Fire Technology Transfer Note

Number - 26 **November 2002**

Wildfire documentation: the need for case studies illustrated using the example of "The Atawhai Fire of 7 May 2002: a case study" by S.A.J. Anderson

Grant Pearce

Introduction

Wildfire documentation is an essential part of fire management and research. Case studies of wildfire behaviour and fire operations document the lessons learned as a result of fire suppression and management actions, and also provide observations of fire behaviour for model testing and development. The report by Stuart Anderson included here, "The Atawhai Fire of 7 May 2002: a case study", is an excellent example of how these two needs can be met. The Atawhai Fire provides a further example of the extreme flammability of scrub fuels under otherwise benign conditions, and provides a good test of the new Scrubland fire danger class criteria. Occurring in a Rural/Urban Interface (RUI) environment, the fire also reinforced a number of issues relating to fire suppression and fire management.

Why a Case Study?

Interest in production of case studies of wildfires has increased significantly over recent years in New Zealand. During his 12 month secondment during 1992-93, leading Canadian fire researcher, Marty Alexander promoted the importance of wildfire documentation through Advanced Fire Behaviour training courses and numerous other presentations and publications (e.g., Alexander and Pearce 1992, Alexander 1994). This emphasis has continued in recent training, in particular, through the current requirement to complete a case study as part of the assessment to obtain NZQA Unit Standard 4648 (Intermediate Fire Behaviour). This was the driver in the case of the Atawhai Fire case study presented here.

It is important to recognise and reinforce that observation and documentation of fire behaviour is an essential component of incident management. It is critical to the development and conduct of safe and effective suppression strategies and tactics. However, it should not be seen as just the realm of the Fire Behaviour Specialist (or fire researchers) and Incident Management Team, as fireline personnel have a key role in observing and relating fire behaviour and any lessons learned during wildfire suppression.

Fire researchers with the Forest and Rural Fire Research Programme have documented numerous wildfires (and experimental burning trials) for the purposes of validation and development of fire behaviour models and fire danger class criteria (e.g., Pearce and Alexander 1994, Pearce *et al*. 1994, Rasmussen and Fogarty 1997, Fogarty *et al*. 1997, Pearce 2001*a*). Other recent research case studies have presented key lessons for fire management learned during significant wildfires, including RUI issues (Fogarty 1996), fire prevention and preparedness (Fogarty *et al*. 1997, Pearce 2001*a*), aerial suppression (Fogarty and Robertson 1997) and firefighter safety (Pearce *et al*. 1999).

Attendance in recent years of several fire managers and research personnel at international training courses including, in particular, the Canadian Wildfire Behaviour Specialist course has also resulted in production of a number of wildfire case studies (e.g., Pearce 2000). The advent of formal rural fire investigation training has also seen increased report preparation (e.g., Pearce 2001*b*, Thompson 2002).

Better documentation of fire behaviour during wildfire events has also occurred as a result of improved situation reporting and Incident Action Plan production stemming from introduction and implementation of the Coordinated Incident Management System (CIMS) process. In future, the potential for auditing of fire operations as a result of the national Operational Review Project is also likely to see an increase in wildfire documentation and case study production.

The 2002 Atawhai Fire

The case study written by the Fire Research programme's newest recruit, Stuart Anderson, on the Atawhai Fire that occurred on the outskirts of Nelson on 7 May 2002, provides an excellent model for wildfire case study preparation whatever the purpose. The case study does a very good job of presenting the key information on the fire as it relates to fire chronology, the fire environment factors of fuels, weather and topography, and their impact on observed fire behaviour.

The 2002 Atawhai Fire was significant in that it burned an area of 30 ha, of mainly gorse scrub but including a small area of pine plantation. Considerable potential also existed for the fire to spread into the adjacent Hira Forest. As a RUI incident where a number of houses had to be evacuated, the fire drew a great deal of attention from the media and general public. The fire was also the second to occur in the same area within 5 years.

The presence of highly flammable gorse fuels resulted in a wildfire of greater intensity than was indicated by the time of day or benign weather and fire danger conditions that prevailed. The fire exhibited two major runs during which extreme fire behaviour was observed, despite fire spread being largely independent of topographic (slope) effects. The fire breached a mowed grass firebreak, and was only contained through a combination of a change in weather conditions (wind speed and direction), fuel changes, and strategic fire suppression.

The Atawhai Fire provided an excellent opportunity to test the new Scrubland fire danger class criteria (FDCC), and underlying fire rate of spread (ROS) model. While the Scrubland FDCC did a reasonable job of predicting fire behaviour potential despite the mild conditions, observed spread rates and calculated head fire intensities were significantly different from those predicted using the new ROS model. As a result, it was suggested that further refinement and validation of these interim models is still required, and this can only be achieved through well-documented wildfire observations and associated case studies.

References cited

Alexander, M.E. 1994. Proposed revision of fire danger class criteria for forest and rural fire areas in New Zealand. National Rural Fire Authority, Wellington. *Circular* 1994/2. 73 p. [also see FTTN 7].

Alexander, M.E.; Pearce, H.G. 1992. Guidelines for investigation and documentation of wildfires in exotic pine plantations. Draft report prepared for the meeting of Australian Forestry Council Research Working Group No. 6 - Fire Management Research, December 9, 1992, Creswick, Victoria, Australia. 10 p.

Anderson, S.A.J. 2002. The Atawhai Fire of 7 May 2002: a case study. Unpublished Report. 27 p.

Fogarty, L.G. 1996. Two rural/urban interface fires in the Wellington suburb of Karori: assessment of associated burning conditions and fire control strategies. *FRI Bulletin No. 197, Forest and Rural Fire Scientific and Technical Series, Report No.* 1. 16 p.

Fogarty, L.G.; Jackson, A.F.; Lindsay, W.T. 1997. Fire behaviour, suppression and lessons from the Berwick Forest Fire of 26 February 1995. *FRI Bulletin No. 197, Forest and Rural Fire Scientific and Technical Series. Report No.* 3. 40 p.

Fogarty, L.; Robertson, K. 1997. Firebombing effectiveness - interim recommended foam consistencies and aerial attack guidelines. *Fire Technology Transfer Note* 13 (November 1997). 4 p + appendices.

Pearce, H.G. 2000. Fire environment and fire behaviour associated with the 1999 Springvale grassfire, Alexandra, New Zealand. Case study prepared as part of the Wildland Fire Behaviour Specialist Course, Hinton, Alberta, February 2000. 21 p + appendices.

Pearce, H.G. 2001*a*. Fire environment and fire behaviour associated with the Blenheim Boxing Day fires. Proceedings, Forest and Rural Fire Association of New Zealand (FRFANZ) 11th Annual Conference, 4-6 July, 2001, Christchurch.

Pearce, G. 2001*b*. Cora Lynn Fire Investigation: Report on the Fire Environment in the Area of and at the Time of Ignition. Report prepared for the Department of Conservation, Canterbury Conservancy, into the cause of the March 2001 Cora Lynn Fire near Arthurs Pass. 6 p + appendices.

Pearce, H.G.; Alexander, M.E. 1994. Fire danger ratings associated with New Zealand's major pine plantation wildfires. In Proceedings, 12th Conference on Fire and Forest Meteorology, October 25-29, 1993, Jekyll Island, Georgia. Society of American Foresters, Bethesda, Maryland. *SAF Publication* 94-02. pp 534-543. [see FTTN 3].

Pearce, G.; Hamilton, R.; Millman, I. 1998. The Bucklands Crossing fire burnover. *Fire Technology Transfer Note* 19 (December 1998). 4 p.

Pearce, H.G.; Morgan, R.F.; Alexander, M.E. 1994. Wildfire behaviour case study of the 1986 Awarua Wetlands fire. *Fire Technology Transfer Note* 5 (December 1994). 6 p.

Rasmussen, J.H.; Fogarty, L.G. 1997. A case study of grassland fire behaviour and suppression: the Tikokino Fire of 31 January 1991. *FRI Bulletin No. 197, Forest and Rural Fire Scientific and Technical Series, Report No.* 2. 18 p. [see FTTN 14].

Thompson, R. 2002. Investigation into the origin and cause of the Atawhai Fire – Nelson, 7 May 2002. Report prepared for the Rural Fire Network Ltd. 19 p + appendices.

The Atawhai Fire of 7 May 2002: a case study

S.A.J. Anderson
Fire Research Scientist
Forest Research

FOREST AND RURAL
FIRE RESEARCH

Contents

Figures

Tables

Introduction

The Atawhai Fire, in the hills on the outskirts of Nelson (see Figure 1), occurred in the early hours of the morning of 7 May 2002. The fire burned through some 30 hectares of dense scrub fuels, comprised mostly of gorse (*Ulex europaeus*). A small area of pine plantation was also damaged during the latter phases of the fire. Whilst not a very large fire, there were some very interesting factors associated with this fire which subsequently drew a great deal of attention towards it, both from a public and fire management perspective.

