Background briefings on emerging issues for fire managers from AFAC and Bushfire CRC.

FIRE NOTE

TOPICS IN THIS EDITION
- FUEL DYNAMICS
- RISK
- NATURAL ENVIRONMENT

ISSUE 127 JUNE 2014

FIRE CYCLE INSIGHTS AID IN BUSHFIRE BATTLE

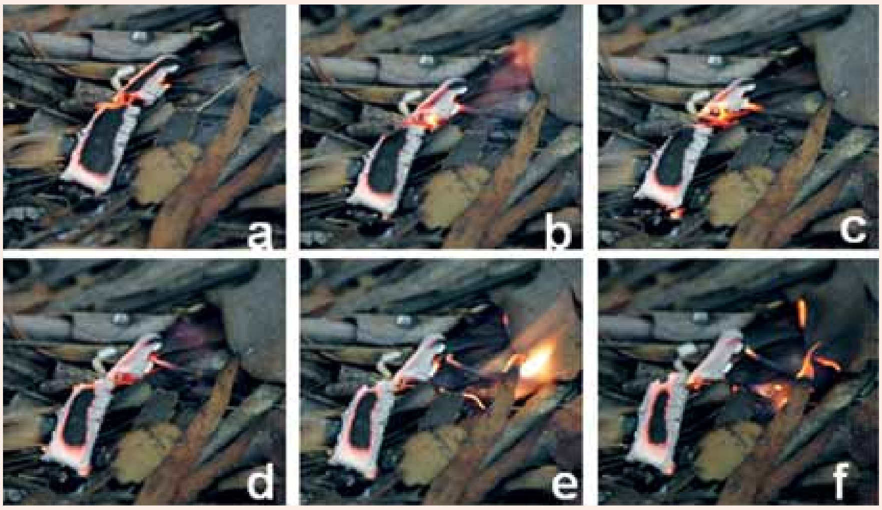

Figure 1: A sequence of six images 0.1 seconds apart showing the ignition of dry eucalypt litter by a glowing firebrand. The firebrand samples were selected to have the combustion and aerodynamic characteristics of small firebrands from the dry forests of southern Australia. See the 'Fire initiation from firebrands' section on page 2.

SUMMARY

Understanding how a bushfire progresses from ignition to conflagration is essential to planning effective suppression strategies and issuing public warnings – thereby saving lives. The period between a fire's ignition and when that fire attains its potential rate of spread for the prevailing conditions (its 'steady state') is the only time when an initial attack can be effective.

This work was the first comprehensive investigation of the factors influencing the lifecycle of a bushfire. It conceptualises a fire from its inception, through its development and growth (both horizontally and vertically) to the point where it begins to throw firebrands and start spotfires, which starts the cycle again.

From this knowledge, predictive models about the probability, number, size, and potential growth rate of fire ignitions were developed. These models can be used to help determine the most effective allocation and deployment of suppression resources, on both a seasonal and incident basis, within a framework of suppression-resource allocation that was also developed during this project. The models may also be applied to prescribed burn planning and implementation.

ABOUT THIS PROJECT

This *Fire Note* gives an overview of the results from the *Fire development, transitions and suppression* project, within the Bushfire CRC *Managing the threat* theme. It is the final *Fire Note* from this project.

AUTHORS

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RESEARCH RESULTS OVERVIEW

CONTEXT

The ability to predict just how fast a new fire outbreak takes to develop up to steady state is critical to effectively dealing with it. This project provides the first insights into the factors that influence the development of bushfires.

BACKGROUND

The time it takes for a fire that ignites from one point to reach its steady state rate of spread has never been investigated in detail. While it has long been known that the time depends upon the weather and fuel conditions, and can range between a few minutes to days, no useable understanding or predictive tool has been developed.

Existing operational fire prediction systems assume a fire has completed its development phase and is spreading at its steady state rate. However, a fire that starts from one point, as most bushfires do (be it from a lightning strike, accidental or intentional ignition), will take some time to reach this steady-state condition as it grows in size spatially and spreads into different layers of vegetation.

Assuming that the fire immediately spreads at the steady-state rate will over-predict the propagation of the fire and under-predict the potential for effective fire suppression, particularly during the early phase, the best opportunity for successful initial attack.

BUSHFIRE CRC RESEARCH

During the past decade fire agencies have increasingly needed to share suppression resources during peak demand periods.

