Implications of Latest Fire Behaviour Research Findings on Fire Fighter Safety Management

N.P. Cheney

CSIRO Forestry and Forest Products, Canberra ACT, Australia

Abstract

The key finding over the last decade is that fire spread is dependent on the width of the fire front, and fires that remain narrow can maintain rates of spread that are well below the potential fire spread for the prevailing conditions. Firefighters undertaking initial attack have no indication that fires may rapidly increase spread rates for small changes in the weather or wind direction. However, an appreciation of the influence on fire width on fire behaviour and new findings that incorporate fuel structure into fire spread predictions can explain many of the "unexpected" changes in fire behaviour.

Despite the advances in academic understanding fire behaviour we have failed to advance teaching and training so that fire managers and firefighters on the fireline understand this knowledge. We need to examine the cultural changes that are influencing the way we tackle fire control and examine the need for a major overhaul of training programs to include practical demonstration of fire behaviour phenomena.

Introduction

The fundamentals of fire behaviour have been well understood for more than 40 years. The available load and structure of the fuel bed, the dead fuel moisture content and the wind speed and the slope of the ground with reference to the direction of the prevailing wind account for more than 80 percent of the variation in rate of spread of a fire burning at its quasi-steady rate of spread. This knowledge allowed the development of a range of burning guides and fire behaviour tables (e.g. McArthur 1962, Peet 1965, Sneeuwjagt and Peet 1976.) that enabled prescribed burning to be conducted with a high level of control. It also delivered the practitioners a good appreciation of the role of the key variables and a appreciation of the possible variation of fire behaviour, particularly at conditions beyond those prescribed for fuel reduction.

The guides worked at relatively low rates of spread because the time to build to a quasi-steady rate of spread was short and the variation in fire behaviour during the growth period was relatively small and therefore relatively unimportant. This period was assumed to be an inherent characteristic and it was generally assumed that for many fires the fires would reach a quasi steady rate in around 20 minutes (Luke and McArthur 1978, Van Wagner 1985, McRae 1999).

The increased variation of fire behaviour at high to very high burning conditions was recognised by people experienced in forest fire control but some considered that improved fire knowledge of high-intensity fires was not a particularly high priority because we can now directly monitor the current behaviour better than ever before (Johnson 1988) and crews can be deployed to sections of the fire where it is safe to work.

Importance of fire width

The role of head fire width on fire spread was first shown in grasslands (Cheney et al. 1993). The importance of increasing headfire width on the speed of fire growth (Cheney and Gould 1995) demonstrated that fires could burn at a quasi-steady rate of spread that was less than the potential rate of spread and the time to reach the potential rate of spread was pretty much stochastic and determined by the fluctuations in wind direction at a given mean wind speed. Relationships between headfire width wind speed and rate of spread similar to those for grassfires have now been established for fires in dry forest fuels (Gould et al. 2003, this conference). The rate of development of forest fires to their potential rate of spread can be very much longer than in grassland due primarily to differences in the rate of ignition and combustion of the coarser forest fuel particles, and the damping of fluctuations of the wind direction by the forest canopy. Under high to very high fire danger conditions, forest fires, starting from a point, may burn all day and still not develop sufficient width to reach their potential rate of spread (Gould et al. 1996).

This slow development combined with the characteristic of wide fires to reach their potential rate of spread immediately there is a change in wind direction (Cheney et al. 2001) is now recognised as critical feature of forest fire fighting that demands safe work practice to avoid being entrapped in the event of a sudden wind change. The concept of the Dead-man Zone has been incorporated in training lessons and a video (Watkins 1999) that has been distributed widely both in Australia and overseas.

The rate of development of fires starting from a point ignition is even more important than simply the potential for a wind change during initial attack. An experiment of 16 simultaneous fires in an 8 year-old jarrah-marri forest, measured by infra-red line scanning at around 7 minute intervals, revealed that forest fires starting from a point source do not necessarily proceed through a continuous build-up phase. 14 of the fires maintained very different quasi-steady rates of spreads that persisted for up to 3 hours while only 2 continued to grow during the same period and approached the potential rate of spread after 3 hours.

The different quasi-steady rates of spread were determined by a variety of factors. Some of them were obvious like burning on negative slopes in relation to the prevailing wind direction. Others were less obvious but probably occurred because the fires remained narrow due to interactions between the fire and the fuel type (Gould et. el. this conference). The mean rate of spread of all fires over 3 hours was 75 m/hr with a range 35 to 126 m/hr. The maximum 20-minute rate of spread measured on the fastest fire was 340 m/hr, which was approaching the potential rate of spread for the prevailing fuel and weather of 426 m/hr.