This is the second fire to have burned across the same area within a period of five years, the last fire occurring in October 1997 and burning an area of some 50 hectares of gorse scrub (the Walter's Bluff Fire). The fire occurred in a Rural/Urban Interface (RUI) area, with the result that a number of houses had to be evacuated as it was felt that they were in danger of being destroyed as the fire burned closer towards them. There was also the potential for a much larger fire, had the fire spread further along the ridge, or crossed the ridge and burned towards Hira Forest to the east of the fire area. The close proximity of the fire to the city of Nelson resulted in it receiving a great deal of media attention (residents of Nelson woke in the morning to find the city covered in smoke from the fire). There were a number of safety issues that subsequently had a major impact on the fire suppression strategy and actions taken. The nature of the fuel complex also resulted in a fire of far greater intensity than would have been expected under the weather conditions at the time.

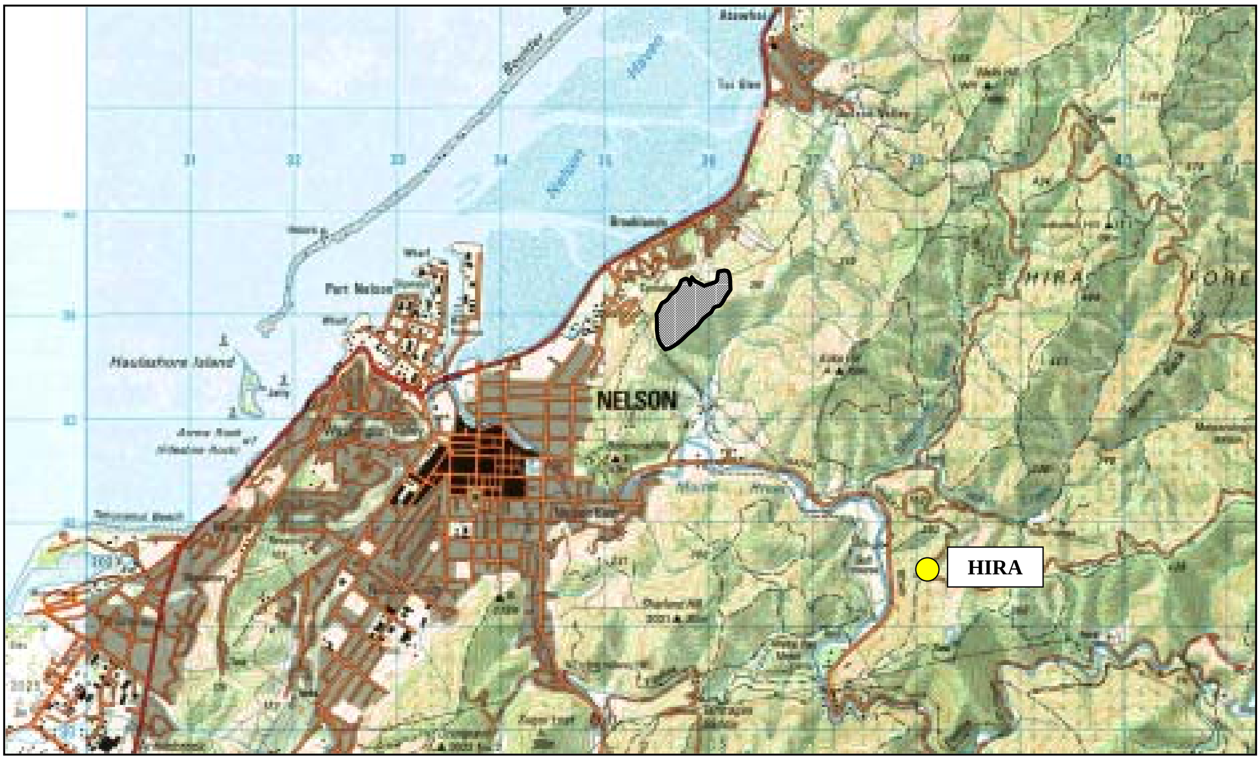


Figure 1. Location of the Atawhai Fire in relation to the city of Nelson and the location of the Hira weather station.

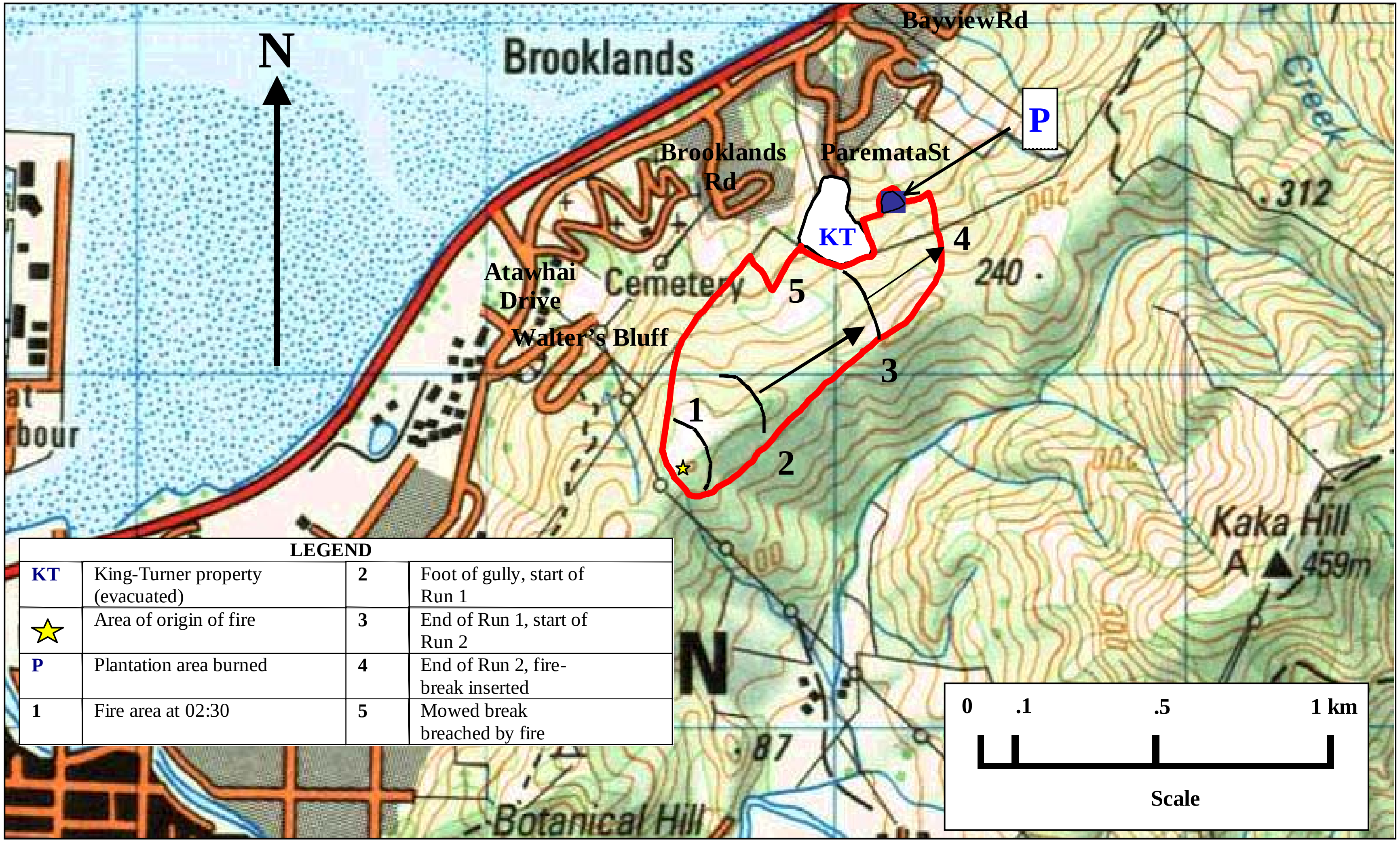


Figure 2. Map of the final area burnt and major runs in the Atawhai Fire.

Fire Chronology

Ignition and initial attack

The fire investigation carried out following the fire has not been able to determine a cause (Thompson 2002). Initial reports indicated that arcing from powerlines adjacent to where the fire started may have been the cause, and this in turn generated a great deal of media publicity. However, this was refuted by the power company and the cause is unknown (the investigation team included a consultant electrical engineer). A thorough investigation of the area where the fire is believed to have started was carried out and a general area of origin has been identified (Figure 2).

The first call reporting the fire was made to the 111 system at 01:17, with reports of a fire approximately the size of a large bonfire. Many subsequent reports were logged through the 111 system. The first response from the New Zealand Fire Service (NZFS) was at 01:20, with an appliance reporting to the Walter's Bluff area (see Figure 2). However, this area was too far away and they moved to the Bayview Road area to observe. There were also numerous reports of electrical flashes and sparks from the powerlines in the Walter's Bluff area. Power was cut to this area, as well as the Atawhai and Hira areas. An initial attack on the fire was not mounted for the following reasons:

- there were concerns of arcing powerlines and the possibility of lines being down;
- it was dark and access to the area was difficult;
- the initial attack firefighters were not totally familiar with the site;
- the scrub fuels were very dense and mostly impenetrable.

