WEATHER CONDITIONS ASSOCIATED WITH THE BROADFORD FIRE

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Abstract: The behaviour of a relatively serious bush fire which broke out on 25 February 1957, near Broadford (Victoria) is described briefly. Estimates of the average linear and areal rates of spread are presented.

The preceding seasonal rainfall distribution and climate are discussed in relation to their effect on the amount and degree of curing of light fuels in the district.

In a survey of the various features of the synoptic weather sequence, it is shown that the fire flared up under the influence of weather conditions which are not generally considered to be conducive to the spread of serious fires.

1. INTRODUCTION

In his list of known meteorological conditions associated with blow-up fires in the United States, Byram (1954) (1) has pointed out that there are many seeming contradictions to the general pattern. Similarly, in Victoria there have been exceptions to the generally quoted maxim that serious fires are associated with hot, gusty northerly winds. Notable among these exceptions was the Broadford fire, which provided a good illustration of a serious fire which started to spread under the influence of a cool southerly wind approximately 30 hours after the passage of a weak cold front. Since these (and similar) exceptions should be taken into account in any future research into the necessary and sufficient criteria for fires, it was considered that a review of the meteorological conditions associated with the Broadford fire would be appropriate.

2. LOCATION

The fire broke out in hilly country of the Divide, and its position is indicated by the circle centre of Map 1. The point of origin in the Sunday Creek public reserve is marked in Map 2.
Map 1 Location of Broadford Fire.
Map 2. Broadford Fire - Final Boundary.
33.

The region varies in height from 900 feet at Clonbinane to 1800 feet at the Checking Station, and although the lower and flatter parts of this region have been cleared for grazing, the slopes and spurs are fairly heavily timbered.

3. FIRE BEHAVIOUR

The fire is alleged to have spread from a campfire which had been used on Sunday 24 February, 1957. The first fire report was made by a forestry observer at Pretty Sally Lookout at 11.10 a.m. Monday 25th. However, because of topography and wind direction the smoke would not have been visible from the tower for some time, and it appears probable that the fire started to spread some time after 10 a.m. Practically the entire spread occurred within the first 12 hours: the hatching on Map 2 indicates those areas on the flanks where spread took place after the initial period.

The fire-control authorities took advantage of the light wind on Tuesday, 26th, to consolidate their position by the employment of extensive precautionary measures. Although there were small sporadic outbreaks, the fire fighters maintained supremacy during Wednesday 27th, when hot, gusty northerly winds prevailed. By that night the fire was regarded as completely under control.

3.1. Linear Spread

Under the influence of SSE winds the fire traversed nearly four miles in the space of 12 hours. Although this corresponds to an average rate of spread of over 25 chains per hour, the head speed varied considerably at times. For example, on the Monday night the fire swept up a steep timbered slope with extreme rapidity and leaped across the Spur Road.

3.2. Area Burnt

Eventually the fire perimeter enclosed approximately 1880 acres. Since the supplementary hatched areas of Map 2 comprise approximately 120 acres, the area burnt during the initial 12 hour spread is of the order of 1760 acres. This corresponds to an average rate of spread of nearly 150 acres per hour.
4. PRECEDING SEASONAL CONDITIONS

4.1. Rainfall

Table 1 shows the totals of monthly rainfall recorded at five towns near the fire site. The bracketed number under each monthly total represents the percentage ratio of each total to the normal rainfall for the month.

Table 1. Monthly rainfall totals (in points) at nearby towns

<table>
<thead>
<tr>
<th>Station</th>
<th>1956</th>
<th>1957</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sept</td>
<td>Oct</td>
</tr>
<tr>
<td>Kilmore (1213 ft)</td>
<td>338</td>
<td>538</td>
</tr>
<tr>
<td></td>
<td>(124)(225)</td>
<td>(60)</td>
</tr>
<tr>
<td>Wallaby Cr. (1720 ft)</td>
<td>556</td>
<td>1055</td>
</tr>
<tr>
<td></td>
<td>(124)(233)</td>
<td>(115)</td>
</tr>
<tr>
<td>Toorourrong (800 ft)</td>
<td>361</td>
<td>647</td>
</tr>
<tr>
<td></td>
<td>(127)(200)</td>
<td>(101)</td>
</tr>
<tr>
<td>Yea (565 ft)</td>
<td>307</td>
<td>389</td>
</tr>
<tr>
<td></td>
<td>(120)(153)</td>
<td>(109)</td>
</tr>
<tr>
<td>Seymour (464 ft)</td>
<td>247</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>(117)(128)</td>
<td>(72)</td>
</tr>
</tbody>
</table>

Table 1 indicates that the fire area had above-average rainfall in September and that the October rainfall was approximately twice the average. In November the totals were more variable and an examination of the daily records for this month showed that some of the falls were local in character. However, it would be reasonable to presume from the November totals that the rainfall in the fire-area would have been close to normal. December rainfall was well below normal and January was an extremely dry month. In February the rainfall within the fire area has been estimated at just below average. However, the February daily records revealed that virtually all the rain at these five stations
Fig 1. Schematic envelopes of Surface Wind Speed and Direction at Essendon.
fell before the sixteenth - only light falls ranging from 3 to 15 points were recorded on 21 February.

