Fire Technology Transfer Note

Number - 28 May 2003

The Miners Road Fire of 2nd February 2003

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Introduction

A fire that broke out on the outskirts of Christchurch (Figure 1) on the afternoon of Sunday 2nd February 2003 eventually burned through nearly 200 hectares of grassland and pine plantation. The Miners Road Fire, as it became known, threatened a number of structures and properties, including Orana Wildlife Park, and caused several evacuations. This resulted in extensive media coverage of the fire, with intense interest in the potential for disaster had the fire got into the Orana Wildlife Park, which houses a range of exotic animals such as lions, cheetah and rhinos - the possibility of lions roaming the outskirts of Christchurch is bound to sell news! The area burned is also important from an ecological point of view, representing one of the few remaining dry savannah grassland areas in Canterbury. A number of native shrubs and trees were lost as a result (Environment Canterbury 2003).

Around the time of ignition, firefighters were already in attendance at another fire on the other side of the city, on the Port Hills. The potential for the Miners Road Fire to have disastrous consequences due to the properties it was threatening, resulted in the largest turnout of firefighters in Christchurch for many years. There was also the potential for the fire to jump major roads and enter a larger and continuous plantation area to the northwest of the fire area.

This *Fire Technology Transfer Note* (FTTN) examines aspects of the fire environment as they relate to the Miners Road Fire, and discusses the observed fire behaviour against fire behaviour expected under these fire environment conditions. Where applicable, explanations are offered for any differences between observed and predicted fire behaviour in the relevant fuel types.

Figure 1. Map of the Christchurch area, showing the location of the Miners Road Fire.

Fire Chronology and Development

Ignition and initial attack

The New Zealand Fire Service Communications Centre in Christchurch received notification of a fire at the north end of Miners Road at 1302[1] on Sunday 2nd February 2003. The fire is believed to have started through contact with cured grasses at the side of Miners Road, by either the exhaust or catalytic converter on the underside of the chassis of a vehicle attempting to turn around at the north end of the road. The period of contact, and the temperature of the exhaust

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[1] All times shown are in NZ Daylight Time (NZDT), unless otherwise stated.

and/or catalytic converter, appears to have been sufficient to ignite the dry and cured grasses. From this moment the fire spread rapidly through the grasses, fanned by the wind. It is estimated that the fire was burning for approximately three minutes before the call was logged. Therefore, for the purposes of this case study, the time of ignition has been taken as 1259.

The NZ Fire Service responded by immediately dispatching the closest available units, the first of which arrived at the scene at 1318. By 1321, three units were in attendance. When these initial appliances arrived, the fire had spread from the edge of the road where it started, and into the farmland on the other side of the adjacent fence (Figure 2). It had burned to within a few metres of the first water race, and had spread along the right flank into a belt of mature pine trees along the driveway of the neighbouring property. These units concentrated initial attack efforts on the head of the fire, but were unsuccessful in stopping the fire's spread.

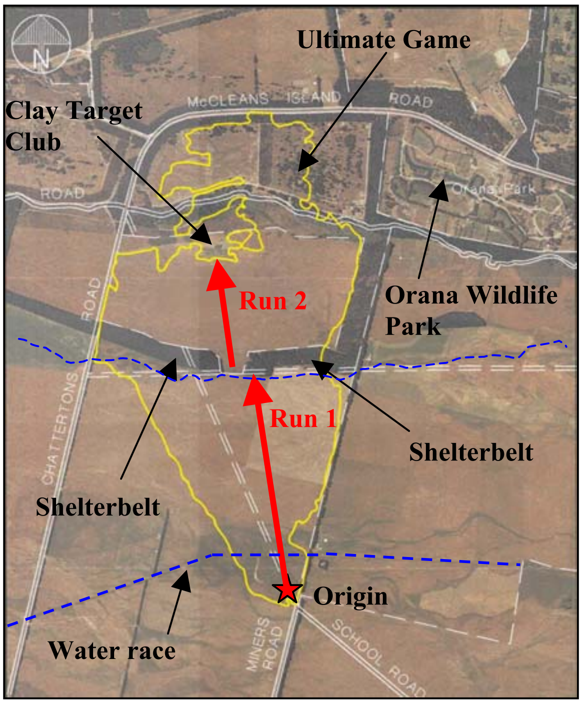

Figure 2. Area burned and major features of the Miners Road Fire (scale 1:15,000). (Source: Terralink and Christchurch City Council).