In order to protect firefighter safety and not to endanger lives unnecessarily, it was decided to monitor the fire and protect property if the need arose. An Incident Control Point (ICP) was established outside the Miyazu Gardens on Atawhai Drive and the Principal Rural Fire Officer (PRFO) of the Waimea Rural Fire District assumed control at 03:56.

Fire growth and suppression

Due to the safety concerns and other factors already outlined, direct fire-fighting was not undertaken until a much later stage. Due to darkness and the concerns with the powerlines, aerial suppression was not considered. A number of resources responded to the fire, including:

- 5 urban appliances (3 NZFS, 2 Stoke Fire Service)
- 2 rural (4 x 4) appliances (1 Carter Holt Harvey, 1 Hira VRFF)
- 1 smoke chaser unit (Hira VRFF)
- 1 command vehicle (NZFS)
- 17 professional firefighters and 5 command personnel (NZFS)
- 21 volunteer firefighters.
-

The Deputy PRFO was also in attendance and assumed the role of Sector Supervisor on the eastern boundary (ridge-line) of the fire. The attending Chief Fire Officer (CFO) of the NZFS assumed control until handing over to the PRFO at 03:56. He then assumed the role of Operations Manager. Additional resources were later requested and included:

- Nelmac Fire Crew (5 firefighters)
- Puklowski Fire Crew (4 firefighters)
- 2 Carter Holt Harvey rural appliances
- 1 bulldozer (arrived at 04:30).

The police were also on site and later assisted with evacuation of properties perceived to be in danger.

The development, spread and suppression of the fire proceeded as follows (refer to Figure 2):

01:17	Initial 111 call received.
01:20	First response (NZFS).
01:55	Fire observed from Brooklands Road by the Deputy PRFO. Fire was still small in size and increasing slowly.
02:30	Deputy PRFO and Hira VRFF tanker with crew arrived on the top of the ridge. By this stage the fire had doubled in size but was still slow-moving, burning down the gully. The crew ran out 3 lengths of hose and started damping down the edges along the firebreak to prevent the fire spreading across it.
02:39	NZFS reported that the fire had increased to approximately 2 hectares in size.
03:00	The fire reached the bottom of the gully and commenced its run along the face of the slope, parallel to the ridge (start of Run 1). The fire crews followed the progress of the fire, damping down the edges of the break along the ridge, but no direct attack was made.
03:30	NZFS positioned crews at Paremata Street to defend property boundaries and structures if necessary.
03:50	The fire reached a point along the face in line with the northern boundary of the King-Turner property (end of Run 1). The rate of spread and flame length slowed here, due to a reduction in the width of the fire front and the wind starting to change direction. Fire crews attempted to attack the fire here, cutting hand line, but the intensity was still too high and they subsequently withdrew.
04:15	With the shift in wind direction, crews assembled at the top corner and started cutting hand line.
04:30	The bulldozer arrived at the fire-line and commenced constructing a break down the slope towards pine plantation on a privately-owned estate. Crews followed the bulldozer with hose line.
04:54	Residents were evacuated from the King-Turner property, as the fire was burning along the northern boundary. A number of other residents were also evacuated from properties in Paremata Street.
05:30	The fire entered the pine plantation, but the bulldozer was able to construct a break around the areas burning and prevent the fire from spreading further.
06:00	The fire was considered to be contained by this stage.

The main run of the fire was made across the face, parallel to the ridge-line. Based on observations from the Deputy PRFO, who assumed the role of Sector Supervisor along the ridge, the travel of the fire along this face can be split into two distinct phases or runs. It is these two runs upon which I have based the discussion of fire behaviour. There were a number of other smaller runs made, as well as considerable areas on the lower boundary that burned as a result of back-burning. However, no observations of these smaller runs were available or recorded. The fire also entered a block adjacent to the northern boundary of the King-Turner property and crossed a mowed firebreak at the top of the block. From a site inspection and photographs of the area, it appears that the fire travelled along rows of mowed, dead grass. A large number of embers were observed being lifted and transported across the break at the top of the ridge-line; however, none of these caused spot fires in the vegetation on the other side. This is most likely due to the fact that the canopy of the gorse scrub would have consisted of green vegetation and, at that time of the morning, would have had a coating of dew. A total area of 30.1 hectares was burned, and this included 0.26 hectares of pine plantation (approximately 10-12 years old). There were no injuries to firefighters, no structures were lost, and there was minimal damage to fences and some property damage due to fire appliances and firefighting operations. There was, however, real potential for the fire to spread beyond the ridge and into Hira Forest to the east, as well as to spread further along the ridge face and threaten more properties.

Public safety and evacuations
As mentioned, there was considerable concern for the safety of properties, and a number of houses were evacuated with the assistance of the police. It is the opinion of the PRFO that, were it not for a conscientious effort to maintain defensible space around the King-Turner property, the property would have been destroyed (Millson, *pers. comm*.). Figure 3 shows the gorse fuels which extended onto the fence-line bordering the property. The roads leading up to some of these properties are very narrow and winding, making it extremely difficult for fire appliances to reach them. The NZFS had great difficulty in negotiating these narrow roads and accessing properties.

Figure 3. Gorse vegetation extending onto the boundary of the King-Turner property.

Mop-up
The fire was contained by approximately 06:00 on 7 May (approximately 5 hours after ignition) and NZFS personnel were stood down between 07:00 and 08:00. After this, mop-up operations commenced. The weather forecast for later on the day of 7 May 2002 was for very strong winds of up to 60-70 km/h (Millson, *pers. comm*.). There was therefore a very real danger of the fire flaring up, and it was imperative to have adequate resources on hand to prevent this. These forecasted strong winds did not eventuate, but the danger was there. A large number of resources were subsequently assigned to mop-up for the remainder of the day (until midnight), and an excavator was brought in to dig up hotspots and disperse any piles of debris. A small crew of four firefighters was assigned to mop-up and recovery of equipment until Friday 10 May.

Fire Environment

Fuels
The fuels covering the burn area consisted mostly of gorse (*Ulex europaeus*), with some bracken fern, broom and blackberry interspersed. The cover was continuous and very dense. The age of the scrub was 5 years old, since the entire area burned in the last fire in October 1997. There was a large amount of heavy dead material (large stems) remaining from the 1997 fire. The average height of fuels over the area covered by "Run 1" was 2m, which equates to an estimated fuel load of 34.8 t/ha (Pearce 2001a). The average height of fuels over the area covered by "Run 2" was 1.75 m, giving an estimated fuel load of 32.2 t/ha. The area of pine plantation which burned (0.26 ha) consisted of pine trees with an approximate age of 10-12 years and a dense gorse understory. Refer to Figure 4 for photographs of the fuel complexes involved in the fire.

