Fire Technology Transfer Note

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A Comparison of the 1986 and 2005 Awarua Wetlands Fires

Fraser Townsend and Stuart Anderson

Introduction

On Thursday the 27th of October 2005, the Awarua Wetlands (Figure 1) suffered its second major fire in the past twenty years. This fire burned an area of 1400 hectares of conservation wetlands (10% of the total wetland area) located 17 km from Invercargill city. The Awarua wetland region is of significant importance as a scientific reserve, with significant ecological values. The other major fire in this area occurred on Tuesday the 28th of October 1986, and burned an area of 1360 hectares. Both of these fires threatened several holiday homes in the area and also posed a considerable risk to the power supply to the Tiwai Aluminium Smelter. This smelter, located at Tiwai Point, is a major contributor to the regional and national economy and extended loss of power supply to the smelter would have resulted in major economic losses.

A previous *Fire Technology Transfer Note* (Pearce *et al.* 1994) summarised the 1986 fire, and a case study has recently been written on the 2005 fire (Townsend 2006) and is attached. This *Fire Technology Transfer Note* compares and analyses these two fires, which occurred at the same time of year (1 day apart) nineteen years apart from each other. Fire environment conditions were similar for both fires, as well as fire behaviour. New fire behaviour models that have become available since 1994 are used to revisit the 1986 fire and to compare it with the 2005 fire.

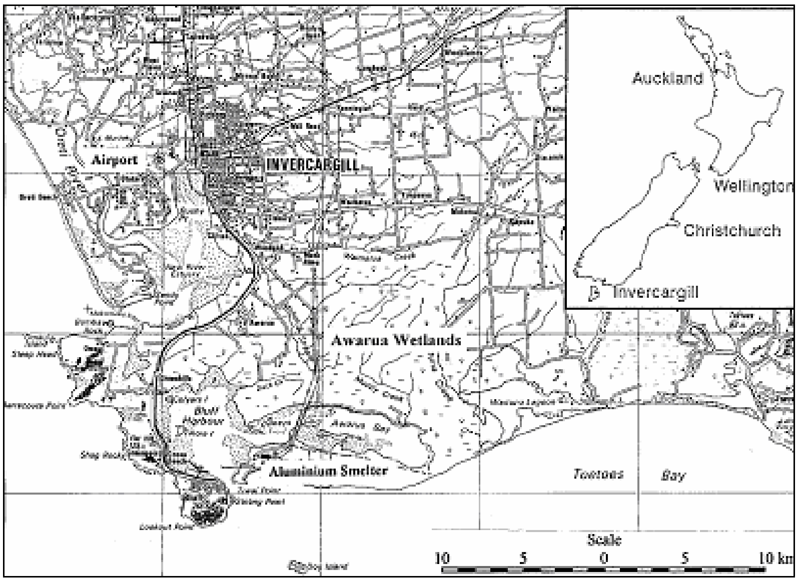

Figure 1. Location of the Awarua Wetlands. (Source: Pearce *et al*. 1994)

Fire Chronology and Development

Ignition and initial attack

Both of the fires discussed here were human-caused. The first fire was started by a vehicle striking and knocking down a transformer pole at 1322 (NZDT) on the 28th of October 1986. The power lines then ignited gorse (*Ulex europaeus*) along the roadside. The fire spread over a period of two hours to burn a total area of 1360 ha (Figure 2). Initial attack on the fire consisted of two helicopters with monsoon buckets along with several crew and fire appliances.

On the 27th of October 2005, a burn-off ignited two days previously by a local farmer flared up under strong northerly winds. The first report of the escaped fire was received at 1158 (NZDT) and by 0630 the next day the fire was contained with a total area burned of 1400 ha, although the majority of this area was burned in four hours. The spread of the fire consisted of a short head fire run of 2.3 km in a southerly direction towards Awarua Bay. Flank fire spread accounted for the majority of the rest of the area that was burnt throughout the day (Figure 2). Initial attack involved three ground crews followed by significant aerial suppression due to the presence of bogs and peat, which restricted ground access.