Fire growth and suppression

Figure 2 illustrates the area burned and major features of the fire area. Fanned by a southerly wind, the fire spread in a northerly direction towards the main shelterbelt/woodlot (which divides the area) across highly cured, improved pasture grassland. Repeated attempts at head fire attack were unsuccessful, and it is estimated that the fire reached this main shelterbelt between 1350 and 1358. Under the prevailing wind direction, the fire would have hit the right hand block of the shelterbelt, some 50 to 100m from the gap in the middle.

The fire crossed a second water race before the shelterbelt, and carried on burning through the gap in the shelterbelt between 1356 and 1404. The fire then proceeded to burn across an unimproved grass area towards the Canterbury Clay Target Club buildings. According to observations at the time, the fire appeared to burn in two directions, to the north-northwest, and towards the northeast. This is possibly due to a venturi-like effect from the wind being funnelled through the gap in the shelterbelt. During this time, the fire also burned through the main shelterbelt on both sides of the gap, largely through flank fire spread. Fire activity in these *Pinus radiata* stands mostly involved the surface fuel layers, with occasional torching into the crowns.

The fire is estimated to have reached the club buildings between 1430 and 1440. The structures were saved due to a combination of suppression efforts, reduced and discontinuous fuels in front of the main area, and green lawns immediately in front of the main buildings. The fire did however burn around the structures, and entered the plantation area behind the club buildings. From here it proceeded to burn into stands of *P.radiata* of varying age classes, burning with high intensity in some areas. The "Ultimate Game" area was threatened (which contained gas cylinders within the compound area), and the potential for the fire to burn into the Orana Wildlife Park was of major concern. The fire eventually reached McLeans Island Road, and spotting across the road into adjacent pine stands was observed.

At the peak of the fire, around mid-afternoon, 17 fire appliances, 12 tankers, 3 helicopters, one fixed-wing aircraft, and more than 100 firefighters were in attendance (NZ Fire Service 2003). This suppression effort, and a change in wind direction from the northeast around 1700, prevented the fire from entering the Orana Wildlife Park, and enabled it to be contained shortly afterwards. The fire burned a total area of 197.5 hectares, including 17.6 hectares of *P.radiata* plantation of varying age classes.

Public safety and evacuations

The fire threatened a number of properties, including Orana Wildlife Park, Canterbury Clay Target Club, the "Ultimate Game" recreation area, an equestrian centre, a camping area, and nearby golf clubs and a driving range. Many of these properties were evacuated, although Clay Target Club members continued shooting, despite the approaching fire! The proximity of the fire to Christchurch, and the fact that it occurred on a fine Sunday afternoon, resulted in thousands of onlookers congesting nearby roads. Police eventually closed and cleared these roads. The plantation area across McLeans Island Road and the nearby Eyrewell Forest were also potentially at risk, had the fire reached the Waimakariri riverbed. No structures were lost, but a few were seriously threatened by the fire.

Mop-up

The mop-up operation took the better part of a week to complete following the fire. Dry conditions experienced in Canterbury at the time caused deep-seated burning in the plantation areas, with burning deep into stump and root systems. These dry conditions and the potential for future flare-ups, resulted in mop-up occupying considerable time and resources.

Fire Environment

Topography

The topography of the area is largely flat (Figure 3), and the elevation is approximately 65m above sea level. Two significant water races cross the area, and the roads bounding the fire area (Chattertons Road, Miners Road and McLeans Island Road) presented the only major barriers to fire spread.

Figure 3. Aerial view of the burn area. (Source: NZ Police).

Fuels

The major fuels covering the fire area were grassland and pine plantation of varying age classes. Other fuels present included scrub and poplar trees (*Populus* spp.).

The grassland areas were separated into two distinct fuel types by the main shelterbelt running from west to east across the fire area. The southern grassland area comprised continuous improved pasture grassland, with an average fuel load of 2.3 t/ha, based on samples collected from the area (Figure 4). The grasses were highly cured, with the degree of curing ranging from 87% to 95%.

Figure 4. Improved pasture grasslands in the area south of the main shelterbelt.

The northern grassland area was quite different, with unimproved grasses, which were discontinuous and patchy in parts (Figure 5). The degree of curing was 92% to 95%, with an average fuel load estimated at 1.5 t/ha, based on samples collected from the area.

Figure 5. The unimproved and sparser grass fuels which characterised the area to the north of the main shelterbelt.

The areas of pine plantation (Figure 6) burned comprised *P.radiata* of varying age classes (refer to Table 1 for a breakdown of areas and age classes). The shelterbelts on the flanks of the fire also consisted of pine trees. There was a belt of Poplar trees (*Populus* spp.) behind the Canterbury Clay Target Club. Various areas also comprised scrub vegetation, predominantly gorse (*Ulex europaeus*), in particular an area on the southern sides of the main shelterbelt.

