

All four components of boundary and block types are assessed in the BRAT. In this section of the BRAT, dropdowns are used for each element being assessed. No 'unknown' categories are available in this section of the BRAT, as that would indicate an even greater risk for the burn – that no ground assessment was being undertaken as part of the preparation of the burn plan.

Weather parameters

The main weather factors influencing fire behaviour, and hence fire risk, are wind speed, relative humidity and recent rainfall (Marsden-Smedley 2009, 2011a; Sullivan 2009). Relative humidity and recent rainfall are the major influences on fuel moisture, with season and temperature having smaller and indirect influences.

Other than season and soil dryness index, all the weather parameters are entered as numbers into the BRAT. These can then be incorporated into the various fire behaviour models used in the "Risk Output Form".

Fuel moisture during planned burning is normally estimated from the prevailing weather and/or measured electronically using meters (Marsden-Smedley 2009, 2011a). Alternatively, fuel moistures may be estimated indirectly using hazard sticks (Eron 1991) or using the soil dryness index (SDI; Mount 1972); relationships between fire behaviour and hazard stick moisture or SDI are summarised in Forestry Tasmania (2005a, 2005b) and Marsden-Smedley (2009; 2011a).

Atmospheric instability has important influences on fire behaviour and hence fire risk (Haines 1988; Bally 1995; Mills and McCaw 2010). Although atmospheric instability has its greatest effects on the day of the burn, it also has significant influence in the days leading up to the day of the burn, with high levels of atmospheric instability resulting in decreased fuel moistures and, hence, enhanced levels of fire behaviour and fire risk.

The fire danger rating (FDR) integrates the influences of weather and fuel conditions on fire behaviour. In Tasmanian vegetation types, when the FDR is 10 or above the risk of fires burning with high rates of spread, intensity or spot fire potential will be high. When the FDR is used, it is critical that the correct rating system is used, with the Forest FDR (McArthur 1973) being used in dry forests and woodlands, the Moorland FDR (Marsden-Smedley 1993) in buttongrass moorlands, and the Scrub FDR (Marsden-Smedley 2002) in dry scrub, heathland and wet scrub.

Fuel moisture, atmospheric stability and fire danger rating are all selected in the revised BRAT from dropdown lists.

Ignition strategy and resources.

The strategy used to ignite burns can have a major influence on the resultant level of

fire behaviour. For example, edge lighting may take from several hours to many days to fully burn out a block. Conversely aerial ignition may be used to fully ignite and burn out a block relatively quickly.

The resources present at a burn, and the response time for additional resources should they be required, have a major bearing on fire risk. Where burns are being conducted with crews having to patrol long lengths of fireline, there will be enhanced risks of fire escapes. Conversely, on highly resourced burns, there will be a greater probability that crews will be able to suppress any escapes that do occur.

Potential impacts on cultural and social factors

Fire has the potential to impact negatively on cultural, ecological, recreational and economic values, depending on the sensitivity of these values and the characteristics of the fire. The presence or absence of these factors in the burning block and within the zone of potential impact needs to be considered. The BRAT does not apply a weighting to these factors, but instead allows the practitioner to subjectively decide which of the values at risk are the most vulnerable, or the most important to the wider community. Social factors and values associated with individual burns are thus not included in BRAT. This element will always require a subjective assessment based on the individual site, burn objectives and community attitude at the time.

Estimation of fire risk in the BRAT

Once the practitioner has entered the risk factors for their burn into the "Data Input Form" (Figure 1), the BRAT applies weightings to each risk factor. The resulting risk scores are combined to give an overall risk rating. The weightings used for the different vegetation types are given in

Table 3. Detailed information on the thresholds used for each of the input parameters is contained in the BRAT's drop-down table worksheet.

The practitioner then examines the "Risk Output Form" (Figure 2) to determine the fire risk profile of the burn. A critical objective of this process is to make explicit which of the risk factors are having the greatest influence on the risk profile of the burn, and hence which factors (if any) need to be modified in order to ensure the burn has an acceptable risk profile.

In the "Risk Output Form", the risk category (between low and extreme) of each of the risk groups is indicated along with the percentage weighting of each of these categories. For example, the level of fuel hazard has an important weighting in all of the vegetation types subject to planned burning, and as a result will normally have a significant weighting during planned burning. In contrast, aspect only has a minor weighting in the BRAT, and so even if burning blocks are located on north-west facing slopes (and hence are in the highest risk category for aspect) the percentage weighting for aspect will be small.

Discussion and conclusions

This version of the BRAT is the result of a comprehensive revision and update of the previous BRAT. This review and updating was required due to poor uptake of the previous version, and to extend the utility of the BRAT to the full range of planned burning performed in Tasmania.

Use of the BRAT aims to enhance the application of planned burning in Tasmania by providing a structured, robust and repeatable methodology for identifying the probability of different outcomes, and hence the major factors influencing the likelihood of different outcomes (e.g. fire escapes) and/or the likelihood that the burn will fail to achieve its target outcomes (e.g. be

Table 3. Percentage weightings applied to the different risk categories in the BRAT.