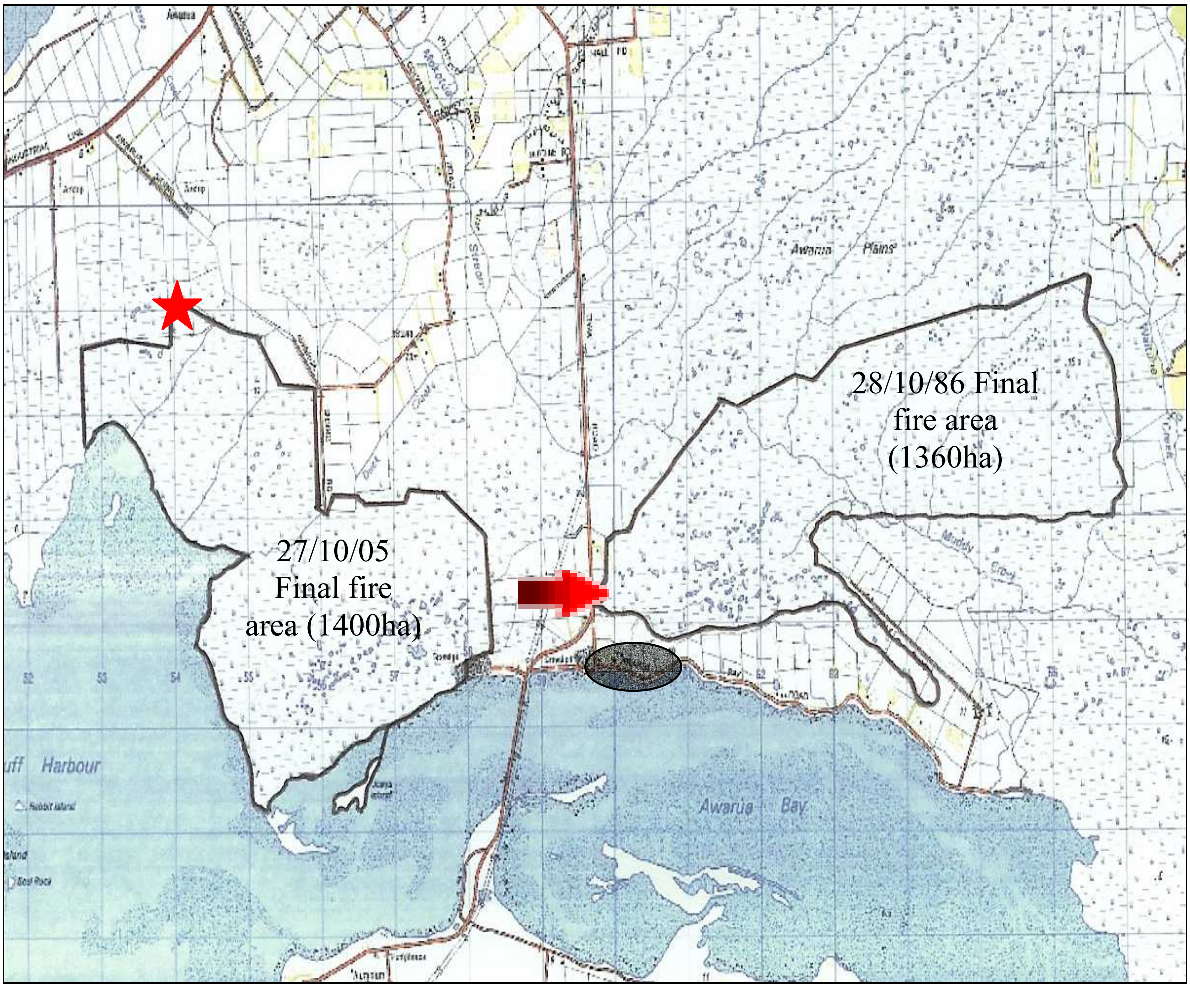

Figure 2. Location of the 1986 and 2005 Awarua Wetlands fires, showing the point of origin and area for each fire. The shaded circle denotes the location of several holiday homes.

