Fire Technology Transfer Note

Number - 14 December 1997

Fire growth, fire behaviour and firefighter safety - A review of the lessons from "A case study of grassland fire behaviour and suppression: the Tikokino Fire of 31 January 1991" by J.H. Rasmussen and L.G. Fogarty

Review by Liam Fogarty

Introduction

How fast can a fire spread? How quickly can a person run? The 1987 Boonoke[1] Fire, one of the fastest recorded grassland fires, had a head fire rate of spread (ROS) of 23 km/h (Noble 1991). Averaging 36.6 km/h, Donovan Bailey (the current world record holder) completed a 100 m dash in 9.84 seconds. Provided that the smoke didn't fill their lungs and sting their eyes so badly to temporarily blind them, someone running at this speed would have been able to outpace the fastest fire over a distance of 100 m. However, lacking the benefit of years of training for 10 explosive seconds on the track, and weighed down by our rural attire (heavy boots and overalls), many of us would be lucky to run at half the speed of Bailey, let-alone as fast as the Boonoke Fire!

Thankfully, most fires spread at speeds much less than 23 km/h. However, firefighters attending the Tikokino Fire of 31 January 1991 found that gusty and variable winds can change the direction and ROS of a grass fire so rapidly, that if they are located along a broad length of fire perimeter without adequate escape routes and safety zones, then they can be quickly overrun (Rassmusen and Fogarty 1997).
This *Fire Technology Transfer Note* (*FTTN*), will discuss aspects of fire growth, fire behaviour and firefighter safety, with particular reference to the lessons learnt from the Tikokino Fire. More details on the fire, evaluation of fire behaviour models and lessons learnt are presented in "A case study of grassland fire behaviour and suppression: the Tikokino Fire of 31 January 1991," and I urge you to read this report.

Fire environment and fire behaviour

Conditions preceding the Tikokino Fire had been dry, and most areas of unirrigated pasture on the flat coastal plains of the Hawkes Bay had died off to be 90 to 100% cured. Daily weather and selected Fire Weather Index (FWI) System values from Napier Airport (54 km away), combined with rainfall data from Gwavas Forest were: temperature 24.5 °C, relative humidity 31%, wind speed 56 km/h, Fine Fuel Moisture Code (FFMC) 91.9 and Initial Spread Index (ISI) 95. The Tikokino Fire, burning in light (estimated 2 t/ha) grass fuels, started at approximately 9.15 pm. No detailed weather readings were taken at the site, but firefighters reported that winds at the fire were occasionally so strong that they had difficulty standing up, and that the conditions had not changed much during the day.

31 January 1991 was a day of extreme fire danger (Figure 1) and, predicably, the Tikokino Fire exhibited erratic and uncontrollable fire behaviour. During the main run of the fire, it travelled 2910 m (±25 m) in 10 to 15 minutes. This is equivalent to a head fire rate of spread of 13 970 m/h (±3035 m/h) and an approximate head fire intensity of 13 970 kW/m

[1] The 1987 Boonoke Fire burnt an area of 120 000 ha in the western Riverina of NSW, Australia (Noble 1991). Midday weather and selected Fire Weather Index System values were temperature 40.6 °C, relative humidity 7%, wind speed 44.5 km/h, Fine Fuel Moisture Code 99.3 and Initial Spread Index 144.6 (Alexander and Pearce, unpublished data).

(±3035 kW/m). Halted by a combination of barriers to fire spread (roads, water races), the possible effect of a shelterbelt on retarding wind speed, and suppression action, the fire burnt 130 ha within 45 minutes of ignition.