Figure 6. The plantation area behind the Canterbury Clay Target Club, showing different age classes of *P.radiata*. (Source: NZ Police).

Table 1. Age classes and area of *P.radiata* burned. (Source: Environment Canterbury).

Age of stand (yrs)	Area burned (ha)
4	1.57
8	4.78
14	1.81
24	3.74
30	5.72
Total area burned	**17.62**

Fire weather

The fire area is located 7km from Christchurch International Airport, and this is also the location of the closest fire weather station (Christchurch Aero). The weather readings obtained from here are regarded as closely representative of weather conditions experienced at the fire site.

From Figure 7a, it is evident that conditions, as depicted using the components of the Fire Weather Index (FWI) System (Anon. 1993), had been gradually drying out from the 1st October 2002. There were a number of significant rain events throughout the summer months, which did reduce the Duff Moisture Code (DMC) and the Buildup Index (BUI). However, the Drought Code (DC) did continue to increase, with only minor reductions from these rain events. This indicates that rainfall was not penetrating deeper organic soil layers, and large downed woody fuels. Fuels were progressively drying out over the months leading up to the fire, which is what one would expect of a typical Canterbury summer.

The graph of Monthly Severity Rating (MSR[2]) for 2002/2003 against the long-term (1961 to 2001) average MSR for Christchurch Aero (see Figure 7b) indicates that this season was not very different to the long-term average for the area. January 2003 was slightly more severe than the long-term average, but not markedly so. Total monthly rainfalls over the period October to November were also not significantly different to the long-term averages for Christchurch Aero (Figure 7c). November was a fairly wet month, and it was only late in December that conditions dried out, and that there was a rapid progression in the curing of grassland areas. The summer of 2002/2003 coincided with an El Niño phase of the Southern Oscillation Index (SOI), but conditions were not significantly different from those normally experienced in an "average" Canterbury summer.

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[2] The MSR is derived from the Daily Severity Rating (DSR). Due to the mathematical relationships within the FWI System, it is generally not regarded as appropriate to simply average FWI codes and indices. The DSR offers a simple and effective means of comparing fire weather conditions (Pearce 1996).