Fire Growth and Suppression

The 1986 fire travelled just under 5 km in the first hour, and after approximately two hours had advanced a total of approximately 7 km under the influence of gale force westerlies (Figure 2). This represented the total spread distance, with an area burned of 1360 ha. Three helicopters were used for suppression, along with six fire appliances and approximately twenty firefighters. The fire was contained through a combination of fuel type discontinuities, the presence of various natural and man-made barriers, and effective suppression action (Pearce *et al.* 1994).

The 2005 fire was predominantly fanned by northerly winds gusting up to 70 km/h. During the latter stages of the fire, wind shifts to the northwest caused the fire to travel eastwards towards the power lines and smelter access road (see Figure 2). Six helicopters were employed for suppression during the day, along with several ground crews. No heavy machinery was utilised due to the nature of the terrain, being a wetland of peat and bogs.

Values at Risk and Safety Considerations

In both fires, ecologically important flora and fauna, several holiday homes and the Tiwai Aluminium Smelter were threatened. The Awarua Wetlands is a managed scientific reserve of considerable ecological importance for bird life. The wetlands host numerous bird species that use the area for resting, feeding and breeding, as well as rare and endangered flora such as the cushion bog (*Donatia* spp.) (Pearce *et al.* 1994). Several holiday homes and farmlands came under threat from both fires (Figure 2) and evacuations of locals took place due to the fire threat, smoke and ash. The power supply to the Tiwai Aluminium Smelter also came under threat from both fires. The impact of the heat from the fire can cause the power lines to sag. The amount of sag depends on the heat release by the fire[1] and this sag can then potentially lead to the lines shorting out and causing power loss. If the power to the Tiwai smelter was cut and not restored within two hours, then it would take up to 6 months to reinstate full production with major direct and indirect costs to the Southland Region and national economy estimated of up to $1 billion (including downstream costs)[2]. However, the 2005 fire perhaps posed a greater threat to the power supply, since the direction of the fire spread (under northwesterly/westerly winds) was towards the power lines. The 1986 fire would only have affected the power lines directly through backfire spread or a change in wind direction to the east.

Safety considerations for both fires included suppression activities around the power lines in the presence of fire and smoke. Firefighters on the ground also had to deal with working in the wetlands, which limited the areas in which they could safely suppress the fire. The strong winds posed a particular issue for aircraft operating in the 2005 fire, therefore long strops were utilised with monsoon buckets. Given the strong winds, monsoon drops close to the ground were required for effective containment and suppression, and the long strops allowed helicopters to maintain a safe flying height. Other safety issues for aerial suppression included snags and low water levels in the ponds used for dip filling.

Mop-up

Mop up of both fires relied on ground crews, as use of heavy machinery was not possible due to the nature of the swampy terrain. The 1986 fire was declared officially out four days later on 1st of November 1986. Kitto's (1986) fire report stated that ground crews extinguished hot spots over several days. This was a similar situation to the 2005 fire, with ground crews tending to hotspots for several days after the fire. Fortunately the main fires only burned through surface fuels and not into the peat, which would have meant prolonged mop-up. A flare-up did occur

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[1] http://www.fws.gov/southeast/refuges/flametip.html. Site visited 19/04/06.

[2] Pers. Comm. Mike Grant – Southern Rural Fire District, Invercargill. 02/03/06.

four days later on 1st of November 2005 in a nearby gorse patch near the gravel pit on the southeast corner of the fire area, but was quickly contained.

Fire Environment

Topography

The Awarua Plains Wetland is situated in an extensive area of low-lying land with gentle ridged topography and contains the large water bodies of the New River Estuary, Awarua Bay, Toetoes Harbour and Waituna Lagoon[3]. Much of the Awarua plain has been drained and converted to pasture, but extensive areas remain in public ownership and are being managed for biological conservation (Johnson 2001). Altitude for this gently undulating area is between 0 and 20 metres above sea level, although it is essentially flat for fire behaviour purposes.