The potential rate of spread was more than 5 times the mean rate of spread of all fires and 12 times greater than the slowest fire even though this fire had maintained a constant rate of spread for 3 hours.

An observer on any single fire would get no idea of the potential rate of spread for the fuel and weather conditions even if he watched it for 3 hours. Thus it is essential to calculate the potential rate of spread when better fire spread tables become available (Project Vesta – see

McCaw et al. 2003 -this conference). If a single fire when observed on initial attack, or a test fire lit to assess the conditions is spreading well below the predicted potential rate of spread, then the observer needs to examine the characteristics of fuel, the fire shape and topography to see if there is some satisfactory explanation.

After 3 hours a series of close ignitions were lit along the upwind edge to burn out the block. These ignitions quickly formed a line of fire 1000 m wide that spread at around 2000 m/hr and over-ran slow spreading fires indicating there was adequate fuel to sustain the potential rate of spread throughout the block. This rate of spread is 26 times the mean spread rate of individual fires starting from points.

Importance of fuel structure

Although the structure of the fuel bed has been recognised as important and considerable effort has been taken to identify the effect of individual fuel components on the spread process (Rothermel 1972) there has been little success in identifying variables for natural fuel beds that adequately or accurately predict fire spread. In Australia we have used fuel load within a particular fuel type (McArthur 1962, 1967) while in the United States fuel types with different behaviour have been identified and assigned fuel characteristics derived from the laboratory that enable the fire model to fit limited observed data on fire spread (Andrews 1986). This approach is not particularly helpful when there is considerable variation within the fuel type, such as is associated with the age since the last fire.

Recent fire behaviour studies have been able to relate fire spread to a numerical quantification of fuel structure (Project Vesta – work in progress). This has allowed the building of a single model that applies to very different fuel structures in the dry forests of Western Australia. The application of this model to different fuel types including shrublands is planned and should give a much better link between fire behaviour and suppression difficulty.

Transfer of fire behaviour knowledge

Although we now have better knowledge of fire behaviour than ever before we seem to have increasing difficulty in transferring this knowledge to fire fighters and people at risk. Every fire season there are incidents that suggest that even the long-known fundamental principles of fire behaviour are not appreciated. Fire crews during the Ku-ring Gai prescribed burning incident attempted to light wet southerly aspects that were too moist to burn and then did not appreciate or anticipate the change in moisture content with aspect and increase the spacing of ignition points to prevent early coalescence of multiple ignitions.

Firefighters regularly light lines of fire during burning-out operations thus ensuring that fires burn at their potential rate of spread immediately and increase the chance of losing control of the fire line though spotting. Burning-out under very high fire dangers have not only extended the burnt area unnecessarily but burns have been set with firefighters directly down wind placing them in serious danger of entrapment (e.g. Linton Fire 1998)

Changes of wind speed and temperature are not always apparent in mountain forests but can be observed by placing an observer in an exposed location. Changes in moisture content are not easy to observe in advance. The relationship between relative humidity and fuel moisture has been long established and yet few, if any, fire management organisations have purchased reliable high-quality instruments to measure humidity or train their staff to maintain them properly.

The regular diurnal change of fire behaviour variables seems to be ignored. Fires continue to be lit on an increasing hazard i.e. in the morning before weather conditions have stabilised for the day. Inexperienced firefighters are surprised when fire behaviour responds to predicable and regular changes during the day (e.g. Messent National Park prescribed fire).

While such simple and fundamental principles of fire behaviour are not understood or ignored, there seems little point in introducing more sophisticated fire behaviour models that will give more precise estimates of fire behaviour. Fire behaviour models are being used more to justify policies and political positions than to manage fire fighter safety. As a result established principles are at best ignored and at worst misconstrued to give conflicting information to the firefighter and the public.

Safe work practice

Traditionally safe work practice has been linked to an understanding of fire behaviour. Even before our recent quantification of the role of fire width on fire spread experienced firefighters knew through practical experience the practices that were dangerous, situations that could dramatically increase fire behaviour and warning signs that indicated that dangerous fire behaviour was imminent even though observed fire behaviour was mild. Through their experience they understood the usual diurnal changes in weather variables and more importantly they understood the range of potential fire behaviour. Safe work practice based on planning for "worst possible" conditions was the norm.