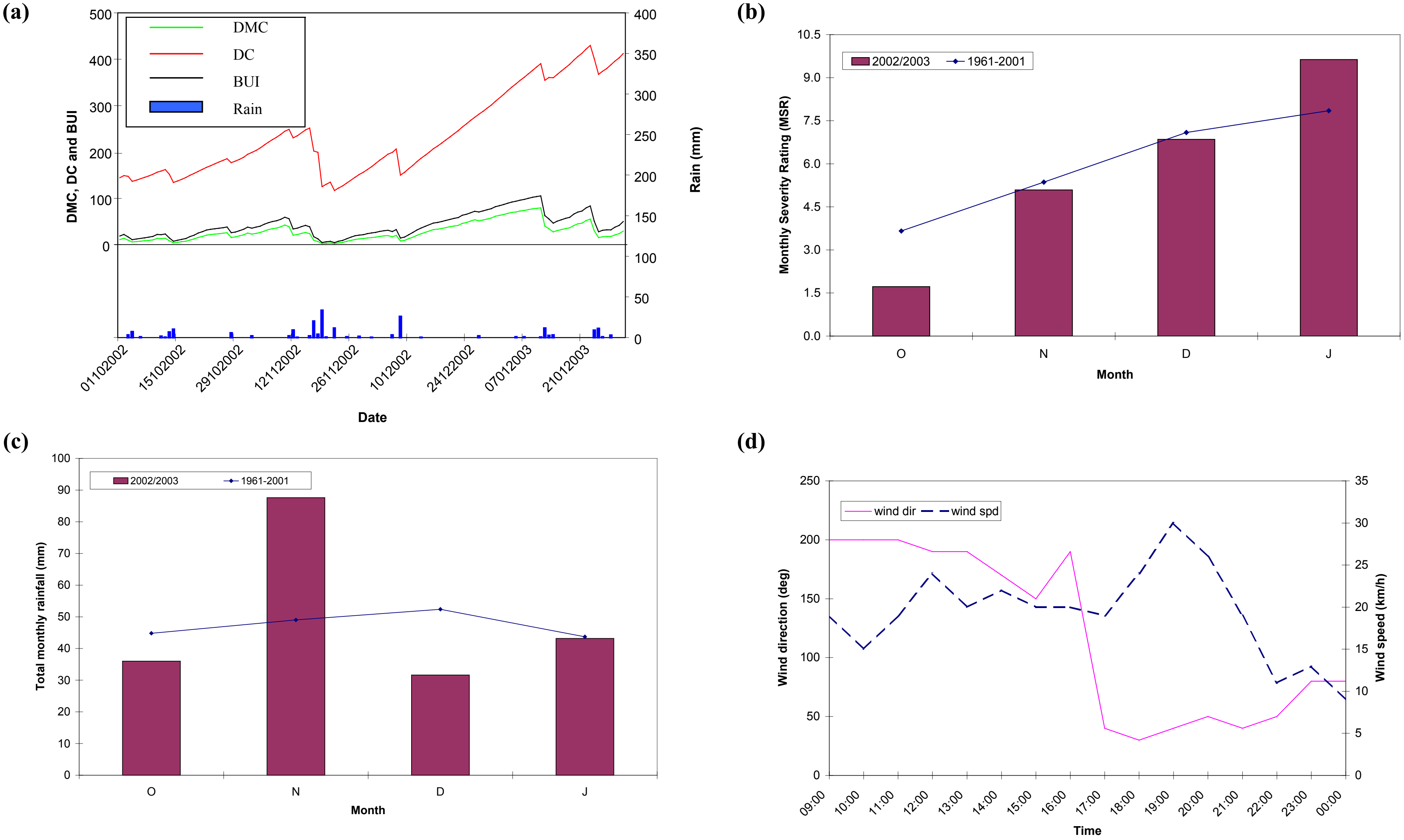

Figure 7. Seasonal trends of **(a)** Duff Moisture Code (DMC), Drought Code (DC), Buildup Index (BUI), and rainfall for the period 1 October 2002 to 2 February 2003 (top left); **(b)** long-term (1961 - 2001) Monthly Severity Rating (MSR) compared with the MSR for the same period in 2002/2003 (top right); **(c)** long-term monthly total rainfall (mm) versus total monthly rainfall for October 2002 to January 2003 (bottom left); and **(d)** hourly wind speed and direction for the duration of the fire (bottom right). All weather readings taken from Christchurch Aero.

The FWI values and Fire Danger Classes recorded at 1300 on 2nd February 2003 were:

FFMC	90.3
DMC	34
DC	425
ISI	12.2
BUI	57
FWI	27.3
Days since rain:	5 (2.8mm on 28/01/03)
Forest Fire Danger Class:	VERY HIGH
Grassland FDC:	VERY HIGH
Scrubland FDC:	EXTREME

The synoptic chart for noon (NZST) on 2nd February 2003 (Figure 8) indicated an area of low pressure east of the South Island, with frontal systems lying to the east and west. The lack of isobars over the South Island indicates light winds from a southerly direction, with the potential for sea breezes to develop during the day in coastal areas. This is in fact what happened during the course of the afternoon, with the northeasterly breeze developing from the coast later that afternoon.

The hourly weather readings and FWI values for the day are presented in Table 2. Conditions at the time of ignition (approximately 1300) were not particularly severe, with an hourly FFMC of 84.1. However, this value, together with the elevated degree of grass curing (90% to 95%), was high enough for the grasses to ignite. The 10m wind speed remained fairly constant for the duration of the fire, ranging from 20 km/h (1300) to 24 km/h (1800), around the time the fire was contained. The prevailing wind direction throughout the main run of the fire was from the south, with a change to northeast around 1700 (see Figure 7d). This wind change was one of the main reasons for the fire being contained. From a fire behaviour perspective, conditions did deteriorate into the afternoon, with the temperature reaching a maximum of 24ºC at 1600, and the relative humidity dropping to 24% at the same time. The wind change to northeast brought with it increased moisture from the coast, dropping the temperature and increasing the relative humidity. Apart from an increase in wind speed from 1800 to 1900 (30 km/h at 1900), conditions improved into the evening with cooler temperatures, increased relative humidity, and lower wind speeds. This allowed fire crews to consolidate containment lines, and so minimise the risk of flare-ups the following day.

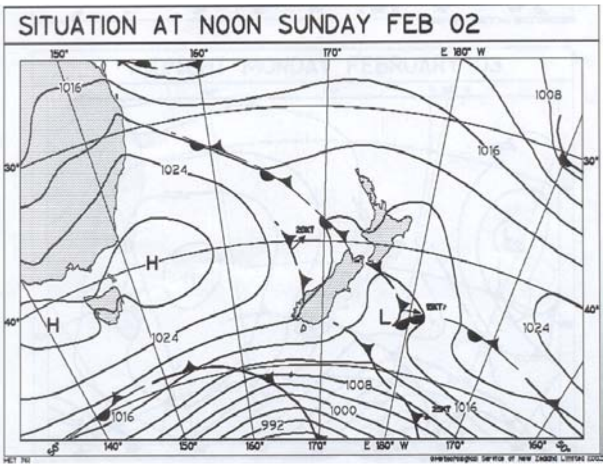

Figure 8. Synoptic chart for noon on 2nd February 2003. (Source: MetService).

