

Buckland's Crossing Firefighter Burnover— A Case Study of Fire Behaviour and Firefighter Safety Implications

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Abstract—On March 24, 1998, a crew of eight rural firefighters were burned over while attempting to suppress a backburning sector of the Bucklands Crossing Fire in North Otago, New Zealand. The fire demonstrates how factors typical of the New Zealand fire environment – steep slopes, highly flammable shrub fuels, and a strong foehn wind effect – combined to produce extreme fire behaviour. Several firefighters sustained varying degrees of injury. They were hit by a blowup that was most likely caused by a rapid reburn through previously underburned shrub fuels. The exact trigger for upslope spread and transition to a crown fire was not definitively identified; however, it was most likely the result of strong winds and localised turbulence, combining with steep topography and highly flammable, preheated shrub fuels. The case study report prepared on this burnover describes the activities of personnel leading up to and during the incident in relation to the fire environment and fire behaviour. Possible causes of the blowup are reviewed, and observed fire behaviour compared to that predicted by available models. Particular emphasis is placed on the contribution and alignment of fire environment factors and their role in triggering fire behaviour escalation. Aspects of firefighter safety during the incident are also discussed, including the performance of protective clothing. The findings highlight the need for increased training of firefighters in fire behaviour and, in particular, greater situational awareness of the fire environment and indicators of extreme fire behaviour potential. The case study provides a number of lessons learned that have relevance worldwide.

Introduction

On March 24, 1998, a crew of eight New Zealand rural firefighters were burned over while attempting to suppress a sector of the Bucklands Crossing Fire in North Otago, New Zealand, that was burning downhill. Three firefighters sustained burn injuries, one serious, and a fourth crew member was hurt escaping into previously burned fuels. The crew were hit by a blowup that was most likely caused by a rapid reburn through previously underburned shrub fuels, a situation highly reminiscent of the 1994 South Canyon Fire in Colorado, USA, where 14 firefighters were killed. The fire demonstrates how factors typical of the New Zealand fire environment – steep slopes, highly flammable shrub fuels, and a strong foehn wind effect – can combine to produce extreme fire behaviour. A case study produced on the incident describes the factors leading up to the burnover, and presents a number of key lessons learned that have relevance in New Zealand as well as for the wider global fire community.

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Case Study

A detailed case study entitled “Fire behaviour and firefighter safety implications associated with the Bucklands Crossing Fire burnover of 24 March 1998” by Pearce and others (2004; see References section for ordering information) describes the activities of personnel leading up to and during the incident in relation to the fire environment and fire behaviour. Within the case study, possible causes of the blowup are reviewed, and observed fire behaviour is compared to that predicted by available models. Particular emphasis is placed on the contribution and alignment of fire environment factors and their role in triggering the temporary escalation to extreme fire behaviour. Aspects of firefighter safety during the incident are also discussed, including the performance of protective clothing. The findings highlight the need for increased training of firefighters in fire behaviour and, in particular, greater situational awareness of the fire environment and indicators of extreme fire behaviour potential. The case study provides a number of lessons learned that have relevance worldwide.

This paper (and the associated poster) aims to promote wider international awareness of the case study’s existence, and represents a further effort at information transfer that follows on from the communication of initial findings soon after the incident (Pearce and others 1998), the production of the detailed case study (Pearce and others 2004), and a brief review of the case study and key lessons learned (Anderson 2004).

Incident Summary

At 07:47 a.m. on Tuesday, 24 March 1998, a fire was reported by a local musterer on his way to work near Bucklands Crossing, some 40 km (25 miles) north of Dunedin (fig. 1). The fire is believed to have been ignited by sparks resulting from powerlines contacting adjacent vegetation in high winds (see fig. 2). Initially, NZ Fire Service structural firefighters from Waikouaiti and Palmerston responded. They were later supported by rural fire crews from Dunedin City Council, local forestry companies and the Department of Conservation. Two helicopters were also used, although the strong, gusty winds initially prevented effective aerial fire suppression.