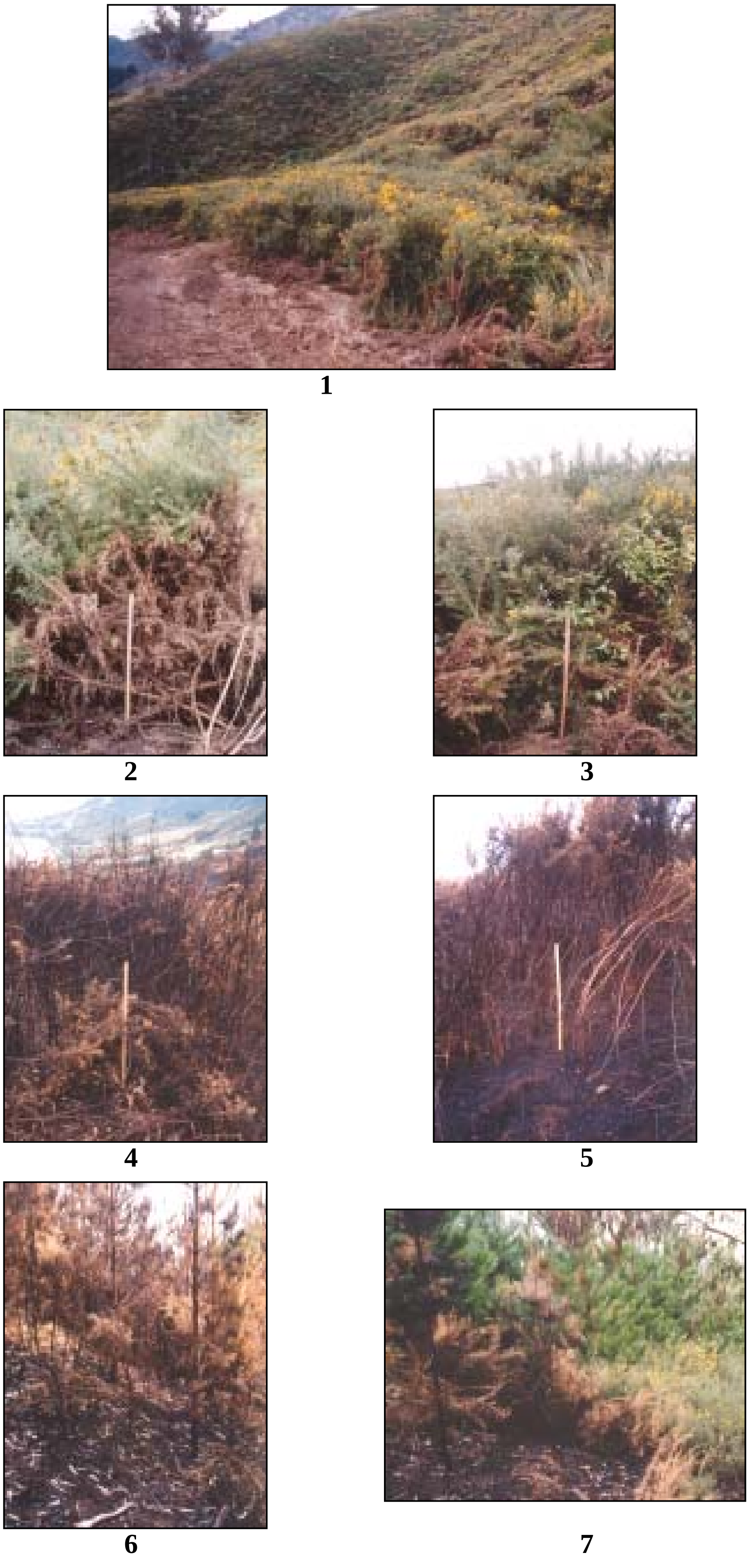


Figure 4. Fuel characteristics:
(1) general overview of fuel complex; (2 & 3) unburned fuels; (4 & 5) burned fuels showing large number of dead stems from 1997 fire; (6) pine plantation area burned, (7) with gorse understory.

Topography

The topography of the area is characterised by a face running from west to east with a north-facing aspect. The angle of the slopes ranges from 16º to 35º. There is a gully running down the western end of the slope, and it is from the foot of this gully that the fire commenced its run towards the King-Turner property. The fire location is approximately 500 m from the coastline, and the elevation ranges from 120 m to 190 m above sea level.

Fire weather

The hourly weather readings from Hira station, as well as the calculated hourly Fine Fuel Moisture Code (FFMC), Initial Spread Index (ISI) and Fire Weather Index (FWI)[1] are included in Table 1. Data for a number of alternative weather stations was available (e.g., Nelson, Nelson Aero). However, the Hira RAWS is the closest station to the site of the fire (3.4 km away - refer to Figure 1), has the most complete record of weather data, and is deemed to be most representative of conditions at the site of the fire (Millson, *pers. comm*.). Table 2 lists weather observations over the period 1 October 2001 to 8 May 2002, the day after the fire. These weather observations are compared against the long-term averages for this period at the Nelson Aero weather station over 33 years (1963 to 1995), as described in Pearce (1996). Also included is a comparison of the Monthly Severity Rating (MSR)[2] against the long-term MSR for Nelson Aero.

---

[1] Explanation of FWI System codes and indexes (after Anon. 1993):

- Fine Fuel Moisture Code (FFMC): a numerical rating of the moisture content of litter and other fine fuels and an indication of relative ease of ignition and flammability of fine fuel.
- Duff Moisture Code (DMC): a numerical rating of the moisture content of loosely compacted organic layers of moderate depth and an indication of fuel consumption in these layers.
- Drought Code (DC): a numerical rating of the moisture content of deep, compact, organic layers and an indication of seasonal drought and the likelihood of fire involving deep duff layers.
- Initial Spread Index (ISI): a numerical rating of expected rate of fire spread.
- Buildup Index (BUI):): a numerical rating of the total amount of fuel available.
- Fire Weather Index (FWI): a numerical rating of fire intensity that combines ISI and BUI and indicates the likely intensity of a fire.

[2] Due to the mathematical relationships within the FWI System, it is generally not considered suitable to average FWI values. The Daily Severity Rating (DSR) has been derived to enable comparisons of these values, and is a numerical measure which rates daily fire severity based on the FWI value. Severity ratings can be calculated for any desired time period by dividing the sum of the individual DSRs by the number of days in the period of interest. In this way, Monthly (MSR) and Seasonal (SSR) Severity Ratings are derived (Pearce 1996).

Table 1. Hourly weather readings for the period 12:00 on 6 May to 23:00 on 7 May 2002 for Hira RAWS. Based on a Microsoft Excel spreadsheet developed by the ***Forest Research*** Forest and Rural Fire Research programme.

								Hourly FWIs			Daily FWIs							Forest			Grassland				Scrubland		
Date	**Time (NZST)**	**Temp (°C)**	**RH (%)**	**Wind dirn (deg)**	**Wind speed (km/h)**	**Rain (mm)**	**Rain 24h (mm)**	**FFMCh**	**ISIh**	**FWIh**	**FFMC**	**DMC**	**DC**	**ISI**	**BUI**	**FWI**	**DSR**	**FFI (kW/m)**	**FFDC**	**POI% (C-6)**	**DoC (%)**	**GFI (kW/m)**	**GFDC**	**POI% (O-1)**	**SFI (kW/m)**	**SFDC**	**POI% (S-1)**
06/05/2002	1200	15.5	58.6	307.6	16.1	0.0	0.0	76.3	1.9	1.3	84.7	4.9	220.2	4.5	9.3	4.7	.42	0	L	32%	50	0	L	35%	3423	VH	72%
06/05/2002	1300	16.6	54.2	307.8	21.1	0.0		77.6	2.6	2.5								1	L	45%	50	0	L	39%	5453	E	75%
06/05/2002	1400	17.0	51.4	298.4	18.4	0.0		78.8	2.5	2.3								1	L	43%	50	0	L	38%	5211	E	77%
06/05/2002	1500	16.6	53.0	302.1	25.4	0.0		79.8	4.0	4.1								2	L	69%	50	0	L	47%	9282	E	79%
06/05/2002	1600	15.7	60.9	301.1	19.9	0.0		80.5	3.2	3.2								1	L	56%	50	0	L	42%	7144	E	80%
06/05/2002	1700	14.5	70.2	308.0	11.8	0.0		80.7	2.2	1.9								0	L	38%	50	0	L	37%	4344	E	81%
06/05/2002	1800	12.1	89.9	338.7	4.1	0.0		80.6	1.5	0.9								0	L	26%	50	0	L	33%	2506	VH	80%
06/05/2002	1900	11.5	100.0	7.7	4.2	0.0		79.7	1.4	0.8								0	L	25%	50	0	L	32%	2224	VH	79%
06/05/2002	2000	11.1	100.0	36.2	7.1	0.0		78.9	1.5	0.8								0	L	26%	50	0	L	32%	2444	VH	77%
06/05/2002	2100	11.5	100.0	309.7	5.7	0.0		78.2	1.3	0.7								0	L	24%	50	0	L	32%	2042	VH	76%
06/05/2002	2200	10.9	100.0	310.2	13.9	0.0		77.5	1.8	1.3								0	L	31%	50	0	L	34%	3337	VH	75%
06/05/2002	2300	11.0	99.8	321.7	9.7	0.0		77.0	1.4	0.8								0	L	25%	50	0	L	32%	2350	VH	73%
07/05/2002	0	10.8	99.5	317.1	7.4	0.0		76.6	1.2	0.7								0	L	23%	50	0	L	31%	1915	H	73%
07/05/2002	**100**	**10.9**	**99.7**	**304.8**	**11.1**	**0.0**		**76.1**	**1.4**	**0.8**			**Time of ignition**					**0**	**L**	**26%**	**50**	**0**	**L**	**32%**	**2399**	**VH**	**72%**
07/05/2002	200	10.7	100.0	336.9	6.0	0.0		75.8	1.1	0.6								0	L	21%	50	0	L	31%	1620	H	71%
07/05/2002	300	11.2	99.7	330.8	8.1	0.0		75.5	1.2	0.7								0	L	22%	50	0	L	31%	1824	H	70%
07/05/2002	400	11.0	100.0	319.0	7.3	0.0		75.2	1.1	0.6								0	L	21%	50	0	L	31%	1682	H	70%
07/05/2002	500	11.5	100.0	72.1	1.6	0.0		75.0	0.8	0.5								0	L	18%	50	0	L	29%	1104	H	69%
07/05/2002	600	11.3	100.0	133.1	2.9	0.0		74.8	0.9	0.5								0	L	19%	50	0	L	29%	1187	H	69%
07/05/2002	700	10.6	100.0	116.1	5.4	0.0		74.6	1.0	0.6								0	L	20%	50	0	L	30%	1409	H	68%
07/05/2002	800	10.2	100.0	107.0	2.5	0.0		74.4	0.8	0.5								0	L	18%	50	0	L	29%	1130	H	68%
07/05/2002	900	11.2	100.0	115.7	4.0	0.0		74.3	0.9	0.5								0	L	19%	50	0	L	30%	1244	H	67%
07/05/2002	1000	14.9	91.3	309.6	6.6	0.0		74.4	1.0	0.6								0	L	20%	50	0	L	30%	1514	H	68%
07/05/2002	1100	16.5	79.2	295.6	10.4	0.0		75.0	1.3	0.7								0	L	24%	50	0	L	32%	2063	VH	69%
07/05/2002	1200	17.9	60.4	295.6	13.7	0.0	0.0	76.2	1.6	1.2	85.1	5.9	223.1	4.2	11.0	4.8	.44	0	L	28%	50	0	L	33%	2870	VH	72%
07/05/2002	1300	18.8	52.4	319.8	9.5	0.0		77.4	1.4	0.9								0	L	26%	50	0	L	32%	2427	VH	74%
07/05/2002	1400	17.3	62.9	299.0	8.7	0.0		78.2	1.5	0.9								0	L	26%	50	0	L	33%	2504	VH	76%
07/05/2002	1500	17.9	53.2	292.1	16.4	0.0		79.3	2.4	2.5								1	L	41%	50	0	L	38%	4844	E	78%
07/05/2002	1600	17.3	51.0	294.1	16.6	0.0		80.3	2.7	2.9								1	L	46%	50	0	L	39%	5612	E	80%
07/05/2002	1700	15.6	57.6	302.2	16.2	0.0		80.9	2.8	3.0								1	L	48%	50	0	L	40%	5972	E	81%
07/05/2002	1800	13.4	70.4	307.9	5.5	0.0		81.1	1.7	1.3								0	L	29%	50	0	L	34%	2994	VH	81%
07/05/2002	1900	12.7	72.1	314.6	10.3	0.0		81.2	2.2	2.1								1	L	37%	50	0	L	36%	4245	E	81%
07/05/2002	2000	11.7	86.7	317.2	10.0	0.0		81.1	2.1	2.1								1	L	36%	50	0	L	36%	4105	E	81%
07/05/2002	2100	11.6	91.7	311.0	13.0	0.0		80.8	2.4	2.4								1	L	40%	50	0	L	37%	4759	E	81%
07/05/2002	2200	11.2	96.9	305.5	4.8	0.0		80.1	1.5	0.9								0	L	26%	50	0	L	33%	2473	VH	80%
07/05/2002	2300	11.3	94.4	302.3	13.5	0.0		79.7	2.2	2.1								1	L	37%	50	0	L	36%	4250	E	79%