This makes it even more important to be able to anticipate short-term fire danger, fire load (the extent, behaviour and density of fires in the landscape), and suppression-resource demands so that resources can be mobilised most effectively. Fire propagation and development information can be used with models of fire occurrence to better understand fire load. This information can assist decision making about resource requirements, allow fire authorities to better determine the transition between initial and extended attack, prioritise between fires, and generally improve planning.

This project investigated factors that are important in influencing the occurrence of bushfires, the successful initiation of spot fires from firebrands, the rate of growth and development of new fires that successfully ignite to steady-state rate of spread, and the transitions of such fires through vertical fuel strata as they increase in intensity and size.

The broad methodology techniques used ranged from case study analysis of historical data for the bushfire occurrence modelling, laboratory-based investigations of fire initiation success and fire-growth modelling, through to numerical modelling of fire transitions through vertical-fuel strata. Researchers developed predictive models about the probability, number, size, potential growth rate and propagation of fire ignitions. In each case, the researchers validated and tested the models against independent datasets to quantify model performance.

A theoretical basis was then used to design a framework within which these predictive models might be used to determine the most effective allocation and deployment of suppression resources in Australian conditions. While such frameworks exist overseas, there is no appropriate tool for Australian conditions. The proposed resource allocation framework, and the models on which it would rely, would form the basis for a nationally consistent, resource-allocation tool that would work over a range of spatial and temporal scales, from district or regional level incident basis, right through to a state and nation-wide seasonal basis.

RESEARCH OUTCOMES

FIRE OCCURRENCE MODELLING

This study investigated two key aspects of fire occurrence:

1. The relative timing of fire outbreaks from different causes.
2. The daily number of human-caused fires.

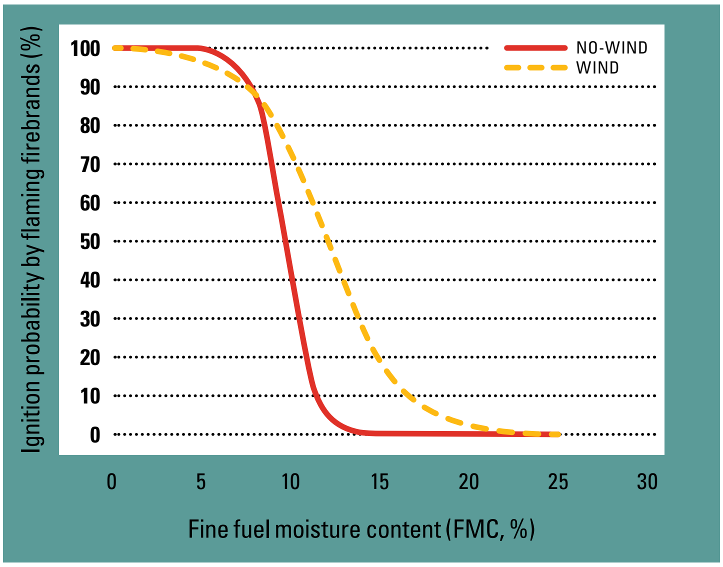


Figure 2: Probabilistic model for the successful ignition of a fuel bed by a flaming firebrand with and without a wind.

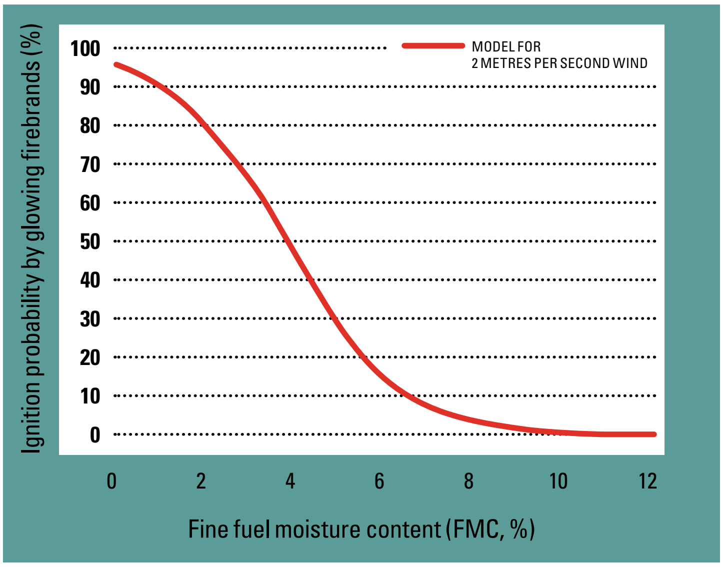


Figure 3: Probabilistic model for the successful ignition of a fuel bed by a glowing firebrand with a 2 m/s wind. In the absence of a wind, glowing firebrands will not ignite a fuel bed.