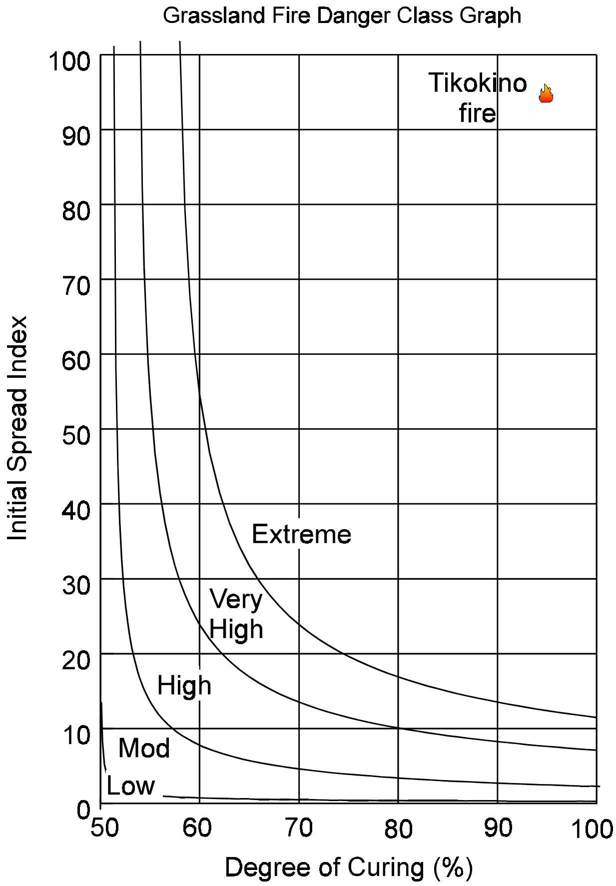

Figure 1. The grassland fire danger level on the day of the Tikokino Fire.

Firefighters overrun by fire

Initial attack had commenced by 9.24 pm. Figure 2 shows that at this time, the fire was no more than 250 m long and 30 m wide. The initial strategy was for two fire appliance crews to contain the grass fire by extinguishing the head and nearby flanks of the fire through direct attack. The crew of Appliance A moved up the north flank and found that the fire was moving more rapidly than they had anticipated. They decided to make a stand against the head fire near the first water race and positioned themselves near the intersection of the race and Makaroro Road, out of the smoke column to the north-east of the head fire (Point 1 in Figure 2). Appliance B had similar problems and moved to the water race ahead of the fire (Point 2 in Figure 2). As the firefighters from Appliance A were preparing to make a stand, the wind blew the head fire in a more north-easterly direction toward them. The speed of advance of the head fire increased and Appliance A and its crew, who were readying themselves to suppress the fire rather than make a rapid sprint to escape, were overrun. At that time, the fire was burning in light fuels and the flame front depth was relatively narrow, allowing the firefighters to step through the flames without injury. One firefighter who remained with the appliance was caught by the fire and suffered minor burns.

In order to avoid a similar incident, the crew of Appliance B retreated to Makaroro Road with the crew still on the back and dragging a hose reel behind the vehicle. Due to heavy black smoke forced along by strong winds, the crew feared for their safety and turned east down Makaroro Road. The fire gained momentum and spread across the road behind them. They were able to escape into the green lucerne crop (Figure 2) which halted the advance of fire on the southern side of Makaroro Road

Lessons from the Tikokino Fire

While providing initial attack firefighters at the Tikokino with a “never to be repeated learning experience”, the situation that they found themselves in was not unique. It was similar to many other incidents (both local and international) where death, injury and near miss events occur when one or more of the common denominators (i.e., small fires, light fuels that are often in an open area, changes in wind direction or speed, fires burning up steep slopes) are present (Wilson 1977, Millman 1993).

So why did the Tikokino Fire turn on the firefighters so dramatically? Grass fire behaviour is influenced by wind speed, fuel moisture content, degree of curing, the level of grazing or trampling, slope and head fire width (Cheney *et al.* in press), which affect rate of spread and, when combined with fuel load, determine fire intensity. Of these factors, wind and head fire width provide the key to explaining the dramatic change in fire behaviour experienced at the Tikokino Fire.