Table 2. Hourly weather readings recorded at Christchurch Aero on the day of the fire, 2nd February 2003.

Time (NZDT)	Temp (°C)	Relative Humidity (%)	Wind Direction (deg)	10 m wind speed (km/h)	Rain (mm)	Hourly FFMC	Hourly ISI	Hourly FWI
0900	14.2	86.1	200	19	0	80.7	3.2	9.5
1000	17	74	200	15	0	80.9	2.7	8.2
1100	20	56	200	19	0	81.7	3.6	10.5
1200	21	47	190	24	0	82.8	5.2	14.3
1300	**22**	**37**	**190**	**20**	**0**	**84.1**	**5.1**	**14.5**
1400	**23**	**28**	**170**	**22**	**0**	**85.6**	**6.9**	**18.3**
1500	**23**	**25**	**150**	**20**	**0**	**87.0**	**7.5**	**19.5**
1600	**24**	**24**	**190**	**20**	**0**	**88.2**	**9.0**	**22.2**
1700	**22**	**46**	**40**	**19**	**0**	**88.3**	**8.7**	**21.6**
1800	**20**	**53**	**30**	**24**	**0**	**88.3**	**11.2**	**25.9**
1900	19	46	40	30	0	88.4	15.3	31.9
2000	17	58	50	26	0	88.2	12.2	27.4
2100	15	75	40	19	0	87.6	7.8	20.0
2200	13	82	50	11	0	86.8	4.7	13.7
2300	14	78	80	13	0	86.3	4.9	14.0
2400	13	79	80	9	0	85.9	3.7	11.4

Fire Behaviour

The Miners Road Fire burned through areas of grassland, plantation forest, and mixed scrub and shelterbelts. Based on observations and information from fire personnel who were present during the main run of the fire, it has been possible to estimate the times the fire reached certain areas or prominent features. Unless fire behaviour observations have been accurately recorded at the time of the fire (i.e., by a dedicated observer), it is always difficult to accurately determine rates of spread based on recollections after the event. The discussion on fire behaviour for this fire focusses on the spread of the fire through the two grassland areas, that is the area between the point of origin and the main shelterbelt; and the area from the northerly side of the shelterbelt to the Canterbury Clay Target Club buildings. Reliable observations of rate of fire spread were obtained from these areas, whilst very little information was available on the rates of spread through the plantation areas. The fire spread was also patchy through these plantation areas.

For the first major run across the grass paddock from the point of origin to the main shelterbelt (a distance of 1200 m over a period of 51 to 59 minutes), the rate of fire spread has been estimated to be 1316 (± 96) m/h. Using the Standing Grass (O-1b) fire behaviour model of the NZFDRS, with a degree of curing of 90%, and an ISI of 6.0 (the average hourly ISI over this period), the predicted rate of spread is 709 m/h. There are a number of possible explanations for this difference between the predicted and the observed rates of spread. The wind speeds used (20-22 km/h) were those recorded at Christchurch Aero, 7km from the fire. It is quite possible that the wind speed at the fire site was higher than this, being an exposed area. The estimated degree of curing was also possibly lower than the actual degree of curing across the whole area. The samples taken to estimate the degree of curing after the fire were from an unburned area adjacent to the burned area, and possibly did not fully reflect conditions throughout the burned area. Observations of the location of the fire front at various times also vary, and this obviously has an effect on the observed rate of spread. Assuming a higher wind speed over this exposed area (25 km/h, which equates to an ISI of 8.0), as well as a higher degree of curing of grasses (95%), the predicted rate of spread becomes 1229 m/h. This is much closer to that calculated from observations.

The calculated head fire intensity[3] was approximately 1540 kW/m. Using the original ISI input of 6.0 and degree of curing of 90%, the predicted intensity is 1241 kW/m. Using the revised ISI of 8.0, and degree of curing of 95%, the predicted intensity is 2151 kW/m. The differences here are largely due to the lower fuel load present (2.3 t/ha), compared to that assumed (3.5 t/ha) within the associated model. Using Alexander's (1994) criteria for effective head fire suppression based on head fire intensity, an intensity of 1540 kW/m implies that direct head fire attack would only be effective using water under pressure and/or heavy machinery. A Length-to-Breadth (L/B) ratio[4] of 4.0 has been calculated for this run, compared to a predicted value of 4.5 (Pearce 2001). This calculated L/B ratio does not take into account the considerable flank fire spread following the main run of the head fire.