They were aware that lighting lines of fire produced more rapid fire spread and that fire behaviour would be reduced if fires were lit so that they coalesced when the burning conditions were becoming milder. The safest place to work was directly on the fire edge with egress onto burnt ground and fire suppression was most effective if fires were attacked while they were small, when conditions were mild at night and before there was time for a significant deterioration of the weather.

Cultural changes have changed attitudes to fire suppression and the tactics employed. These include the expansion of parks and reserves with the concomitant reduction of production forestry in native forests, the decline in the forestry workforce and silvicultural burning, and most importantly the local knowledge of fuel and terrain.

There has been a dramatic increase in the role of emergency service organisations and the availability of a large workforce of volunteer labour means that firefighters can be mobilised over long distances and set to tasks on fires in fuels and terrain that is very different to their local experience. Increasingly fire fighting is carried out in the heat of the day when the fire behaviour has the potential to change rapidly and withdrawn at night on the grounds that conditions for fire fighting are unsafe. More resources are deployed than is necessary to do the task and if inadequately supervised, firefighters are likely to become bored and adopt a casual approach to fire suppression.

This workforce is increasingly tanker-based and is deployed on tasks that require a limited understanding of fire behaviour and priority is increasingly given to property protection rather than direct fire suppression. Burning-out from an established road network is often the only task they are capable of undertaking. Because large numbers of people are deployed who are unfamiliar with the terrain, fire fighting tends to be done during the day when there is less chance of getting lost en-route to the fire, and thus losing the valuable advantage of securing the fire at night when the fire behaviour is least intense and most stable.

Is there a way forward?

The fires of the 2003 summer demonstrated dramatically that the fundamentals of fire fighting remained unchanged. Initial attack has to be fast and efficient and the fire will not be secured until it is surrounded by a bare-earth fire line and all the fuel within the control line is burnt out. If initial attack is delayed beyond the first night and indirect fire fighting is deployed then the chances of containing the fire before the onset of extreme conditions is greatly reduced. When indirect attack has grossly enlarged the fire perimeter it is almost inevitable that extensive damage will result when fires develop conflagration proportions during extreme weather regardless of the number of people placed into property protection.

We have to recognise that there has been an immense change in the practical application of fire behaviour knowledge at all levels in our fire fighting community. This knowledge cannot be replaced by book learning by instructors who themselves have no practical fire behaviour and fire suppression experience. Fire behaviour officers who have not studied fire behaviour in the field need to be stood aside until they can back their academic learning with practical experience. Fire management officers and fire planners need to be able to demonstrate that their plans can meet the test of real fires and not theoretical simulations or desk-top fantasies.

All of this requires a restructuring of our training curricular. Universities and tertiary colleges should abandon the pretence of teaching fire behaviour if they are not prepared to expose their students to practical summer fire behaviour exercises that demonstrate the theoretical concepts learnt in the classroom. The fire agencies need to fill the inevitable gap. Each agency needs to create positions of fire behaviour research/instructors who can take the latest findings on fire behaviour and test them in the field so they can truly understand the inherent variation of fire behaviour and can properly instruct both staff and senior management on the consequences of agency policy.

We have pretended that prescribed burning is the way to give fire behaviour instruction yet most agencies do not use the available burning guides to determine the expected fire behaviour and determine ignition patterns. Fires are lit in a knowledge vacuum and while they may be observed nothing is learnt. The analogy is in sport. You don't play sport to get fit – you get fit to play sport. Likewise you don't undertake prescribed burning to learn – you learn to undertake prescribed burning.

Fire training areas need to be set aside (I seem to have said this before). Fire behaviour officers and their students need to adopt the procedure of predicting behaviour then lighting fires, throughout the year, to test the established guides and any theoretical concepts with practical exercises. Only then will we have a fire community that understands the phenomenon they are trying to manage.

Conclusion

We have made significant advances in our understanding fire behaviour in the last decade and can plan for safe work practice when fire fighters are engaged in direct fire fighting. The capacity of fires starting from a point-source to maintain a quasi-steady rate of spread that is well below the potential rate of spread for the prevailing conditions means that fire fighters need to understand the concept of potential fire behaviour and the factors required to predict it.

The increasing use of indirect fire fighting is accompanied by a reduction of fire behaviour knowledge. If the use of prescribed fire decreases there is less opportunity and less incentive to understand the nuances of fire behaviour. Our fire behaviour training curricular needs drastic revision and the provision for practical fire behaviour training in a range of fuel types and conditions to demonstrate theoretical concepts. If we do not address this problem we can expect there to be an increase in large fire incidents and the potential for fatal accidents in the future.

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