At around 11:25 a.m., a crew of eight rural firefighters were burned over while attempting to suppress a backing sector of the fire. The crew had parked their fire appliance on the crest of a steep ridge in a burnt out sector of the fire, and were deploying a hoseline downhill toward a fire edge burning slowly downslope (see fig. 3). The fire had already burnt out the catchment on one side of this ridge and was backing downhill beneath manuka (*Leptospermum scoparium*) shrub fuels down into the adjacent catchment where the crew were deploying the hoseline. Before being able to charge this hoseline, the crew were overrun by a “fireball” exploding from the gorse-filled (*Ulex europaeus*) gully beneath them (see fig. 4). Three firefighters sustained burn injuries, one serious, while a fourth crew member received minor injuries whilst evacuating. The driver and another crew member took shelter behind the appliance and, along with the remaining two crew members, were uninjured. (Fire shelters are not used in New Zealand, so their use was not an option available to firefighters in this situation. However, it is unlikely that crew members would have had sufficient time to properly deploy shelters due to the rapid approach

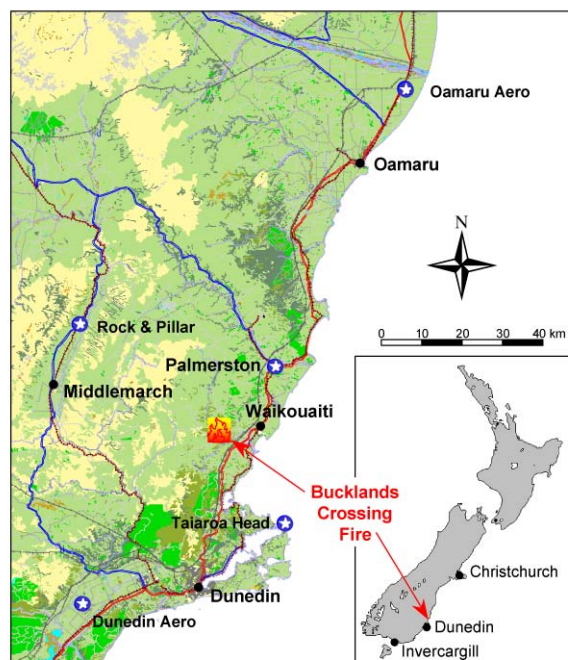


Figure 1—Location of the Bucklands Crossing Fire in relation to local population centres (●) and weather stations (★).

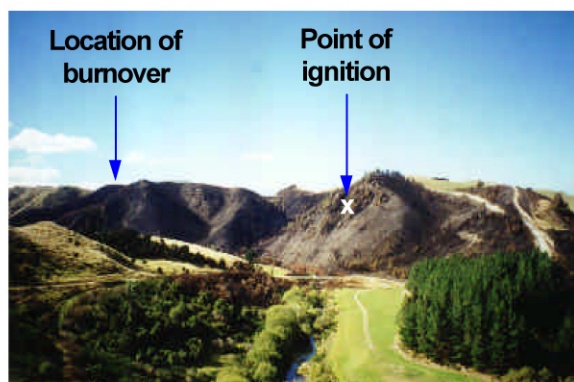


Figure 2—General view of the Bucklands Crossing Fire looking northeast to the fire's point of ignition and burnover location.

of the fire and strong, gusty wind conditions.) Damage to the fire appliance as a result of the burnover was also significant (see fig. 5).

The fire continued to burn for several hours after the incident before being contained later in the day. However, mopping up of hot spots continued over the next 7 days and the fire was not declared out until April 2. The fire burned an area of around 200 ha (495 acres), including two small woodlots of *Pinus radiata* totalling 20 ha (50 acres); the remainder of the area was grazed pasture and manuka or gorse-covered slopes. Several kilometres of fencing were damaged and some stock were also lost.

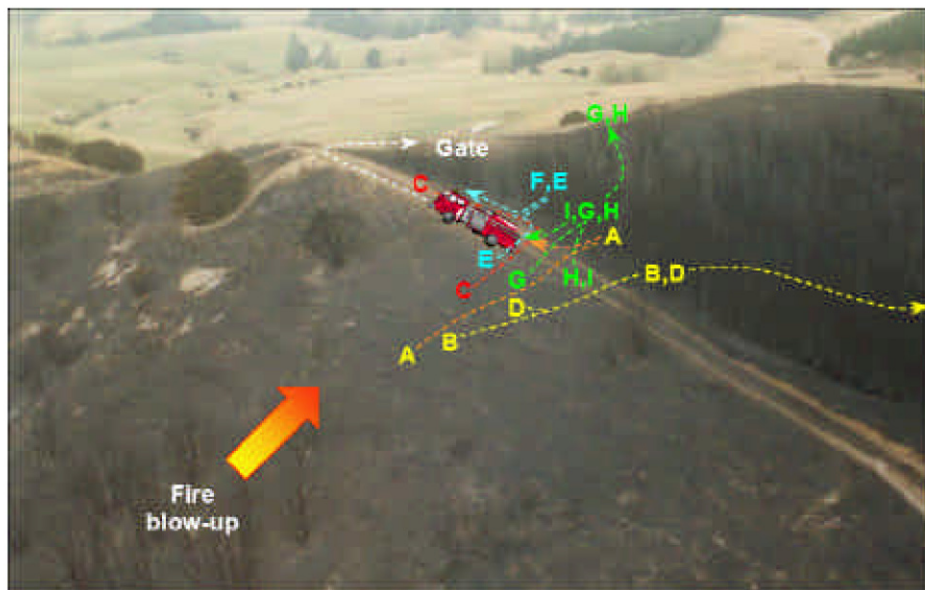


Figure 3—Locations and escape paths taken by the fire crew members during the burnover (letters denote individual firefighters).