The study was undertaken using fire incident records and data from south west Western Australia.

As expected, the incidence of vegetation fires is strongly related to fire danger and fuel moisture conditions, with ignitions from all cause categories (covering such things as lightning, arson, accidents, etc) being more frequent during periods of elevated fire danger. The different cause categories had a range of sensitivities to fire danger and fuel moisture.

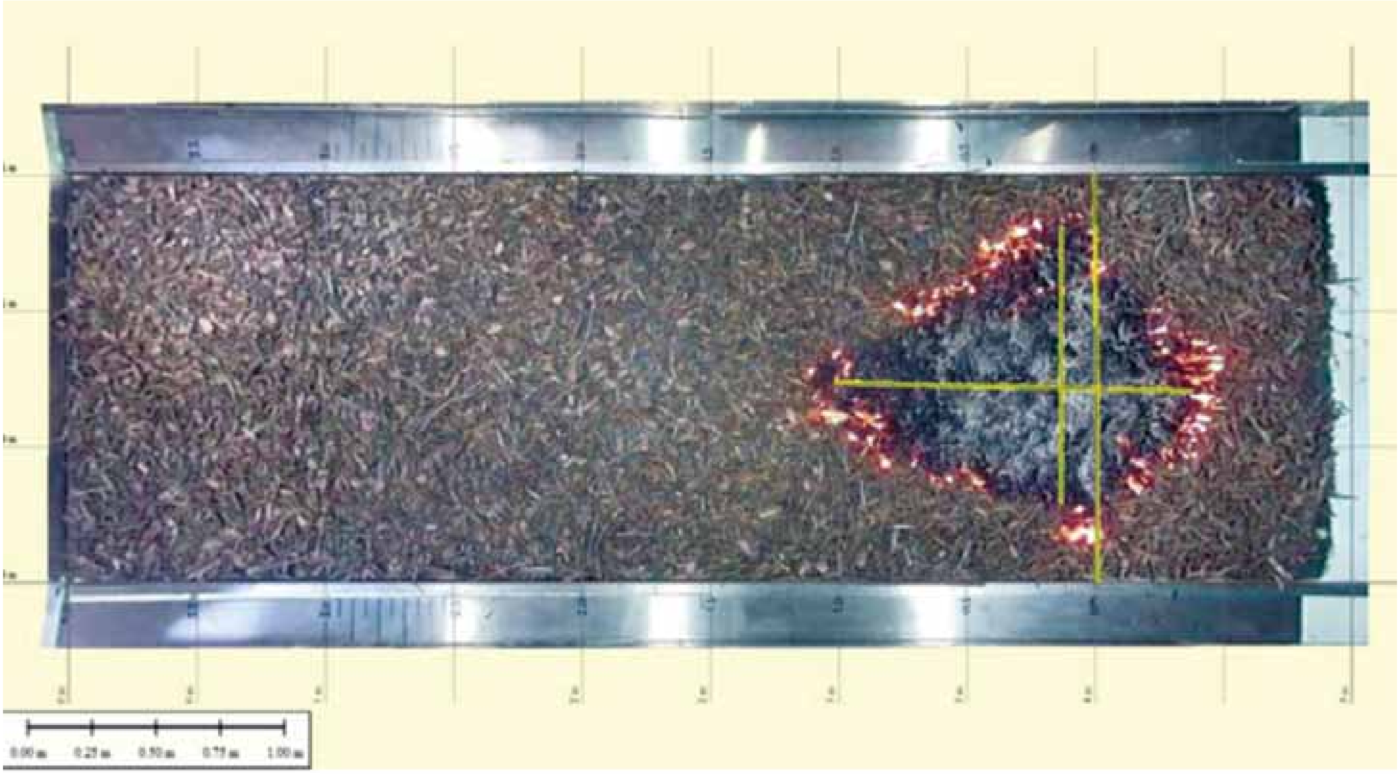
Findings show that the models have reasonable accuracy (between 81 and 99%). Fire management agencies could use these models to inform their daily operational resource planning. For full details of this study, see *Fire Note* 123 and Plucinski *et al* (in press).

FIRE INITIATION FROM FIREBRANDS

The objective of this study was to quantify the probability of flaming ignition of a selected fuel bed type by standard flaming and glowing firebrands. The fuel bed was the litter of a dry sclerophyll forest excised intact to preserve the structure of the profile to soil depth. The firebrand samples were selected to have the combustion and aerodynamic characteristics of small firebrands from the dry forests of southern Australia (Figure 1, page 1).