		Fire-attributes vegetation type ¹					
		Df, Dd, Dp	Ds, Hh	Ws	Bs	Gr	We
Fuel							
Inside burn block	Fuel-hazard	20	20	20	20	11	20
	Spotting	10	10	10	5	1	10
Adjacent to block	Fuel-hazard	10	10	10	10	6	10
Weather							
FDI	Day of the burn	10	7	12	8.5	20	12
	Next day	2	2	2	2	2	2
	Over following 3 days	1	0.5	1	0.5	1	0.5
Stability	Day of the burn	2	2	2	2	2	2
	Preceding 2 days	1	1	1	1	1	1
Fuel moisture	Inside block	2	5	5	0.5	6	3
	Adjacent to block	2	5	5	8	2	4
Site							
Inside burn block	Aspect	1	0.5	1	0.5	1	1
	Slope	3	3	3	4.5	5	3
	Position	1	1	1	1	1	1
Adjacent to block	Aspect	0.5	0.5	0.5	0.5	0.5	0.5
	Slope	1	1	0.5	0.5	2	0.5
	Position	0.5	0.5	0.5	0.5	0.5	0.5
Block type and boundary	Boundary type	3	3	3	5	5	2
	Boundary accessibility	3	1	1	2	4	2
	Shape	0.5	0.5	0.5	0.5	1	0.5
	Size	0.5	0.5	0.5	0.5	1	0.5
	Access within block	0.5	0.5	0.5	0.5	1	0.5
	Fall back boundary type and distance	1	1	1	2	2	1
Ignition							
	Pattern	3	3	1	3	3	2
	Technique	1	1	0.5	1	1	0.5
	Duration	1	1	0.5	1	1	0.5
Resources							
	Number of personnel	5	5	3	5	5	5
	Machines/Aircraft	2.5	2.5	2.5	2.5	2.5	2.5
	Response time	2.5	2.5	2	2.5	2.5	2.5
Preparation	Conducted prior to burn	10	10	10	10	10	10
TOTAL		100	100	100	100	100	100

¹Df = dry forest, Dd = dry eucalypt woodland, Dp = damp sclerophyll forest, Ds = dry scrub, Hh = heathland, Ws = wet scrub, Bs = buttongrass moorland, Gr = native grassland, We = flammable weeds and bracken.

performed at too low an intensity to reduce fuel hazards adequately). The use of this standardised and structured system will allow for a more consistent and repeatable application of risk assessment, and will also clarify and make explicit the compromises and trade-offs that have to be made when undertaking planned burning.

BRAT also allows the practitioner to identify the criteria that have the greatest influence on the level of fire risk, and hence how the risk may be reduced. If a burn has excessive risk, the practitioner can modify selected criteria to determine which parameters are elevating the burn risk, and which could be modified to minimise burn risk. For example, if a burn has excessive risks associated with spotting, the burn risk profile could be reduced by burning with lower Soil Dryness Index (SDI; Mount 1972), or at higher relative humidity, or in a cooler season, in order to increase the fine-fuel moisture content (i.e. the moisture content of fuel particles with a diameter of less than or equal to six millimetres, see Marsden-Smedley 2011a). Where spotting is identified as an issue, other risk management strategies could include increased resources, additional boundary works, or even moving the burn boundaries to a location with lower risk.

The BRAT also has an important role in documentation of the planned burn risk assessment process. Preparation and review of this documentation has the potential to enhance the ability of organisations to learn from past practices and mistakes (including during public inquiries or inquests), and incorporate such lessons into current and future management. The BRAT will play an important role in fire management training by guiding practitioners through, and making explicit, the different burn risk factors that need to be considered. It will assist senior managers or other responsible officers in their assessment and approval of planned burns. In addition, the BRAT could be used to assist with public education by providing information on the relative merits of different fire management options, and

the need to balance and manage numerous risk factors.

As an example, the Tasmanian Parks and Wildlife Service uses the revised BRAT as part of a standardised risk assessment in its planned burning procedures (Figure 3). Risk assessment is undertaken concurrently with the preparation of an Operational Burn Plan, with the “Risk Output Form” being submitted with the burn plan (and other relevant information such as traffic management plans) for the approving officer to review. Who can approve a burn plan is determined by the overall risk of the burn (Figure 3). If a burn does have an adverse outcome, it is appropriate for the risk assessment inputs to be reviewed as part of the standard after-action review process. Such reviews will help in the ongoing refinement of the model, and also serve as a check to ensure the burn was conducted within the parameters identified in the risk assessment.

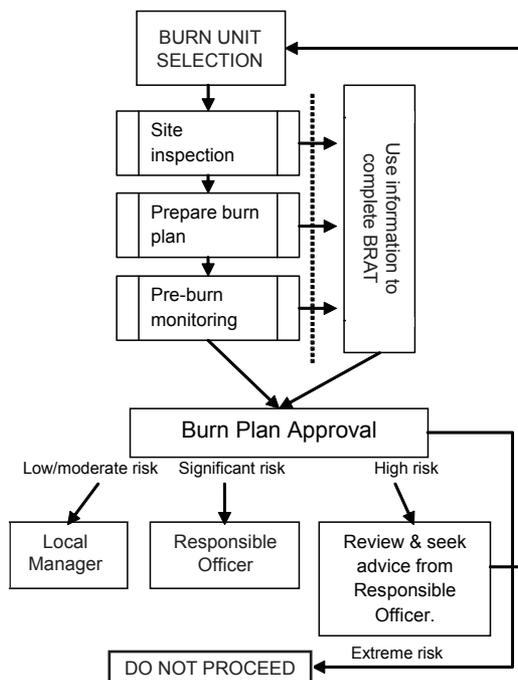


Figure 3. Example application of the Burn Risk Assessment Tool: Tasmanian Parks and Wildlife Service fire operations.

It is anticipated that the BRAT will be a dynamic system, and will be updated and expanded with new information and changes in procedures. Therefore, prior to conducting a planned burn, practitioners should ensure they have the current version, which will be available from the authors of this paper or from one of the Tasmanian fire management agencies.

This paper, reviewing fire risk assessment, is the second in a series updating the systems

used for conducting planned burning in Tasmania. The first paper in this series (Marsden-Smedley 2011a) covered the background information and literature regarding planned burning, while the third paper (Marsden-Smedley 2011b) covers the revised guidelines for conducting planned burning. The information and systems in these three papers will allow for enhanced application of planned burning for fuel management and ecological management.

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