The weather over this period was markedly different from the long-term average weather observations. By comparing the long-term total monthly rainfall against the total monthly rainfall for the period October 2001 to May 2002 (see Figure 5), it is apparent that the rainfall was above normal for the period from 1 October until January. Total rainfall was lower than normal for the months of March and April, and the first eight days of May saw no rain at all. This is verified by examining Drought Code (DC) values for this period. The trend in the DC over the period October 2001 to May 2002, compared to the long-term average, is shown in Figure 5. The DC reached a value of 125 on 8 January 2002. A number of significant rain events caused it to drop down to a low of 7 on 15 January 2002 (rainfall recorded for the 24-hour period to noon on 15 January 2002 was 58.6 mm). The rainfall received over this period was therefore sufficient to penetrate the deeper, compact, organic layers and raise their moisture content. The effect that these rain events had on the DC is illustrated in Figure 5, with significant rainfalls clearly lowering the DC. Thereafter a period of drying continued up until the day of the fire, with the DC reaching 220 at noon on 6 May 2002. This indicated a reasonably dry state of the deeper, compact organic layers and that mop-up of any fire in the area would be moderately difficult (as was the case with this fire). The plot in Figure 5 appears to reflect the actual conditions reasonably accurately, with the DC appearing below the long-term average as a result of the wetter months experienced from October 2001 to February 2002. However, the latter period from early April to May shows the DC climbing above normal values, thus indicating a drier-than-normal condition of deeper organic layers than would normally be anticipated at that time of year.

Table 2. Monthly weather and Severity Rating (MSR) for the period 1 October 2001 to 8 May 2002, compared to long-term data from the Nelson Aero weather station.

Month	Average Temp. (°C)	Long-term average Temp. (°C)	Average RH (%)	Long-term average RH (%)	Average Wind speed (km/h)	Long-term average Wind speed (km/h)	Total Rain (mm)	Long-term total Rain (mm)	Monthly Severity Rating (MSR)	Long-term MSR
Oct	16.6	15.0	77	67	10.4	20.5	352.4	81.8	0.11	0.87
Nov	16.8	16.8	76	66	12.7	23.0	188.2	83.8	0.10	1.59
Dec	18.3	18.7	87	67	12.0	22.9	199.0	77.3	0.10	2.39
Jan	20.1	20.3	85	64	9.3	22.4	139.6	76.6	0.07	3.69
Feb	19.6	20.5	68	64	11.6	19.6	56.4	57.5	0.66	4.07
Mar	19.3	19.1	70	65	11.9	17.4	40.4	78.1	1.00	2.31
Apr	15.8	16.5	83	66	7.6	14.2	63.4	87.7	0.44	1.14
May	16.4	13.3	61	69	13.5	11.5	0.0	90.1	0.25	0.47

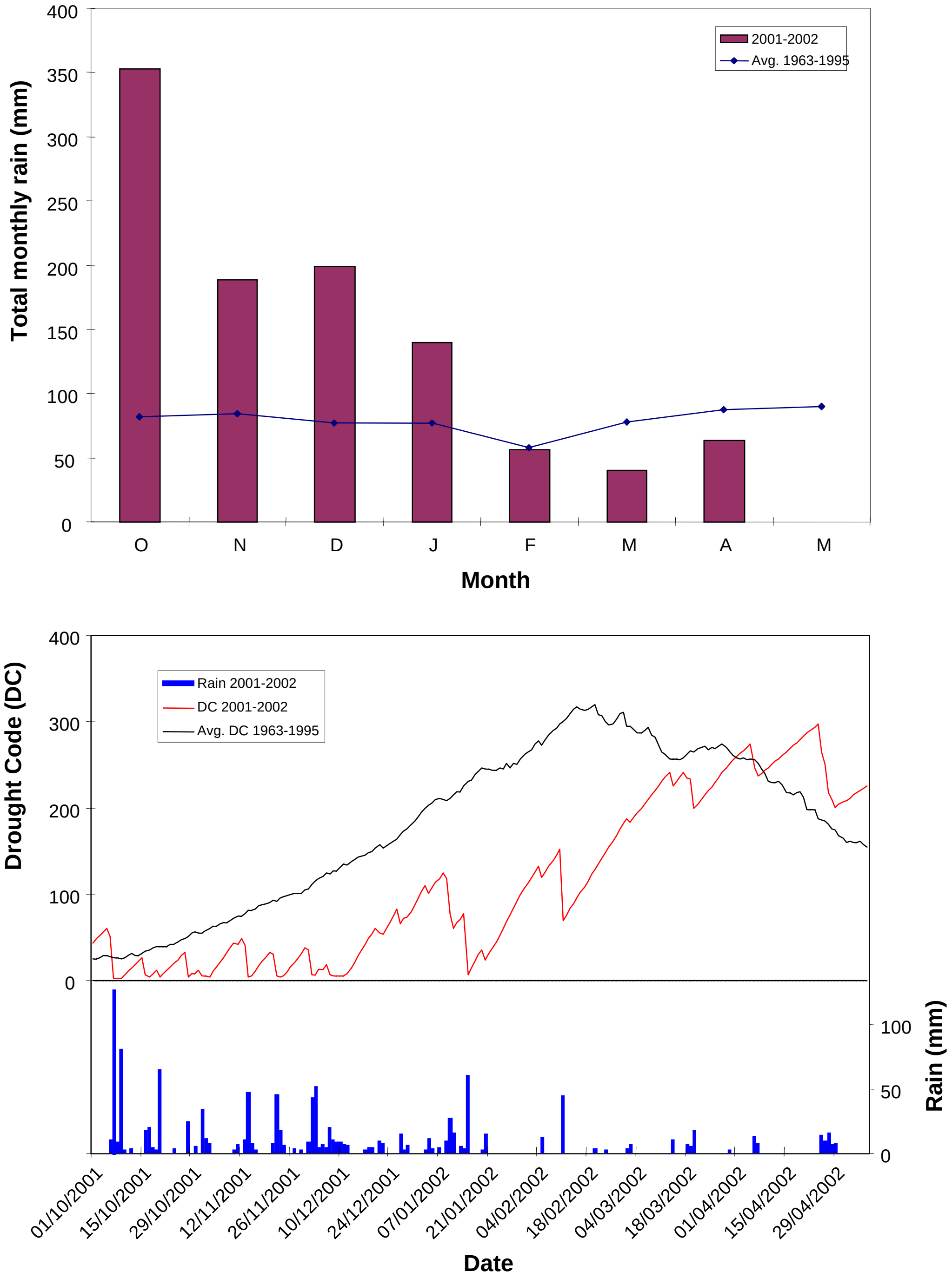
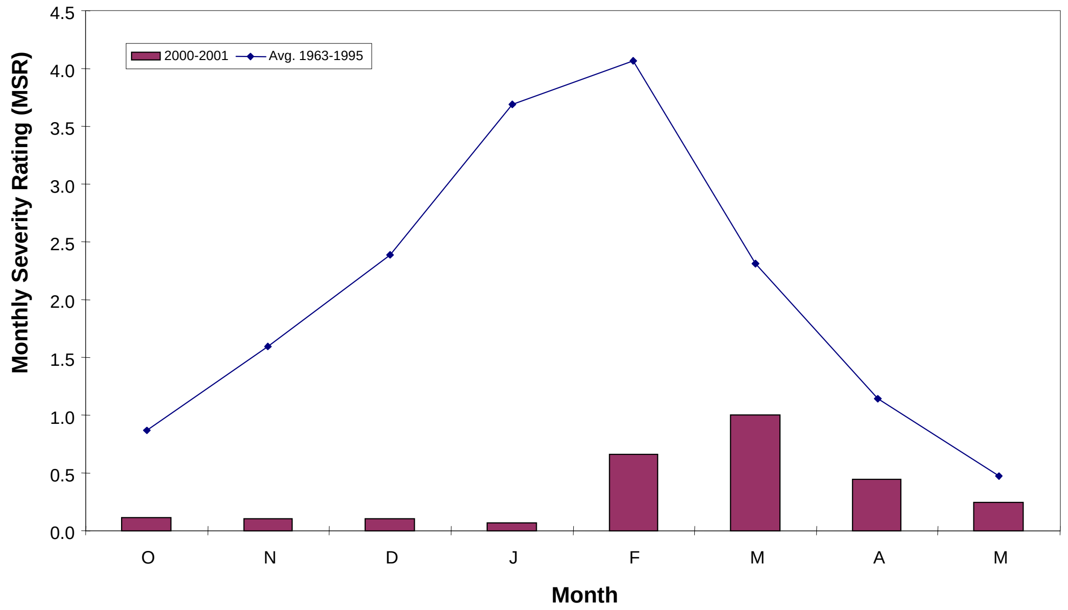