Figure 4—Topography in the area of the ridge where the burnover incident occurred.



Figure 5—Damage to the fire appliance, including tail lights, foam proportioner, pump cover and rubber hose fittings.

Fire Environment

The fire occurred in rugged terrain comprising steep slopes that drop sharply to the meandering course of the Waikouaiti River below. Slopes of 30 to 40° (55 to 85 percent) are common, and many rock outcrops occur throughout the fire area. Several side gullies drain into the main river course with steep, narrow ridges in between. The burnover occurred on one of these ridges (fig. 4; also see fig. 6), which consisted of a 30° (58 percent) slope on the lee side which had been burned over earlier, a narrow ridge crest some 4 to 5 m (13 to 16 ft) wide, and a 25° (47 percent) slope on the upwind side leading down to the shrub fuels under which the fire was backing downhill.

Fuels in the broader fire area consisted of radiata pine woodlots, manuka, and gorse shrubs, and grazed pasture, some with scattered tussock grasses. Dense 2 to 3 m (6 to 10 ft) tall manuka shrubs covered the lee side of the ridge on which the incident occurred. This had been burnt out earlier in a rapid uphill fire run. Grass fuels with scattered short tussocks covered the open ridgetop where the appliance was parked (see fig. 6), and this too had been burnt out prior to the crew arriving. These grass fuels extended some 30 to 40 m (100 to 130 ft) down the upwind slope to 3 to 4 m (10 to 13 ft) tall manuka shrubs (fig. 7 left). This shrub vegetation was initially only underburnt, but burned out completely at a later time. The manuka stand extended some 30 to 50 m (100 to 165 ft) to the gorse-filled gully bottom below (fig. 7 right).



Figure 6—Views of the ridge on which the burnover incident occurred, illustrating the steepness of the slope in the direction from which the flame front came, the burnt out grass fuels along the ridge crest, and the distance between the vegetation and the site where the fire appliance was parked (as indicated by the utility).



Figure 7—Fuels in the burnover area, including (left) partially burned manuka shrub fuels on the ridge adjacent to where the burnover occurred, and (right) burnt gorse fuels below the location of the burnover, in the area where the blowup is believed to have originated.

The fire occurred during warm, windy conditions in a period of extended dryness. Weather and Fire Weather Index (FWI) System (Van Wagner 1987) values (see fig. 8a) for midday on March 24 were: temperature 25.5 °C (78 °F), relative humidity 35 percent, wind speed 16 km/h (10 mph), 6 days since >0.6 mm (0.02 inches) rain, Fine Fuel Moisture Code (FFMC) 92.0, Duff Moisture Code (DMC) 41, Drought Code (DC) 569, Initial Spread Index (ISI) 12.9, Buildup Index (BUI) 70, and Fire Weather Index (FWI) 31. Recorded temperatures on the day of the fire reached 27 °C (81 °F) and higher values were reported at the fire site (fig. 8b); however, these values of temperature and relative humidity were not unusually high or low, respectively, for this area. Gale force northwesterly winds that exceeded 80 km/h (50 mph) initially restricted aerial suppression operations and, although they dropped off during the day, the erratic strength and direction of the wind contributed to unpredictable fire behaviour.