Ignition was studied in a small purpose-built wind tunnel that created air speeds of 1 m/s (metre per second) and 2 m/s across the fuel bed sample (equivalent to wind speeds of about 15 km/h (kilometres per hour) and 30 km/h respectively in the open for a dry eucalypt forest.

For flaming firebrands in the absence of wind, a fuel moisture content of 14% or less is necessary for ignition to commence, with a 50% probability of successful ignition once fuel moisture content is below 9% (Figure 2, above). In the presence of wind, the fuel moisture content can be as high as 21%, with a 50% probability of successful ignition once fuel moisture content is below 13%. At moisture contents less than about 7%, ignition is essentially guaranteed from



▲ Figure 4: Rectified plan image of an experimental fire in the CSIRO Pyrotron. From a series of such images, rate of spread can be measured with great precision.

any flaming firebrand equivalent to the standard sample.

For glowing firebrands, fuel-bed moisture content and wind speed were the key explanatory variables. For a wind speed of 2 m/s at the fuel level, a fuel moisture content of 10% is required for ignition from a standard glowing firebrand to commence, with a 50% probability of successful ignition once the moisture content is less than 4% (Figure 3, page 2). The importance of wind in ignition from glowing samples suggests that air-flow turbulence may play a large role in determining successful ignition from glowing firebrands.

FIRE GROWTH AND DEVELOPMENT

The CSIRO Pyrotron (a bushfire wind tunnel) was used to experimentally study fires ignited from a range of sizes in a continuous bed of fine, dry eucalypt litter fuel and rate of spread measured precisely (Figure 4, page 3). Two regimes of fuel bed moisture content and two regimes of wind speed were studied.

Rates of forward spread of fires were correlated with the size of the ignition as well as wind speed and moisture content, with fires from larger ignitions spreading more rapidly than those from smaller ignitions.

Fires from all line ignitions showed an immediate rapid increase in rate of spread over the first 1-1.5 metres that then reduced in magnitude before steadily increasing again. This ignition-line effect's similarity to large field experiments, like Project Vesta, suggested that some aspect of plume development is just as critical at the scale of the wind tunnel as it is in the field.

Analysis of these data resulted in a model that suggests that, under extreme fire weather conditions (fuel moisture content <5% and 30 kph wind speed), a fire starting from a point in uniform, dry sclerophyll litter will take about 20 minutes to reach steady-state rate of spread (Figure 5, page 4). Under milder conditions, a fire may take an hour to reach steady state.

The results of these studies are most applicable to prescribed fire, but they also provide important insights into fire development in eucalypt litter and indicate the importance of time in fire control, which increases with fire danger.

END USER STATEMENT

This project has significant implications for firefighting agencies. By providing a greater understanding of the conditions for fire initiation and growth, it could substantially increase the accuracy of fire-spread predictions. More accurate timing of early fire predictions will improve community warnings and advice and potentially save lives.

The results from this research will provide the evidence for fire agencies to refine management practices that rely on fire behaviour and fire load information. These improvements to operational procedures will increase firefighter safety, assist with resource allocation for first attack and potentially increase suppression effectiveness. For agencies with a volunteer-based workforce operating under heavier demands, greater efficiency in resource allocation is increasingly important. This work will play an important role in fire management in Australia in the future.

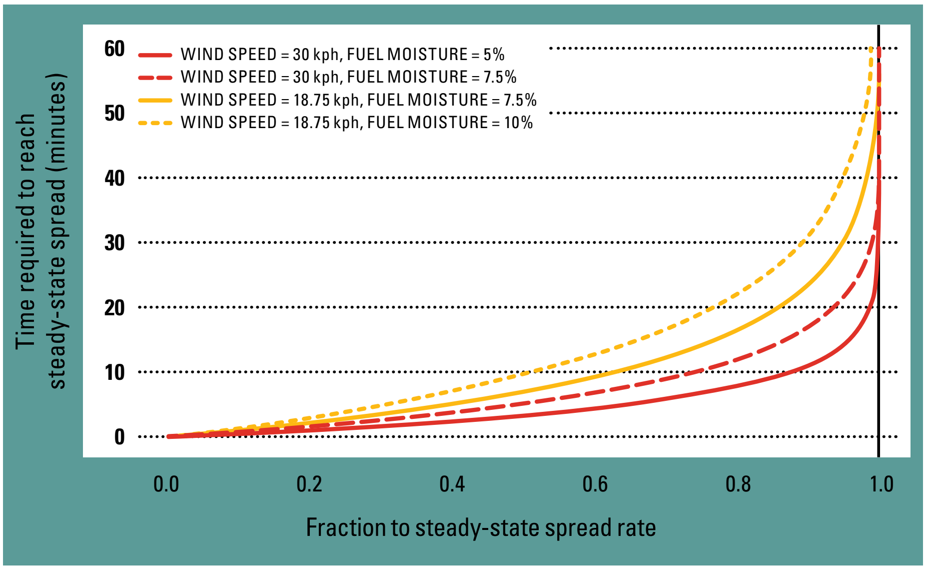
– Simon Heemstra, Manager Community Planning, New South Wales Rural Fire Services