Figure 5. Total monthly rainfall (top) and Drought Code with daily rain (bottom) for the period 1 October 2001 to 8 May 2002, compared against long-term values for Nelson Aero weather station (1963 to 1995).

This departure from long-term trends is particularly evident by comparing the Monthly Severity Rating (MSR) and Cumulative Daily Severity Rating (CDSR) against the long-term values for Nelson Aero (Figure 6). The CDSR is obtained by summing individual DSR values for the period of interest (i.e., from 1 October 2001 to 8 May 2002). The long-term CDSR was calculated by summing individual DSR values for each year, and then averaging these values over that period of time. The plot of MSR for the 2001/2002 season against the long-term MSR values clearly illustrates that the 2001/2002 season was markedly different to a "normal" season. This is particularly true for the period October to February. Thereafter, the MSR did start to approach more "normal" (or expected) values. The plot of 2001/2002 CDSR against the long-term values is again a clear indication that values were significantly below those that would normally have been expected.



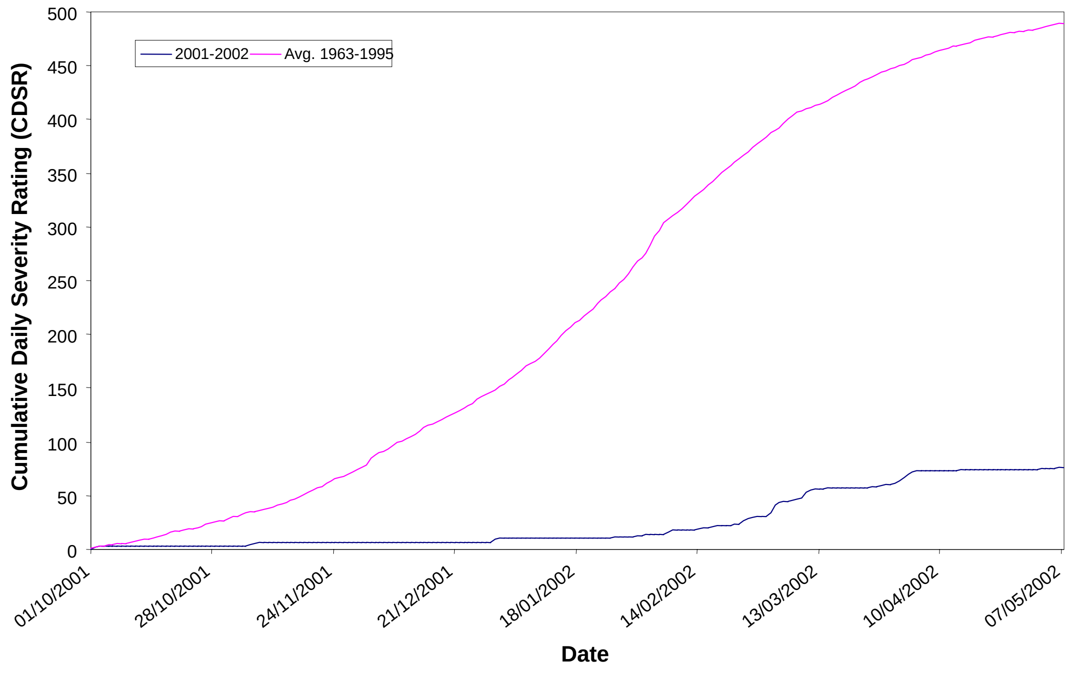


Figure 6. Monthly Severity Rating (MSR), top, and Cumulative Daily Severity Rating (CDSR), bottom, values for the period 1 October 2001 to 8 May 2002, compared against long-term values for Nelson Aero weather station (1963 to 1995).

The last significant rain event prior to 7 May had been a rainfall of 6.0 mm for the 24-hour period to noon on 29 April. Cumulative rainfall for the period noon of 23 April to noon 29 April was 45.8 mm. This reduced the Fine Fuel Moisture Code (FFMC) from 78.2 on 23 April to 0 on 29 April. This effectively meant that there was no probability of ignition occurring on 29 April. The Build-up Index (BUI) was also significantly reduced over this period (21 to 0). The Duff Moisture Code (DMC) was similarly reduced (12 to 0), with the Fire Weather Index (FWI) also 0. The Scrubland Fire Danger Class for these days was Low[3]. It would therefore be fair to say that on 29 April 2002 there was no chance of a fire igniting and spreading in scrub fuels.

At noon on 6 May, the afternoon before the fire, fire weather readings were the following:

FFMC: 84.7
DMC: 5
DC: 220
ISI: 4.5
BUI: 9
FWI: 4.7
Scrubland Fire Danger Class: EXTREME
Forest Fire Danger Class: LOW
Grassland Fire Danger Class: LOW

Whilst the DMC, BUI and FWI were not particularly high, the FFMC and DC were moderately high, and the Scrubland Fire Danger Class was EXTREME. It has already been mentioned that the DC showed a steady climb from 15 January, when it reached a low of 7. Although there had been rain since then, it was not sufficient to significantly decrease the DC and prevent its overall increase for this period. Rainfall had therefore not generally been penetrating these deeper, compacted organic layers. The period after 29 April and up until and including 7 May was characterised by north-west winds and lower relative humidities. There had also been no rainfall since 29 April, when 6 mm was recorded. Wind speeds of 31 km/h and 22.1 km/h were recorded on 3 and 4 May respectively. This resulted in a steady drying-out of the fine fuels; the FFMC increased from 0 to 85, and the Scrubland Fire Danger Class from LOW to EXTREME over a period of one week. It is interesting to note that on the days of 6 and 7 May, the Forest Fire Danger Class (Alexander 1994) was LOW, whilst the Scrubland Fire Danger Class was EXTREME. This illustrates the extreme flammability of these fuel complexes and how they are capable of carrying fires of extreme intensity after a relatively short period of dry weather.

[3] The Scrubland Fire Danger Class is based on 10-m wind speed and FFMC, with a standard scrub fuel load of 20 t/ha assumed (Pearce 2001b). However, the actual fuel loads (as discussed in the earlier section on fuels) were considerably higher than this (34.8 t/ha and 32.2 t/ha). These actual fuel loads were derived from visual observations of height and cover (Pearce 2001a).