Fuels

The area is dominated by scrub and rushes, with the major species being Manuka (*Leptospermum scoparium* var. *scoparium*) and Wirerush (*Empodisma minus*). These two species account for approximately 90% of the total species present. A more detailed description of fuels is contained in Townsend (2006), and Figure 3 shows comparisons between fuels from 1986 and 2005. Fuel loads were estimated to be 10 t/ha in 1986 and 18.4 t/ha in 2005. Estimates for 2005 have been based on fuel load models developed by Ensis since 1994 (Fogarty and Pearce 2000).

Fire Weather

In the week prior to the 1986 fire, air temperatures averaged under 16ºC. A total of 15.5 mm of rain fell between the 20th and 22nd of October 1986, with smaller amounts totalling 1.1 mm occurring in the following days. This includes a 24-hour accumulation of 0.2 mm recorded at 9 a.m. on the day of the fire. Before the 2005 fire, the Invercargill area had been experiencing a general drying trend since the 11th of October. This dry spell occurred after regular rain events over the previous two months. Hourly weather readings are shown in Table 1, and a more detailed analysis of the weather for the 2005 fire is contained in Townsend (2006).

Table 1. A comparison of hourly weather readings for the 1986 and 2005 fires (1986 temperature and relative humidity - Invercargill Aero; Wind speed, wind direction and rainfall - Comalco NZ Aluminium Smelter Plant; 2005 – all data from Invercargill Aero).

Time	Temperature (ºC)		Relative Humidity (%)		Wind Direction (deg)		Wind Speed (km/h)		Rainfall (mm)	
(NZST)	1986	2005	1986	2005	1986	2005	1986	2005	1986	2005
1200	12	20	75	46	260	350	46	37	0	0
1300	12	21	81	43	260	350	50	39	0	0
1400	12	19	74	49	260	340	43	39	0	0
1500	13	19	76	49	260	340	52	35	0	0
1700	13	18	67	49	260	340	46	32	0	0
1800	12	18	69	52	260	350	54	35	0	0
1900	11	18	73	45	260	350	57	33	0	0
2200	11	15	81	51	270	10	57	24	0	0
2300	10	16	82	52	270	360	54	28	0.1	0

[3] http://www.doc.govt.nz/Publications/004~Science-and-Research/Miscellaneous/PDF/nzwetlands13.pdf. Site visited 27/02/06.

Figure 3. Comparisons between Awarua in 1986 (left hand side) and 2005 (right hand side). The top photo set shows an aerial view of the area burned in 1986 and a view looking north towards the area burned in 2005. The middle photo set shows a roadside view of fuels adjacent to the Tiwai smelter power lines. The bottom photo set shows a comparison between Manuka fuels (*Leptospermum scoparium* var. *scoparium*).

The major run of the 1986 fire occurred under moderately cool ambient temperatures (12-13ºC), high relative humidity (76-82%) and nearly overcast skies, but exceedingly strong surface winds (43-50 km/h) (Pearce *et al.* 1994). Weather conditions were significantly different for the 2005 fire. The main run occurred under warmer temperatures (~20ºC), lower relative humidity (~46%) and slightly lower wind speeds than the 1986 fire (37-41 km/h). Wind directions were also different for both fires, evident from the spread direction in Figure 2. The 1986 fire was predominantly fanned by strong westerly winds and the 2005 fire by north/northwesterly winds.

The Daily Fire Weather Index (FWI) system values from 1986 and 2005 are shown in Table 2. These values were calculated at 1200 NZST on the day of each fire. The FWI system values for the two fires are reasonably similar. As a general guide, a Fine Fuel Moisture Code (FFMC) value of 70 is required for successful ignition. In both cases, the FFMC was well above this threshold level. Duff and deeper organic (peat) layers were generally moist, as indicated by the low Duff Moisture Code (DMC) and Drought Code (DC) values in both cases. This meant that both fires were surface fires, with little deep-seated burning, also evident by the low Build-up Index (BUI) values. The strong winds in 1986 and 2005 resulted in high Initial Spread Index (ISI) values for both fires. The FWI values are very similar and indicate high frontal fire intensities.

Table 2. A comparison of the noon Fire Weather Index values for the 1986 and 2005 Awarua fires (* assumes a degree of curing of 100%).