4.2. Interpretation of Seasonal Conditions

The wet spring of 1956 provided sufficient carry-over soil moisture to produce an abundant grass growth which was still relatively green at the end of December. Although there were no prolonged spells of hot weather during January, the abnormally dry and sunny conditions were responsible for the extensive curing of pastures and grasses. The rains early in February promoted the growth of new shoots, but due to the lack of carry over soil moisture from January these shoots did not develop to any great extent. The remaining mature and fully cured grass growth rapidly dried off after the last rains in February, and by the 25th these light fuels presented a high fire hazard.

5. SYNOPTIC WEATHER SEQUENCE

5.1. Weather on the day prior to Outbreak (Sunday 24 February)

A weak cold front (associated with a low pressure system centred south-east of Tasmania) passed over the Broadford district during the early morning hours, but no rain was recorded. A high pressure system centred over the Western Bight (some 200 miles south-east of Esperance at 6 a.m.). After the passage of the front over Victoria, the westerly winds during the morning gradually backed to become fresh and gusty southerlies by mid-afternoon.

Consistent with approach of the anticyclone the Laverton (1 p.m.) upper air sounding indicated the formation of an incipient subsidence inversion at 780 mb (approximately 7000 ft). Below this level considerable turbulent mixing from the surface to 5000 ft was evidenced by the temperature lapse rate (slightly less than dry adiabatic), and dew point lapse rate (closely approaching the constant mixing ratio line). The Essendon upper winds in this turbulent layer were all southwesterly at 2 p.m., backing to lighter southerlies by 8 p.m.

Maximum temperatures in the area were approximately normal for February, as can be seen from Table 2.
Fig 2. Schematic representation of Temperature and Humidity at Essendon.
Table 2. Maximum temperatures at surrounding stations

<table>
<thead>
<tr>
<th>Station (Height above MSL)</th>
<th>February 1957</th>
<th>Normal February Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sun 24th</td>
<td>Mon 25th</td>
</tr>
<tr>
<td>Alexandra (681 ft)</td>
<td>87</td>
<td>71</td>
</tr>
<tr>
<td>Benalla (559 ft)</td>
<td>90</td>
<td>79</td>
</tr>
<tr>
<td>Bendigo (731 ft)</td>
<td>79</td>
<td>73</td>
</tr>
<tr>
<td>Essendon (aerodrome) (268 ft)</td>
<td>77</td>
<td>65</td>
</tr>
<tr>
<td>Euroa (674 ft+)</td>
<td>87</td>
<td>73</td>
</tr>
<tr>
<td>Kyneton (1677 ft)</td>
<td>74</td>
<td>65</td>
</tr>
<tr>
<td>Mt. St. Leonard 67 (2000 ft)</td>
<td>-</td>
<td>59</td>
</tr>
<tr>
<td>Seymour (454 ft)</td>
<td>-</td>
<td>69</td>
</tr>
<tr>
<td>Watsonia (340 ft +)</td>
<td>75</td>
<td>68</td>
</tr>
</tbody>
</table>

+ Height of railway station
* Normals not prepared for these stations

Plots of the screen temperature, dew point and relative humidity at Essendon from 24 to 28 February are shown in Fig. 2.

5.2. Weather During the day of Main Spread (Monday 25 February)

Synoptic Situation: By 6 a.m. the cold front had moved well east to a position over the Tasman Sea, and the intensifying high also moved eastward to position some 300 miles due south
of Ceduna S.A. From the centre of this anticyclone a ridge extended along the Victorian and New South Wales coastlines. As the day progressed the ridge penetrated further north along the N.S.W. coast, but deepening troughs began to appear in both ridge flanks. The detailed 3 p.m. surface chart for Victoria and southern New South Wales (Map 3) clearly shows the existence of one trough in eastern Bass Strait, and the other (containing a closed row in south-east New South Wales) extending over central-east Victoria.

The circled figures in Map 3 represent the three-hourly corrected pressure tendencies (in tenths of a millibar) between 12 noon and 3 p.m. Pressure falls at Wodonga and East Sale in eastern Victoria suggest the existence of a relatively small area of weak cyclogenesis superimposed on the generally-rising pressure field.

In addition, the distribution of these pressure tendencies implies an increase in the pressure gradient between Kilmore and Benalla in north-central Victoria. This effect was corroborated by observations at the fire site of "a fairly strong SSE wind during the early stages which increased in velocity towards the evening". On the other hand the decrease in pressure gradient at Essendon (associated with the approach of the anticyclone centre) was reflected in a general decrease in wind velocity toward evening, as shown in the schematic wind trace (Fig. 1).

The closed circulation centred at Kiandra (N.S.W.) was probably less intense than indicated by Map 3 due to the assumptions involved in reducing high-level station pressure readings to mean sea level pressure by standard methods.

Temperature and Humidity: It is evident that the camp fire was relatively inert for several hours before it eventually broke away some time after 10 a.m. Conditions during the day were mild to cool and from considerations of altitude and the inland maximum temperature gradient, the maximum temperature within the vicinity of the fire region has been assessed at between 65°F and 70°F. The dew point at this time was estimated to be 43°F, and correspondingly, the minimum relative humidity would have been approximately 40 per cent.