VERTICAL FIRE TRANSITION AND PROPAGATION

This study investigated the growth of fire through the vertically separated, horizontally stratified structure of dry sclerophyll forests from a first-principles perspective. Each fuel stratum within a forest is distinct (e.g. surface, near-surface, elevated, etc) and plays a different but significant role in determining fire behaviour.

A model based upon the fundamental physics of conservation of energy, heat transfer and combustion was developed that describes the escalating behaviour of a fire burning in the understorey of eucalypt forests as it ignites and spreads through higher strata of fuel, from surface litter to near-surface, elevated and ultimately into the tree crowns.

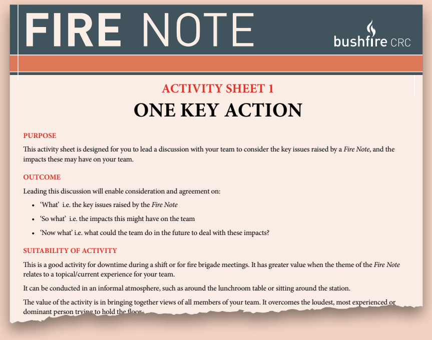
Preliminary evaluation against experimental



▲ Figure 5: Analytical model of time of growth of a point ignition fire to steady-state rate of spread. Under extreme weather conditions a fire in dry eucalypt forest may reach steady-state in 20 minutes.

NOW WHAT?

What three things stand out for you about the research covered in this *Fire Note*? What information can you actively use, and how? Tools are available at www.bushfirecrc.com/firenotes to help, along with activities you can run within your team.


FIRE NOTE

bushfire CRC

ACTIVITY SHEET 1

ONE KEY ACTION

PURPOSE

This activity sheet is designed for you to lead a discussion with your team to consider the key issues raised by a *Fire Note*, and the impacts these may have on your team.

OUTCOME

Leading this discussion will enable consideration and agreement on:

- 'What' i.e. the key issues raised by the *Fire Note*
- 'So what' i.e. the impacts this might have on the team
- 'Now what' i.e. what could the team do in the future to deal with these impacts?

SUITABILITY OF ACTIVITY

This is a good activity for downtime during a shift or for fire brigade meetings. It has greater value when the theme of the *Fire Note* relates to a topical/current experience for your team.

It can be conducted in an informal atmosphere, such as around the lunchroom table or sitting around the station.

The value of the activity is in bringing together views of all members of your team. It overcomes the loudest, most experienced or dominant person trying to hold the floor

fire data shows that the model works well, with acceptable agreement against expected trends and observed fire behaviour. However, a better understanding of the thermodynamic environment preceding a flame front is necessary to refine the model. This would require instrumentation of field fires.

FIRE-SUPPRESSION, RESOURCE-ALLOCATION FRAMEWORK

A conceptual framework for a suppression resource-allocation model suitable for use in Australia was developed. The framework uses inputs that describe the environment (weather, terrain, fuels and population), historical fire patterns, and suppression (resources and dispatch protocols) to calculate fire load and suppression capability available for each simulation scenario.

Fire load and suppression capability would then be entered into a containment simulation to estimate the suppression effort (e.g. resource use and cost) and the fire outcome (e.g. area burnt, time to containment). The containment simulation will be based on fire initiation, fire growth and fire transition models developed in this project, combined with suppression productivity models. Simulations spanning multiple fire seasons will be used to predict the long-term outcomes for each set of input scenarios.

Strategic resource-allocation modelling systems tailored for Australian regions would require considerable time and resources to develop and require significant support from fire management agencies. More information is available in Sullivan *et al* (2014).

FUTURE DIRECTIONS

This project provides the first insight into the behaviour of developing fires and is the basis for the development of a national bushfire suppression resource allocation tool for Australia.

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AFAC is the peak body for Australasian fire, land management and emergency services, creating synergy across the industry. AFAC was established in 1993.