YEAR	FFMC	DMC	DC	ISI	BUI	FWI	Scrubland FDC	Grassland FDC*
1986	83.2	10	71	17.1	15	19	E	E
2005	87.5	13	59	19.5	17	21.3	E	E

The synoptic weather charts (Figure 4) show that in both cases, a cold front was moving up and over the Southland region during the period of the fires. In 1986, a large anticyclone was sitting to the west and an intense low-pressure system to the southeast, whereas in 2005 an anticyclone was sitting to the northeast. This explains the different wind directions for the two fires. The isobars around the low in 1986 were a lot closer than in 2005, accounting for the stronger winds experienced in 1986 (refer to Table 1).

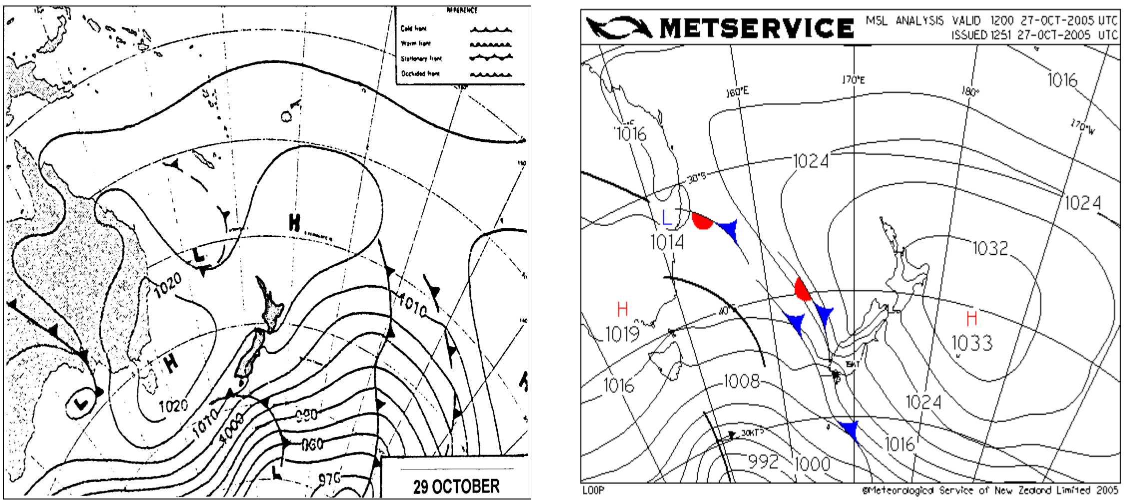

Figure 4. Synoptic weather charts for 0100 (NZDT) on 29/10/86 (left) and 1200 (NZDT) on 27/10/05 (right). (Source: MetService).

Fire Behaviour

Observed values for rate of spread compare reasonably well with those predicted for both fires, with the exception of the predictions using the Grassland model for the 2005 fire (Table 3). The Grassland rate of spread model has been included here, as this was used for the analysis of the 1986 fire (Pearce *et al.* 1994), before the current Scrubland rate of spread model was developed. The predictions of rate of spread using the Scrubland model compare reasonably well with those observed for both fires. Although the ISI value was higher in 2005 than 1986, the observed rate of spread was lower for the 2005 fire. There are a few possible explanations for this. The two fires occurred in different areas of the wetland, and probably had different fuel type distributions and continuity. The fuels in the 1986 fire possibly consisted of a greater proportion of grassy-type fuels (such as sedges, rushes and grasses) than clumps of scrub, compared with the fuels in the 2005 fire, which had a greater proportion of scrub than grassy fuels. Overall rate of spread would therefore have been faster in the 1986 fire due to more grassy fuels, compared with the 2005 fire, which contained more scrub and burned at a slower rate of spread, even although the ISI was higher. This also explains the significant over-prediction of rate of spread using the Grassland model for the 2005 fire. The FWI System values provided for the 2005 fire are also more accurate than those used for the 1986 analysis. In 1986 the only available FWI System values were those calculated at noon, which are intended to predict burning conditions during the peak period of the afternoon (between 1500 and 1700). These calculated noon values were modified using the actual average wind speed over the duration of the main fire run, but this is still not as accurate as the hourly calculation of FWI values throughout the day. Since 1994, hourly calculated FWI System values of FFMC, ISI and FWI have become available and these provide a more accurate indication of fire behaviour potential throughout the day. The current Scrubland rate of spread model still requires a considerable amount of further development, evident by the variability of the data used to develop the current version, as well as the lack of data in the ISI range of 10-20 (Anderson 2006). Continued documentation and analysis of wildfire events will provide valuable data to enable further improvements to the model. A further possible explanation for the differences between observed and predicted rate of spread for both fires is the varying levels of accuracy and reliability of data collected at time of the fires. The above discussion reinforces the need to modify and adapt fire behaviour models to local conditions based on local knowledge and experience (the "art and science" of fire behaviour prediction).