At 01:00 on 7 May, 17 minutes before the first report of the fire was logged, the FFMC was 76.1 (see Table 1). An FFMC of 74, which equates to a fine fuel moisture content of approximately 30% (the moisture of extinction), is generally regarded as the threshold below which a fire will not spread (Alexander 1994). This FFMC value of 76.1 was sufficiently high to allow ignition of the fine fuels and for the fire to spread, despite the low ISI and FWI (see Figure 7). The temperature at 01:00 was 10.9 ºC with a relative humidity of 100%. The Scrubland Fire Danger Class at this time was VERY HIGH. The fire was able to ignite, spread and burn with a fierce intensity in weather conditions which would not have been expected to produce such fires. This again illustrates the ability of scrubland fuels to produce fires of extreme intensity and behaviour. For the period from ignition to containment of the fire (01:17 to 06:00), the wind speed reached a maximum around the time of ignition (it was 11 km/h at 01:00). The wind direction was from the north-west until around 04:30, when it started changing to south-east. The wind speed also decreased between 04:00 and 05:00 from 7.3 km/h to 1.6 km/h respectively. This agrees with observations from personnel at the time of the fire. The direction of the flame front subsequently changed with this change in wind direction, allowing firefighters to launch an attack and contain the fire. Throughout the duration of the fire, the Scrubland Fire Danger Class remained HIGH. Although the fire weather codes and indices were not very high, with the possible exception of the DC, the fire behaviour and intensity was far greater than what would have been anticipated given these conditions. The reasons for this will be discussed in the section dealing with fire behaviour. A weather forecast obtained during the run of the fire for the remainder of the day predicted strong winds of up to 60 - 70 km/h. This was a very real concern for containing the fire before the arrival of these winds, and damping down hotspots sufficiently to prevent flare-ups. However, these strong winds did not eventuate.

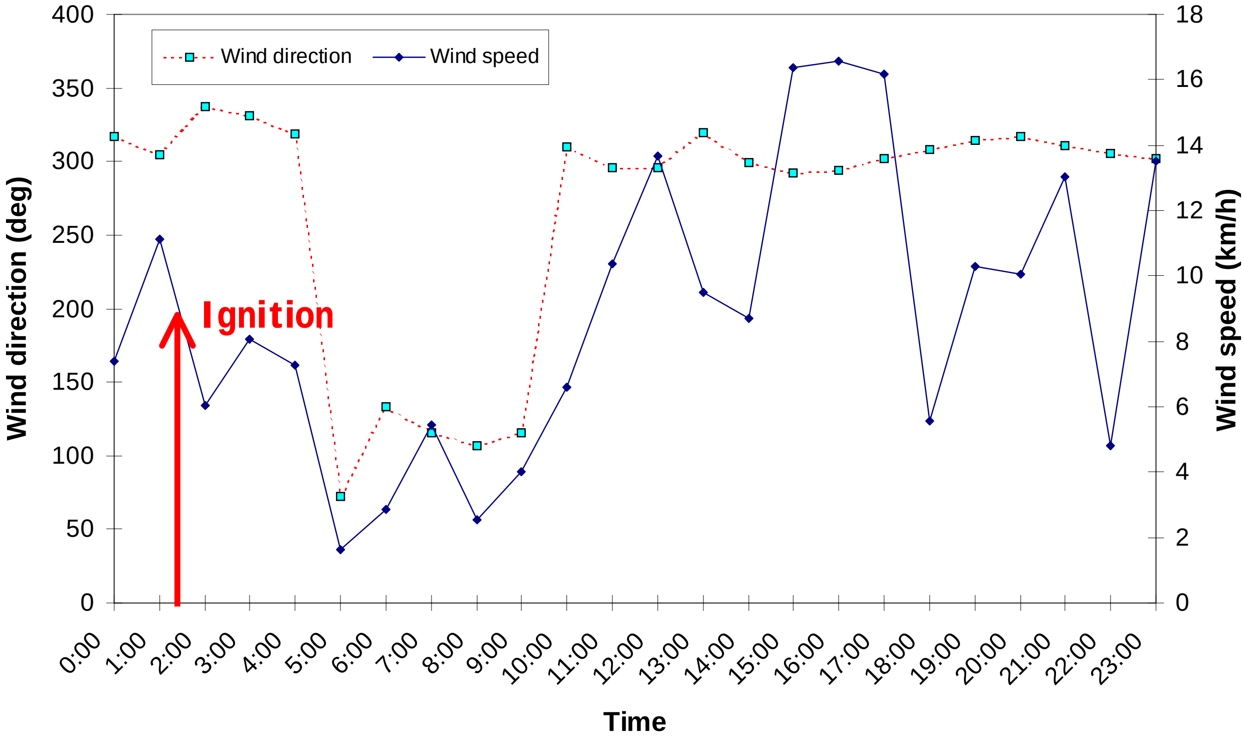


Figure 7. Hourly wind speed and direction recorded at Hira RAWS for 8 May 2002.

Fire Behaviour

Observations of fire behaviour and travel times by the Deputy PRFO have enabled two separate "runs" to be identified and accurately described (see Figure 2). These two runs occurred along the face, parallel to the ridge-line. The first run was that from the base of the gully up to the point above the northern boundary of the King-Turner property. The second run was from this point to the north-eastern corner of the fire area, from where the bulldozed firebreak was constructed. This was the point where the wind, and subsequently the fire front, changed direction, allowing a firebreak to be constructed and the fire to eventually be contained. The reason for this fire being split into two separate runs is that the fire changed in intensity and rate of spread from the boundary of the King-Turner property, most likely due to a narrower fire front and the wind starting to change direction (Thompson 2002). Table 2 illustrates the observed against the predicted observations for the two separate runs.

Table 3. Observed vs predicted fire behaviour.

	Run 1		**Run 2**	
Distance of run (m) Duration of run (min) Scrub height (m) Fuel load (t/ha)	450 50 2 34.8		200 40 1.8 32.2	
	Observed	**Predicted**	**Observed**	**Predicted**
Rate of spread (m/h)	540	189	300	166
Flame length (m)	5	5.2	4.5	3.8
Head fire intensity (kW/m)*:	9400	3290	4830	2670
Length-to-Breadth (L/B) Ratio	3.4	2.8	1.5	2.3

* calculated using the simplified formula, I=(w x r)÷2, which assumes a heat of combustion value of 18 000 kJ/kg.

As can be seen from Table 2, the observed and predicted values are significantly different. This can largely be explained by the nature of the fuel complex, and the impact of topography (i.e., the fire environment). Fuel loadings were calculated using the model produced by the ***Forest Research*** Forest and Rural Fire Research programme (Fogarty and Pearce 2000). For models to predict the rate of spread and other fire behaviour predictions, refer to the Interim Field Guide produced by the Fire Research programme (Pearce 2001a). As has already been stated, the fuel complex consisted of a large amount of dead stems and woody material which were remnants from the October 1997 fire. Fuel loads were therefore considerably higher than those predicted. This high loading of dense and dry material significantly increased the intensity of the fire. Table 3 illustrates the implications for fire suppression based on head fire intensity. For Run 1, the predicted fire intensity was 3290 kW/m. This indicates that direct attack on the head fire would only have been possible during the early stages of ignition. Thereafter, head fire attack would only have been possible with aerial suppression. However, the observed head fire intensity was 9400 kW/m, which is considerably higher and indicates that direct attack on the head fire was not possible. The intensity observed during this run explains why it was not possible for crews to mount a direct attack on the fire and why, when they attempted to do so, they had to withdraw.

The rate of spread of the head fire during Run 1 was also considerably faster than that predicted (540 m/h vs 189 m/h). This is also most likely due to the nature of the fuel complex (i.e., the higher fuel loadings). It is also important to consider topography when discussing the observed fire behaviour. Although the angle of the slopes were in the range of 16° to 35°, for the purposes of the two runs the terrain has been regarded as being level (i.e., no correction has thus been made for slope). The reason for this is that the main fire spread was across the face of the slope, due to the prevailing wind direction at the time of the fire. Areas below the runs were burned through flank and back fire activity. The fire was thus wind- and fuel-driven, and not slope-driven, as would have been expected with a different wind direction, or no wind at all. Differences in observed versus predicted fire behaviour possibly also indicate that further revision and development of the scrub fire behaviour model is required, particularly the underlying assumptions made in the model (i.e., the assumed fuel load of 20 t/ha).

Table 4. The minimum fire suppression resources required to contain the head of a fire burning in each of the Fire Danger Classes (Alexander 1994).

Fire Danger Class	Fire Intensity Range (kW/m)	Minimum fire suppression resources for direct head fire attack
LOW	0 - 10	Hand crew.
MODERATE	10 -500	Hand crew and back-pack.
HIGH	500 - 2000	Water under pressure and bulldozer.
VERY HIGH	2000 - 4000	Aircraft and long term retardants **may** be effective **but it may be too dangerous for ground crews.**
EXTREME	> 4000	**Head fire attack will probably not be effective and is too dangerous for ground crews.**

In the case of Run 2, the predicted rate of spread was 166 m/h, compared to an observed rate of spread of 300 m/h. Observed and predicted fire intensities were also significantly different: 4830 kW/m and 2670 kW/m, respectively. The slightly lower fuel loading and flame length for this run can be attributed to a lower fuel height. However, the fire still showed a far greater rate of spread and intensity than was predicted. The greater intensity is again most likely due to the greater fuel loading from the remnant fuels of the 1997 fire. The decrease in the rate of spread from Run 1 to Run 2 can probably be attributed to the fact that from the start point of Run 2, the width of the fire front was significantly reduced, and the wind was starting to change direction. Studies carried out in grass fuels in Australia have found that the width of the head fire and wind speed are significant factors influencing the rate of spread. It was found that rate of spread decreases with a narrower head fire width, whereas fires with a wide parabolic head had a faster rate of spread (Cheney *et al.* 1993; Cheney and Gould 1995). The wind change at the end of this run to the south-east, as well as the decrease in wind speed, sufficiently changed the direction and rate of the forward spread of the fire front to enable construction of a firebreak and direct firefighting to commence.