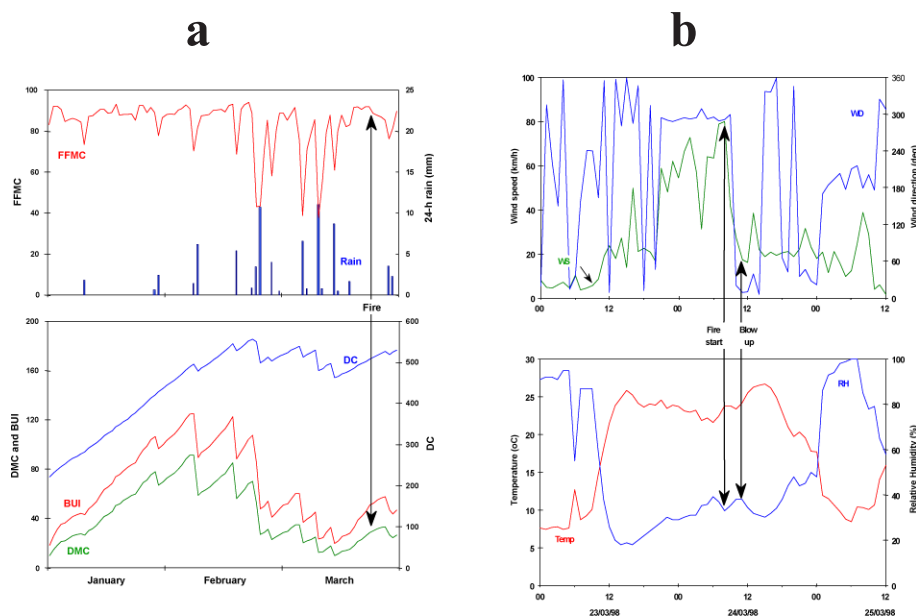


Figure 8—(a) Wetting and drying cycles for the FWI System moisture codes leading up to ignition of the Bucklands Crossing Fire on 24 March 1998; and (b) diurnal weather patterns recorded before, during, and after the initial run of the Bucklands Crossing Fire.

Fire Behaviour

The firefighters involved in the Bucklands Crossing Fire burnover reported being hit by a “fireball” originating from the gully below them. This may have been the result of a collapsing fire whirl or convection column, flash-over, or even a carbon dust explosion. However, the most likely cause was a flame extension or “rollover” associated with an uphill run and reburn through the preheated shrub canopy. The collapse of the fire front as such a run reached the end of the shrub stand (see fig. 9) would push flames along the ground and, together with the pulsing of the flame front as volatile gases are burned, would create an effect similar to that of a fireball or flashover observed by the firefighters. It would also produce extreme flame lengths capable of reaching the 30 to 50 m (100 to 165 ft) to the ridge where the fire appliance was parked.



Figure 9—Example of flame front collapse in New Zealand manuka shrub fuels during experimental burning trials observed from consecutive photographs.

While the situation may seem unusual, similar incidents have happened in the past (surface fuels consumed/canopy fuels unburned and preheated, steep slope, severe fire weather, including upslope winds or flow)—for example, the 1994 South Canyon Fire in the USA (Butler and others 1998). In particular, the potential for extreme or “unusual” fire behaviour existing from a preheated canopy has been recognised for many years (Editor 1958; NWCG 1993, 2006). Fatalities and “near hits” are often intimately linked to temporary escalations in extreme fire behaviour (see for example Alexander 2004; Wilson 1977). The Bucklands Crossing Fire illustrates that the development of extreme fire behaviour can take many forms. In this case, the fire effectively burned as an independent crown fire.

So was the situation predictable? It is unlikely that the momentary escalation in extreme fire behaviour would have been predicted in a quantitative sense with currently available models (such as Viegas 2006). The situation is not one that would necessarily be modelled in a computer simulation, addressed through outdoor experimental burning or studied in a laboratory setting (M. Alexander, pers. comm.). However, there have been enough similar situations in the past to at least qualitatively be cognizant of the potential for extreme fire behaviour. While the exact cause of the blowup could not be definitively identified, a number of factors relating to recognition of extreme fire behaviour potential and associated implications for firefighter safety were highlighted as a result of the incident and are described in detail in the case study, including:

- Common denominators of fatal and “near hit” fires (Millman 1993, 2000; NWCG 1996, Wilson 1977).
- Alignment of fire environment factors (Campbell 1991; Cheney and others 2001).
- Effect of atmospheric stability and upper level winds (Byram 1954).
- Transition from surface to crown fires (Butler and others 1998).

Firefighter Safety

The Bucklands Crossing Fire is also of interest from the human factors standpoint. The firefighters perceived this situation as benign; otherwise, they would not have engaged the fire in the manner they did (that is, approaching the fire from an upslope location). However, obviously some degree of

complacency and/or lack of situational awareness were also involved. Several fundamental principles of safe firefighting were breached, and the authors of the case study have taken care to point these out without criticising the individuals (and with their permission and support) or decisions taken, in the hope that these valuable lessons can be learned from.