The head of the fire was reported to hit the main shelterbelt on the western (right-hand) side, approximately 100 to 150 m from the gap in the middle. It then crossed the water race, burned through the gap and across the second grassland area to the Canterbury Clay Target Club buildings (a distance of 600 m). This is considered to be the second major run of the fire, since it crossed the water race, and would have undergone another acceleration phase. The estimated times for the start of this run vary (between 1356 and 1404), due to the varying estimations of when the fire would have reached the shelterbelt. Similarly, the time at which the fire reached the buildings also varies (between 1430 and 1440). The

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[3] Calculated using the formula $I=(w \times r)/2$, where I is head fire intensity (kW/m); w is available fuel load (t/ha); and r is head fire rate of spread (m/h) (Alexander 2000).

[4] The Length-to-Breadth Ratio (L/B) provides an indication of a fire's expected shape, assuming that the growth of a fire is largely governed by wind speed. With constant wind direction, the fire shape will resemble that of an ellipse (Alexander 1985).

observed rate of spread across this area has been estimated to be 1065 (± 127) m/h. Using the O-1b Standing Grass fire behaviour model and a degree of curing of 92% with an ISI of 7.2 (the average hourly ISI over this period), the predicted rate of spread was 981 m/h.

There are a number of factors to consider relating to this fire run. It is well known that shelterbelts have a significant impact on wind speed, with open shelterbelts (such as this one) reducing wind speed by up to 50% over a distance of up to 5 times the tree height. Reductions in wind speed can occur for distances of up to 25 times the tree height (Simpfendorfer 1989). There can therefore be no doubt that this shelterbelt would have had an impact on wind speed, despite the gap in the middle of the shelterbelt (causing wind speeds to accelerate through this area). Grass fuels were also sparser in this area than in the area of the first run (1.5 t/ha vs. 2.3 t/ha), and appeared more discontinuous. This grassland area consisted of unimproved grasses, as opposed to improved pasture grasses in the area of Run 1. It is again possible that the estimated degree of curing (based on samples collected from the area) was lower than the actual degree of curing across the whole area. Therefore, assuming a degree of curing closer to 100%, together with a decrease in wind speed of 10% over the distance of the run (which reduces the hourly ISI to 6.7), the predicted rate of spread becomes 1048 m/h. A degree of curing of 95% (and wind speed reduction of 10%) results in a predicted rate of spread of 943 m/h. These predicted rates of spread are close to that calculated from observations (1065 m/h). A head fire intensity of 800 kW/m was calculated based on observations, versus a predicted intensity of 1720 kW/m (using the hourly ISI of 7.2). The significantly lower fuel load (compared with the assumed fuel load of 3.5 t/ha) largely explains this difference.

It is also worthwhile considering the observed fire behaviour across the entire grassland area (from the point of origin to the Clay Target Club buildings), compared to that predicted. The fire behaviour models within the NZFDRS are intended for broad aerial application. The combined area of these two runs represents a larger area of grassland, with differences in fuel properties, as would normally be experienced across grassland areas. Considering this as one large run also eliminates the variability around the time the fire front reached the main shelterbelt. The distance of this run from the point of origin to the Clay Target Club buildings is 1800 m, with a total time of 91 to 101 minutes. This gives an observed rate of spread of 1128 (± 59) m/h. Assuming an average grass fuel load of 1.9 t/ha, the calculated head fire intensity across this run is 1072 kW/m. Using an average hourly ISI for this period of 6.5, and a degree of curing of 90%, the predicted rate of spread is 801 m/h, with a head fire intensity of 1400 kW/m. However, it is most likely that the degree of curing across the entire area was higher than this, and that the hourly ISI would also have been slightly higher due to the exposed area on the southern side of the shelterbelt being the larger area of the fire run. Therefore, assuming an average hourly ISI of 7.0, and an average degree of curing of 95%, the predicted rate of spread becomes 1008 m/h, much closer to that based on observations. This higher rate of spread predicts a head fire intensity of 1760 kW/m, considerably higher than that calculated from observations. This is again most likely due to the lower average grass fuel load used (1.9 t/ha) than that assumed (3.5 t/ha).

Figure 9 represents a plot of the Miners Road Fire using the Grassland Fire Danger Class Criteria (Alexander 1994). Using the noon FWI outputs and a degree of grass curing of 92%, the fire is placed in the VERY HIGH Fire Danger Class. The two grassland runs, as well as the combined run over both grassland areas, are also plotted in Figure 9. It is apparent that conditions were similar over the duration of these runs. Using a standard degree of grass curing of 95%, the ISI values for the combined run (7.0) and Run 2 (6.7) place both of these fire runs in the HIGH Fire Danger Class. The ISI value for Run 1 (8.0), places this run in the VERY HIGH Fire Danger Class. This corresponds with the higher head fire intensities calculated for this run (1540 kW/m), in comparison to Run 2 (800 kW/m). The Fire Danger Classes are based upon the head fire intensity, and are related to the degree of difficulty of head fire suppression.