Table 3. Comparison between observed and predicted values of rate of spread, head fire intensity, flame length and fuel load for the Awarua wetlands fires on 27/10/05 and 28/10/86.

	1986 Fire (Scrubland Model)		1986 Fire (Grassland Model)	
	Observed Value	**Predicted Value**	**Observed Value**	**Predicted Value**
Fuel Load (t/ha)	14.5	18.4	10	10
Head Fire Intensity (kW/m)	27200	33400	18750	19300
Flame Length (m)	5 to 8	9.3	5 to 8	7.3
Rate of Spread (m/h)	3750	3630	3750	3865

	2005 Fire (Scrubland Model)		2005 Fire (Grassland Model)	
	Observed Value	**Predicted Value**	**Observed Value**	**Predicted Value**
Fuel Load (t/ha)	18.4	18.4	18.4	18.4
Head Fire Intensity (kW/m)	25000	24000	25000	42320
Flame Length (m)	8 to10	8	8 to 10	10.4
Rate of Spread (m/h)	2700	2500	2700	4600

Development of fuel load models for scrub fuels (Fogarty and Pearce 2000) since 1994 has also allowed for a more accurate determination of available fuel load (and calculation of head fire intensity) for scrub fuels for the 2005 fire analysis. For the analysis of the 1986 fire, the fuel load of 14.5 t/ha used for the observed values was determined by destructive sampling in the wetlands in 1994[4]. This value is the average of the sampling range between 11.4 and 19.6 t/ha. The fuel load of 10 t/ha used for the Grassland model predictions was based on visual estimates from photos (Pearce *et al.* 1994). The different fuel loads used for the 1986 fire analysis result in significantly different calculations of head fire intensity (and flame length), which can have a significant impact on suppression planning and effectiveness, as well as fire-fighter safety. The observed and predicted head fire intensities for the 2005 fire are reasonably similar, due to the observed and predicted rates of spread being similar. No destructive sampling was undertaken following the 2005 fire, and the fuel load was estimated using the available fuel load model for Scrub fuels (Manuka/Kanuka) using an average height of 1.0m.

A plot of the two fires on the Scrubland Fire Danger graph (Figure 5) shows that the fires occurred under similar levels of EXTREME fire danger, and were well above the threshold of effective suppression using crews and water under pressure (Alexander 1994). This is validated by the reliance on aerial suppression at both fires. The Scrubland Fire Danger model was not available in 1994, but the Grassland Fire Danger for the 1986 fire (the most appropriate model available for the 1994 case study) also indicated EXTREME fire danger (based on a degree of curing value of 100%).