Table 2 also includes a comparison of observed versus predicted flame lengths. The predicted flame lengths have been calculated using the equation of Byram[4] (1959). Using the observed fire intensity for each run, the predicted flame lengths are reasonably close to those observed at the time of the fire. This indicates that the fire intensities calculated from observed rates of spread and actual fuel loads are in fact reliable indicators of the intensities produced at the time of the fire. Comparisons of actual versus predicted Length-to-Breadth (L/B) Ratios for the two runs are also given in Table 2 (refer to Pearce 2001a). The L/B Ratio is intended to give an indication of a fire's shape, assuming that the growth of a fire is largely governed by wind speed. With constant wind direction, the shape of a fire will resemble that of an ellipse. Using this relationship, it is therefore possible to predict the expected shape of a fire (Alexander 1985). This does, however, depend on other factors, such as fuel and topography. In the case of this fire, the shape of the burn was generally not elliptical, largely due to the topography and the cross-slope fire spread (driven by the wind direction).

[4] Using Byram's equation for fire intensity, it is possible to solve for flame length (L), if the fire intensity (I) is known. The equation is: $I=259.833(L^{2.174})$, where I is the fire intensity (kW/m), and L is the flame length (m).

Another interesting aspect of the fire behaviour was the breaching of a mowed firebreak at the bottom of the face at the northern boundary of the King-Turner property (see Figures 2 and 8). The fire burned through the block of gorse below the break and crossed the mowed firebreak of approximately 15 m to continue burning up and along the face. The grass curing percentage for the Nelson/Hira area was recorded as being 50% by the NRFA. This is generally regarded as the minimum threshold for fire spread, below which a fire will not spread through grasslands (Cheney and Sullivan 1997). Unfortunately, the width of firebreak required to stop scrub fires at different intensities is generally not known (Fogarty 1996). A general guideline for a firebreak width of 1.5 times the flame length is often referred to (e.g., Byram 1959). This assumes that severe spotting is not taking place. In this instance, spotting was not a significant factor (Ashford, *pers. comm*.). With an average flame length of 2 m in this area, a firebreak of 7.5 m width would be considered sufficient to prevent breaching from a fire of this intensity. It could be safely assumed that the 15 m width of this break would have been more than adequate to prevent breaching. From photographs and an inspection of the site, it has been determined that lines of mowed grass were present in the break. This mowed grass was dead and would have had a degree of curing considerably higher than 50%. It is most likely these lines of mowed, cured grass which enabled the fire to burn across the break and into the scrub fuels on the other side. Using the Cut (or Matted-Down) Grass model of the NZ Fire Danger Rating System (NZFDRS) and assuming a degree of curing of 70% with an Initial Spread Index (ISI) of 1, a predicted rate of spread of fire in this fuel type is 34 m/h (Pearce 2001a).

Figure 8. Mowed break breached by the fire. Fire burned along the lines of mowed grass.

Conclusions

The Atawhai Fire of 7 May 2002, whilst not of great significance in terms of the area burned, is of significance for various other reasons. The proximity of the fire to the city of Nelson, the fact that it occurred in a Rural/Urban Interface (RUI) zone, and that properties had to be evacuated as it was felt that they were in danger, resulted in a great deal of publicity and media attention. There was also the potential for the fire to develop into a much larger fire had it crossed the top of the ridge, or burned further along the slope face towards the residential properties. Had the fire crossed the ridge and burned eastwards, an extensive area of continuous fuels could have allowed it to spread towards Hira Forest. From a fire behaviour and fire management perspective, the fire was very interesting as it largely did not conform to what would have been predicted or expected under the circumstances.

There were a number of safety concerns which were the main reasons behind the decision being taken not to mount a direct attack on the fire, but rather to monitor the fire and protect and defend property as and when necessary. The fact that the nearby powerlines were thought to be down (and arcing) was the main reason for the initial crews at the scene not entering the area. The scrub fuels were also dense and almost impenetrable. Aerial attack was also not an option, due to safety concerns with aircraft operating at night and in unfamiliar terrain. Had the fire occurred during daylight hours, aerial suppression and active firefighting would most likely have taken place. The fire behaviour observed over the two runs, which have been accurately described and recorded from observations at the fire, is significantly different to the predicted fire behaviour, given the existing weather conditions and fire environment factors. This can be largely explained due to the fact that the fuel loadings were considerably higher than those predicted. This is in turn due to the fact that the fuel complex consisted of a large amount of dead stems and larger woody material from the 1997 fire. As has been discussed in the previous section on fire behaviour, the differences in rates of spread possibly indicate that further refinement and validation of the interim Scrubland Fire behaviour model is required (refer to Pearce 2001b). The fire was actually driven by wind and fuels, and not by topography, as may have been expected given the terrain. Instead of spreading upslope, the wind direction forced the fire front to travel across the slope. Had fire behaviour predictions been carried out at the time of the fire, a thorough understanding of the fuels, as well as the other two components of the fire environment (topography and weather) would have been necessary to avoid such significant under-prediction of rate of spread and fire intensity. It was ultimately a change in the weather conditions (specifically wind direction and speed) which enabled the fire to be contained and brought under control.

The Rural/Urban Interface (RUI) issues surrounding this fire are a major cause for concern. This is the second fire to have burned across this area in 5 years, property development further up the hills and into the dense scrub fuels is continuing, and recommended minimum setback distances for structures from vegetation are largely being ignored. It has been suggested that the publicity surrounding this fire be used as a public education exercise. This may not prevent similar fires from happening in the future, but it may help to prevent loss of and damage to property.

Acknowledgements

I would like to extend my thanks to Chris Millson, Doug Ashford (Rural Fire Network Ltd), and Robin Thompson (Fire Investigator and Forestry Consultant), for their assistance and supplying me with all the relevant information to enable compilation of this case study. Thanks are also due to Grant Pearce (***Forest Research*** Forest and Rural Fire Research programme) for comments and advice.

References

Alexander, M.E. 1985. Estimating the length-to-breadth ratio of elliptical forest fire patterns. In Donoghue, L.R.; Martin, R.E. (editors). Proceedings of the 8th Conference on Fire and Forest Meteorology, April 29-May 2, 1985, Detroit, Michigan. Society of American Foresters, Bethesda, Maryland. SAF Publication 85-04. pp 287-304.

Alexander, M.E. 1994. Proposed revision of fire danger class criteria for forest and rural fire areas in New Zealand. National Rural Fire Authority, Wellington. Circular 1994/2. 73 p.

Anon. 1993. Fire Weather Index System Tables for New Zealand. National Rural Fire Authority, Wellington, in association with the New Zealand Forest Research Institute, Rotorua. 48 p.

Byram, G.M. 1959. Chapter 3. Combustion of forest fuels. In: Davis, K.P. (editor). Forest Fire: Control and Use. McGraw-Hill, New York. pp 61-89.

Cheney, N.P.; Gould, J.S. 1995. Fire growth in grassland fuels. International Journal of Wildland Fire 5(4): 237-247.

Cheney, N.P.; Gould, J.S.; Catchpole, W.R. 1993. The influence of fuel, weather and fire shape variables on fire-spread in grasslands. International Journal of Wildland Fire 3(1): 31-44.

Cheney, P.; Sullivan, A. 1997. Grassfires: fuel, weather and fire behaviour. CSIRO Publishing, Collingwood. 110p.

Fogarty, L.G. 1996. Two rural/urban interface fires in the Wellington suburb of Karori: assessment of associated burning conditions and fire control strategies. New Zealand Forest Research Institute, Rotorua, in association with the National Rural Fire Authority, Wellington. FRI Bulletin No. 197, Forest and Rural Fire Scientific and Technical Series, Report No. 1. 16 p.

Fogarty, L.G.; Pearce, H.G. 2000. Draft field guides for determining fuel loads and biomass in New Zealand vegetation types. New Zealand Forest Research Institute, Rotorua and Christchurch. Fire Technology Transfer Note 21 (April 2000). 9 p + appendices.

Pearce, G. 1996. An initial assessment of fire danger in New Zealand's climatic regions. New Zealand Forest Research Institute, Forest and Rural Fire Research Programme. Fire Technology Transfer Note 10 (October 1996). 28 p.

Pearce, H.G. 2001a. Interim field guide to fire behaviour in New Zealand fuel types. Forest Research Forest and Rural Fire Research Programme, Christchurch. (November 2001). 40 p.

Pearce, G. 2001b. Introducing the new Scrubland fire danger class criteria. New Zealand Forest Research, Forest and Rural Fire Research Programme, Christchurch. Fire Technology Transfer Note 22 (November 2001). 9 p. - draft.

Thompson, R. 2002. Investigation into the origin and cause of the Atawhai Fire - Nelson 7 May 2002. Report prepared for the Rural Fire Network Ltd. 19 p + appendices.