A Fire Danger Class of VERY HIGH indicates that head fire suppression will only be effective using helicopters and/or fixed-wing aircraft. This explains the effectiveness of the helicopters and fixed-wing aircraft on the day of the fire, as observed by fire personnel. This VERY HIGH Fire Danger Class (based on the noon values) possibly over-estimates the fire danger levels on the day, largely due to the fact that the hourly ISI values never reached the noon standard ISI value of 12.2 (hourly values of ISI from 1300 to 1800 ranged from 5.1 to 11.2), and again due to the lower grass fuel loads present than that assumed (3.5 t/ha) in the criteria.

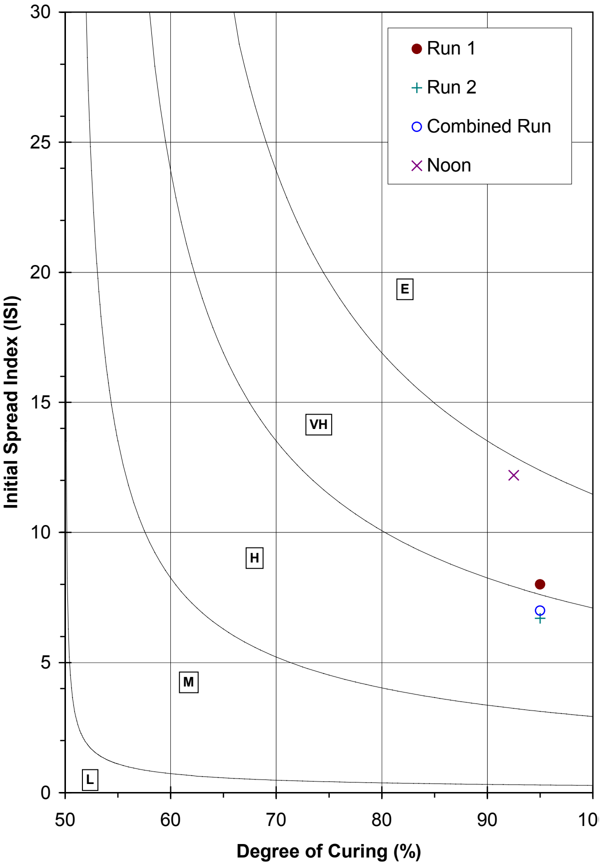

Figure 9. The Grassland Fire Danger Classes for the Miners Road Fire, plotted using the noon standard values of the FWI System, as well as the hourly values for the respective fire runs.

Although detailed observations of fire rates of spread are not available for the plantation areas burned, it is worthwhile including some discussion on the fire behaviour observed in these areas. The fire spread through the main shelterbelt was largely due to flank fire activity, particularly in the left-hand shelterbelt (the head of the fire only burned into the right-hand side). The fire in these areas was largely a surface fire, with almost total consumption of the duff materials taking place (Figure 10). This is what would have been expected, given the high values of the DMC (34) and BUI (57). The deep-seated burning (down to depths of 300mm) into the roots and stumps is also due to the high DC values (425), indicating a very dry state of deeper organic layers and downed woody material. There was scorching quite high on some stems, with the occasional tree torching. However, the fire did not become a crown fire, largely due to the absence of significant ladder fuels (it was a mature pruned stand with relatively little scrub in the understory). Referring to tables for the probability of crowning in plantation fuels (Pearce 2001), an intensity of greater than 4000 kW/m was required for the fire to enter the crown fuels in a stand pruned to 6m (or with a live crown base height of 6m). This indicates that the head fire intensity in the shelterbelt was less than this threshold value. There were also significant areas of gorse before this main shelterbelt, which significantly increased the intensity of the fire and most likely contributed to torching of mature pine trees at the edge of the shelterbelt. It was noted that the fire easily crossed the two water races during its first run (one was 270m from the point of origin, the other before the main shelterbelt at the end of Run 1). Using the criteria defined by Wilson (in Alexander 1994) for firebreak breaching, there was a 70% chance of the 2-3m wide water race being breached by fire (in the presence of trees). Bearing in mind that these water races were lined with gorse, it is hardly surprising that they offered little resistance to fire spread.

Figure 10. The burned area in the understory of the main shelterbelt, demonstrating largely a surface fire (left); one of the areas of younger *P.radiata* burned, which clearly shows some of the crown fuels consumed by the fire (right).