As mentioned previously, a fairly strong SSE wind prevailed and its influence in driving the fire directly in front of it, across the lie of the land, is clearly shown in
Map 2. Although wind speed is an important factor in the rate of fire spread, the combined effect of temperature, humidity, and wind direction at all times during this day is not representative of those conditions which are generally considered to be conducive to the spread of serious fires.

Upper Air Observations: Corresponding to the further approach of the anticyclone and the development of the ridge extending up the New South Wales coast, the Laverton 1 p.m. upper air sounding showed the presence of a very deep subsidence inversion above 825 mb (approximately 6000 feet). From the surface to 850 mb (5000 feet) the temperature lapse rate was again just less than the dry adiabatic, but the temperature of the air mass in this layer was some $13^\circ$F lower than that for the corresponding time for the previous day. Between 850 and 825 mb (representing a layer approximately 800 ft thick) the air was convectively unstable. Owing to the relatively small thickness of this layer, its elevation, and the dampening effect of the deep inversion immediately above, it is a moot point whether any significant convective effects occurred when the whole air mass was subsequently lifted over the Divide.

5.3. Weather Conditions following Initial Spread (Tuesday 26 February)

During this day the anticyclone centre moved east over the South Victorian coast, and consequently winds were light and variable during the morning. During the afternoon at Essendon a gentle southerly sea breeze set in, gradually veering during the evening to become a light northerly by midnight. However, cup anemometer readings on the Spur Road (Point A, Map 2) showed that a 10 knot southerly breeze persisted until at least 9 p.m. From observations of bracken cinders (which were swept high over the Spur Road) it was also evident that this southerly wind persisted to a height of several hundred feet.

Temperature: Maximum temperatures within a 40 mile radius of the fire area (Table 2) were some 10 to $20^\circ$F higher than corresponding readings for the previous day. The Laverton 1 p.m. upper air sounding also showed extensive warming and drying out of the air mass from the surface to 7000 ft. Although the lapse rate was strongly super-adiabatic in the first few hundred feet from the surface, it is probable that the presence of two inversions (at 2000 and 4500 ft respectively) would have damped out any large-scale convection.
Since the Essendon screen temperature reached a maximum of 77°F some time after 4 p.m., and higher maximum temperatures than this were observed inland, it may be expected that the lower inversion would have been destroyed by surface heating. This seems to be confirmed by observations around 5 p.m. of the smoke from two smaller fires, (between Melbourne and Broadford) where the near vertical columns were seen to terminate abruptly at approximately 4000 ft. From the top of each column the smoke spread laterally south under the influence of light northerlies at that height.

Wednesday 27 February

The anticyclone in moving further east over the Tasman Sea, was centred by 6 a.m. some 200 miles east of Gabo Island. A shallow, but rapidly moving depression was located over the Bight approximately 300 miles south of Eucla. At Broadford, a fresh, gusty NNE wind was in evidence at 7 a.m., and Fig. 1 indicates that this speed and gustiness were maintained until 6 p.m. Temperatures rose during the day, and the Essendon maximum of 90°F around 4.30 p.m. indicated that temperatures within the fire area would have exceeded a 2 p.m. aspirated reading of 86°F on the Spur Road (Point A, Map 2) in the fire area.

The Essendon 8 a.m. pilot balloon flight gave the following readings:

<table>
<thead>
<tr>
<th>Height</th>
<th>Dirn.</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>N</td>
<td>23 knots</td>
</tr>
<tr>
<td>2000 ft.</td>
<td>N</td>
<td>42 &quot;</td>
</tr>
<tr>
<td>5000 ft.</td>
<td>NW</td>
<td>25 &quot;</td>
</tr>
<tr>
<td>7000 ft.</td>
<td>W</td>
<td>6 &quot;</td>
</tr>
</tbody>
</table>

This wind profile clearly illustrates the existence of a "jet current" as described by Byram (1954) (2). Although this low level jet current had practically disappeared by 2 p.m., the Laverton 1 p.m. sounding still showed the presence of extreme instability in the layer between the surface and 2500 ft.

6. CONCLUSION

Although most of the serious fires in Victoria have been associated with hot, dry northerly winds preceding the passage of a cold front, the case of the Broadford fire
clearly demonstrates that fire spread is not uniquely
determined by these "classic" surface fire-weather
conditions. The mechanism by which small fires are
transmuted into large fires is not perfectly understood as
yet, but in recent years it has become increasingly
apparent that meteorological features of the lower
troposphere play an important role in determining fire
behaviour.

Byram (1954) (3) has shown the tendency of the
upper wind speed profile to fall into fairly definite
classes at those times when extreme fire behaviour exists,
and preliminary work at the Bureau of Meteorology has
confirmed some of his findings.

Thus, in the light of future knowledge of the
relation between atmospheric conditions and bushfires it
may be possible to account for the development of fires
under what are generally considered to be unusual
conditions.

7. ACKNOWLEDGEMENTS

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of the fire behaviour.

REFERENCE

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