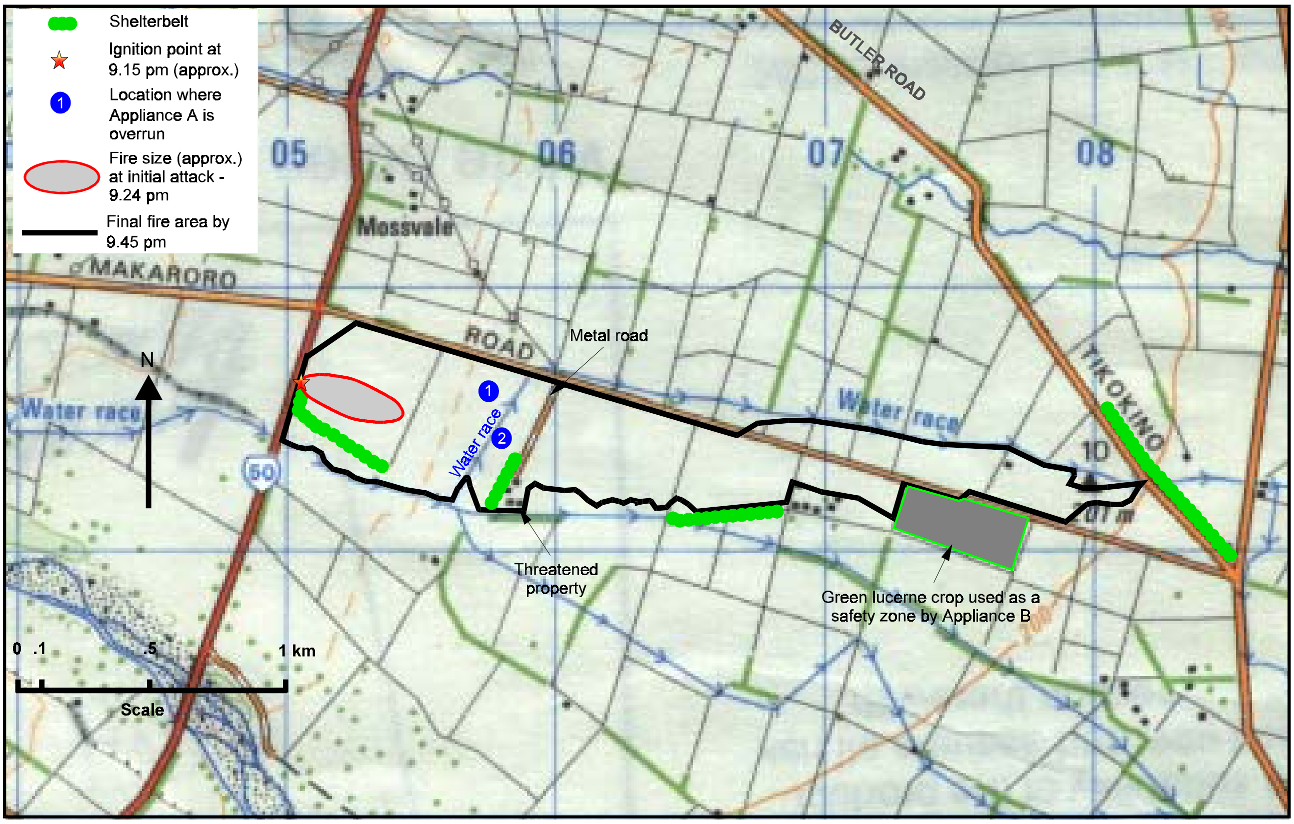

Figure 2. Map of the Tikokino Fire.