One of the basic safety rules recognised by firefighters around the world is to never place oneself uphill on a slope above unburned fuels with a fire burning beneath you (see for example NWCG 2004). In deploying where they did in this instance, the crew leader and his crew broke this basic rule and immediately placed themselves in a potentially dangerous situation. While the crew leader did recognise the potential for the fire to “flare-up” and spent a considerable amount of time sizing up the fire prior to choosing to locate where they did, he believed that the fire would spread upgully under the influence of the local windflow. With the benefit of hindsight, he should have recognised the potential that existed for a rapid upslope run toward the crew’s location, due to the combined influences of the slope steepness, partially burned shrub fuels, and predominant, rather than localised, wind direction. Downhill fireline construction from above a fire has been identified as a particularly dangerous tactic only to be undertaken when there is no tactical alternative; so much so, that it has its own checklist of guidelines surrounding its use (NWCG 2004). In addition to the potential for a rapid uphill run of fire, the inherent dangers in use of this tactic also include the inability to establish a safe anchor point and that a safe escape route from a fire travelling uphill cannot be assumed (ETC and CFFC 2000).

The concept of LCES (Lookout(s), Communication(s), Escape routes and Safety zone(s); after Gleason 1991) or LACES (where the ‘A’ stands for Awareness or Anchor points; after Teie 1994; Thorburn and Alexander 2001) is also an internationally recognized set of fireline safety reminders that can dramatically reduce the probability of an entrapment or burnover. While it was not used in firefighter training in New Zealand at the time (but has subsequently been adopted as a result of this incident), consideration of a number of the factors encapsulated within the LACES concept may have resulted in a different outcome. The deployment of a lookout with a good overview of the fire area may have identified the potential for an escalation in fire activity that might have altered the crew leader’s deployment tactics or provided earlier warning. In conducting his sizeup, it could also be debated that the crew leader reacted to observed fire activity as opposed to being aware of the fire behaviour potential presented by the immediate fire environment factors, both individually and in combination. In addition, the ability to assess the broader fire environment to anticipate or recognise factors that may lead to dangerous situations is also essential. In this case the crew were unaware of the exact location of the fire or associated level of fire activity in the gully below them, and therefore of the blowup potential that existed as a result. The provision of information from adjacent sectors or use of a lookout to observe the wider fire area could therefore have facilitated broader awareness and appreciation of both current and potential fire behaviour. Suppression tactics and strategies should also consider the values-at-risk against the need for suppression. In this instance, the injuries were sustained in attempting to suppress an area of vegetation burning within the fire perimeter with little or no value. A culture of situational awareness, and continual review of strategies and tactics based on the fire environment, therefore needs to be instilled in all firefighters and fire management personnel (Anderson 2004).

The firefighters involved in the burnover incident were saved from more severe injuries by the short duration of their exposure to heat and flame, the

fact that they were correctly attired in their protective clothing (fig. 10), and that they received immediate attention from onsite medical services. While these were positive outcomes, there were also a number of other safety issues that were identified as a result of the incident that are addressed in the case study. In addition to the performance of personal protective equipment (PPE), these include:

- firefighter training and competency
- safety rules and reminders
- operational procedures
- alternative escape options (also see Alexander 2006)



Figure 10—Damage to personal protective clothing from Firefighter C (who received the most serious burn injuries), including Nomex coveralls, cotton T-shirt and fibreglass helmet.

Key Lessons Learned

The Bucklands Crossing burnover incident highlighted a number of factors that, had they been considered, might have indicated that the crew were undertaking suppression in a potentially dangerous situation.

- The crew were approaching the fire from above, on a steep slope with partially burned fuels between them and the fire in the gully below (that is, downhill fireline construction).
- Firefighters must have an understanding in the subjects of personal safety and vegetation fire behaviour, and must apply this knowledge at all times during sizeup and ongoing fire suppression.
- Firefighters must consider both the individual and combined influences of the fire environment factors on current and potential fire behaviour.
- Fire crews must also have an appreciation of fire behaviour potential in the broader fire environment, in addition to the immediate area in which they are working (that is, situational awareness).
- The lack of a lookout that could monitor fire activity in the area beneath the crew was a serious oversight in this particular case.
- A culture of situational awareness, and constant review of strategies and tactics in light of changes in the fire environment, need to be instilled in all fireline and supervisory personnel.

- Suppression strategies and tactics should also consider the values-at-risk against the need for suppression.
- Firefighter training should use reminders such as the Common Denominators and LACES to reinforce potentially problematic aspects of fire behaviour and firefighter safety.
- All training undertaken must also emphasise the correct use of protective equipment.
- Examples such as this incident can be used to clearly demonstrate the benefits of picking up on the lessons learned.

There are a great many fuel/vegetation types and fire environments in the world where a similar situation could develop to the Bucklands Crossing Fire burnover – hence the importance of disseminating this kind of information internationally to the wider global fire community.

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