Once the fire had burned around the club buildings and entered the area of poplar trees, mass lifting and transportation of embers in the form of burning leaves was observed from these trees. This is interesting, given that poplars are often regarded as being of low flammability and not a contributing factor to intense fires. However, this mass ember transport through burning leaves is significant, and has been observed in extreme conditions in stands of Trembling Aspen (*Populus tremuloides*) in Canada and the USA. Cured leaves have been observed to blow ahead of the fire front, causing short-range spotting. Wind speeds greater than 15 to 20 km/h are generally required before this will occur (Quintilio *et al.* 1991). Wind speeds when the fire entered the Poplar belt were approximately 20 km/h.

The fire burned with varying intensity through the plantation areas, particularly in younger age classes where sufficient ladder fuels were present to allow the fire to enter the crowns. Trees were also closer spaced in these younger stands, resulting in higher fuel loads. The dry conditions, reflected in the high DMC, DC, and BUI values, resulted in deep burning into duff layers and root systems. The Forest Fire Danger Class was HIGH to VERY HIGH throughout the main burning period (1300 to 1800), and resultant head fire intensity in pine plantations could have been expected to range from 1500 kW/m to over 4000 kW/m (Pearce 2001). Some spotting was also observed into the plantation area across McLeans Island Road, but crews at the scene quickly extinguished these spot fires.

Discussion

Whilst the most value, in terms of fire behaviour observations, has been gained from the fire spread over the two main grassland areas, anecdotal observations of fire behaviour in the other fuel types have also been of significance.

The analysis of fire behaviour shows that the O-1b Standing Grass model of the NZFDRS did reflect actual fire behaviour reasonably well. The most significant difference between observed and predicted rates of spread in grassland was noticed for the second major run. However, by taking into account the nature of the fuels, reduced wind speed due to the shelterbelt, and the fact that observations of fire spread varied, these differences are mostly accounted for. Reliable and accurate observations of fire behaviour in the plantation areas were not available, but observations that were gathered are once again what would have been expected given the fire environment conditions. Drier conditions at that stage of the fire season were reflected in the elevated FWI values (specifically DMC, DC, and BUI). Given these values, deep-seated burning into duff layers and root systems would have been expected, and this is exactly what occurred. Predicted intensities for the fire in forest fuel types (based on the Forest Fire Danger Class Criteria) indicated head fire intensities of less than 4000 kW/m. A crown fire would not be expected to occur in a mature, pruned plantation under these conditions, and the fire in the main shelterbelt was largely a surface fire. Where crowning did occur in younger stands, this was due to lower pruning heights and the presence of ladder fuels. Lower pruning heights (and therefore lower crown base height) do reduce the fire intensity threshold for crowning to occur (Pearce 2001). The fire did therefore largely conform to what would have been expected, given the FWI System outputs on the day.

The fire was eventually contained due to a combination of suppression efforts, weather conditions, and fuel type change (the fire moved from flashy grass fuels to heavier plantation fuels). Reduced wind speeds, temperature, and increased relative humidity, reduced fire activity significantly and allowed consolidation of containment lines overnight. A particular safety concern was the change in wind direction from S to NE around 1700. Had the left flank of the fire not been contained by this time, this whole flank could have become a head fire. This emphasises the need for knowledge of the fire environment and a strong focus on safety at all times.

Conclusion

The Miners Road Fire provided valuable fire behaviour information for the ongoing development and improvement of the New Zealand Fire Danger Rating System (NZFDRS). It showed that NZFDRS outputs did reflect fire behaviour on the day. Differences in observed versus predicted fire behaviour are largely due to fuel properties and weather inputs, particularly wind speed. This enforces the importance of local knowledge when assessing inputs for site-specific fire behaviour prediction (as opposed to prediction across a broad area).

Documentation of wildfires is an invaluable source of fire behaviour information, for testing and validation of existing fire behaviour models, and development of new fire behaviour models within the NZFDRS. Fire environment conditions at wildfires are often at the more extreme end of the scale, and the types of conditions under which experimental burning is not typically possible. This is therefore a valuable opportunity for "real-life" observations to be documented. Wildfire documentation and case studies are also useful for development and conduct of safe and effective suppression strategies and tactics, and presenting key lessons for fire management from experiences in wildfire situations. It is essential that lessons learned during wildfire suppression be communicated to fire personnel, in order to benefit from these lessons (Pearce and Anderson 2003). It is therefore not only the responsibility for fire researchers to document and write up case studies of wildfires. In fact, it is most often fire personnel present at the time who are more suited to documenting and gathering evidence, since fire researchers often only arrive at the scene several hours (or even days) after the fire (Alexander and Pearce 1992). This is particularly the case in NZ, where wildfires are often of short duration.

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