Wind

Wind drives grassland fires. Wind pushes a fire into unburnt fuels, blows the flame over to increase the rate of preheating and ignition, increases the supply of oxygen and throws a mass of embers ahead of the front, enhancing the combustion process (McArthur 1996). In unstable conditions such as those experienced at the Tikokino Fire, winds may fluctuate rapidly and sometimes violently, swinging 25 to 30^{o} either side of the prevailing direction and gusting 50% above and below the average speed. Because grass fires are exposed to the full force of the wind, the sporadic nature of wind in unstable conditions causes them to spread in fits and starts, making fire suppression difficult and dangerous (McArthur 1966).

Head fire width

The maximum ROS of grassland fires only occurs when the head fire is sufficiently large to interact with the prevailing conditions (Cheney and Gould 1995). In burning conditions such as those experienced at the Tikokino Fire, it is anticipated that a head fire width of over 250 m would have been required before a fire could achieve its maximum potential ROS and intensity. Given the small size of the head fire at the time of initial attack, it is probable that the rate of fire spread was less than half the rate that could be expected if the Tikokino Fire was fully developed.

Fire growth, fire suppression and firefighter safety

When firefighters mounted their initial attack on the Tikokino Fire it was still growing. Because the head fire was still small, the fire was not exhibiting the extreme fire behaviour that would threaten several firefighters and injure one.

Herein lies a problem for the initial attack fire boss. The initial growth phase of a fire can provide an opportunity for the suppression of fires that would be impossible to control once they reach their maximum potential rate of spread and intensity (Alexander 1992). However, analysis of the Tikokino Fire shows that potential fire behaviour can be easily underestimated during this growth phase. This is particularly the case at wildfires such as the Tikokino Fire, where unstable wind conditions are experienced. From the time that the fire is initially sized-up and suppression is initiated, short duration wind gusts may fan the fire in a number of directions and cause the head fire to widen rapidly. This action reduces the time taken for the fire to reach the size needed for reaction with the prevailing burning conditions and may cause a quantum leap in head fire behaviour when the wind returns to the prevailing direction. Similarly, wind gusts can temporally turn a flank (which is usually wider than the head in windy conditions) into a head fire. If firefighters are located in unburnt fuels as they were at the Tikokino Fire, the blow-out along the affected flank can endanger them.

After initial attack, the Tikokino Fire was contained by concentrating suppression efforts on the less intensely burning flanks of the fire. The success of this strategy reinforces the view of McArthur *et al.* (1982) that, in Extreme fire danger conditions, firefighters should move from the rear toward the front of the fire, using a blacked out edge nearby to provide an easily accessible safety zone. In less extreme conditions, it may be tempting to directly attack the head of the fire, but if a fire can be contained using this approach, then it can be successfully and more safely be contained by attacking the flanks, following the recommendations of McArthur *et al.* (1982).

Conclusion

Burning in severe weather conditions, the Tikokino Fire of 31 January 1991 exhibited extreme fire behaviour. At the time of initial attack, the head fire had not reached its maximum rate of spread and intensity, so firefighters attempted to make a stand to prevent further spread. At this time, gusty variable winds fanned the fire in a number of directions, and the north-eastern flank of the fire threatened several firefighters and injured one.

Firefighters attending vegetation fires need consider fire behaviour and safety related factors. These include:

1. The behaviour of fires in light and open fuel types is highly responsive to changes in wind speed and direction.
2. Fire growth and acceleration is influenced by time since ignition, as well as other factors that affect the development of the fire front (e.g., wind speed and direction, head fire width, slope and fuel type).
3. Gusty variable wind conditions that fan the fire in a number of directions can change fire behaviour dramatically. In particular, they can cause the size of the head fire to increase rapidly or turn a flank into a head fire.
4. Fire intensity, which varies around the fire perimeter and is generally greatest at the head, dictates the limits of effective fire control and should be considered in the development of fire suppression strategies.
5. Making a stand involves a high risk, particularly when one or more of the common factors associated with fatality and near miss events are present.

Acknowledgments

The comments provide on this FTTN by Grant Pearce and Ken Klitscher (FRI) are appreciated.

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