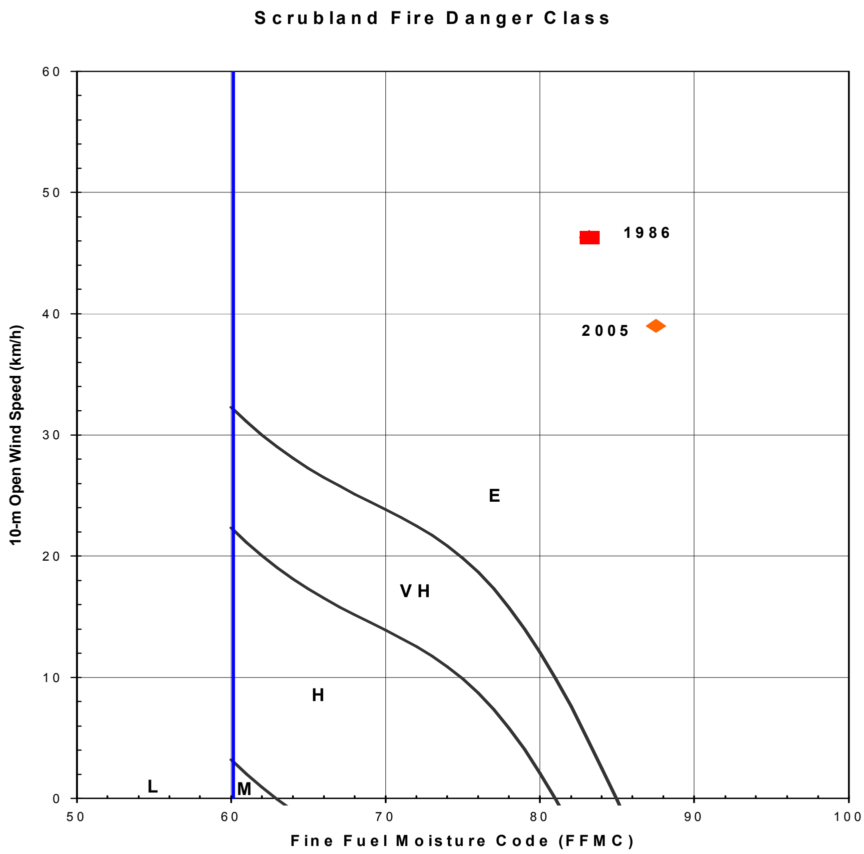

Figure 5. Scrubland Fire Danger graph of the 1986 and 2005 Awarua fires. (Source: Alexander 1994).

[4] Pers. Comm. Grant Pearce – Ensis, Christchurch. 10/07/06.

Conclusion

Fire behaviour knowledge has increased significantly since 1994, when the 1986 Awarua Fire case study was produced. Our understanding and knowledge of fire behaviour and fire danger rating is continually improving through significant progress in bushfire research (Anderson 2006), and fire managers around the country are implementing this knowledge at an operational level. By comparing these two fires that occurred in the same area under similar conditions of fuels and fire weather, it has been possible to collect valuable information for the ongoing refinement and validation of fire behaviour models. Observed fire behaviour was very similar between the two fires, and it has been particularly useful to revisit the 1986 fire and compare this against the recently developed Scrubland rate of spread and fire danger models, which were not available in 1994 when the original fire case study was produced. These models represent significant advances in fire behaviour knowledge, both in New Zealand and internationally. Improved models for assessment of fuel load are now also available. The Grassland fire spread model compared well with observed rate of spread in 1986, likely due to the greater presence of vegetation that would exhibit characteristics of a grass fire. Modifying fire behaviour models to suit local fire environment conditions is critical, and this requires fire managers to have a sound understanding of the basis, assumptions and limitations of the models, together with local knowledge and experience.

Both of these fires also illustrate the flammability of scrub fuels and their ability to produce fires of high intensity and rapid rate of spread under relatively moderate conditions. The strong winds were certainly a factor in the rapid development and spread of these fires, but the Fire Weather Index System values (apart from the Initial Spread Index) did not indicate particularly dry conditions conducive to high-intensity fire behaviour.

The 2005 fire was the second fire to have threatened the vital power supply to the Tiwai Point Aluminium Smelter in the past 2 decades. The direct and indirect costs of the smelter shutting down due to an extended loss of power supply would result in significant and long-term damage to not only the regional, but also the national economy. The authors would suggest that mitigation measures be considered to prevent another fire threatening this important national asset. Measures could include a combination of fuel management and careful management of fire in and around the Awarua wetland area. The fact that the 2005 fire resulted from an escaped burn-off also places the onus on landowners and rural residents to be responsible in their use of fire.

Acknowledgements

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