Fuels, Weather and Behaviour of the Cascade Fire (Esperance Fire #6) 15-17 November 2015

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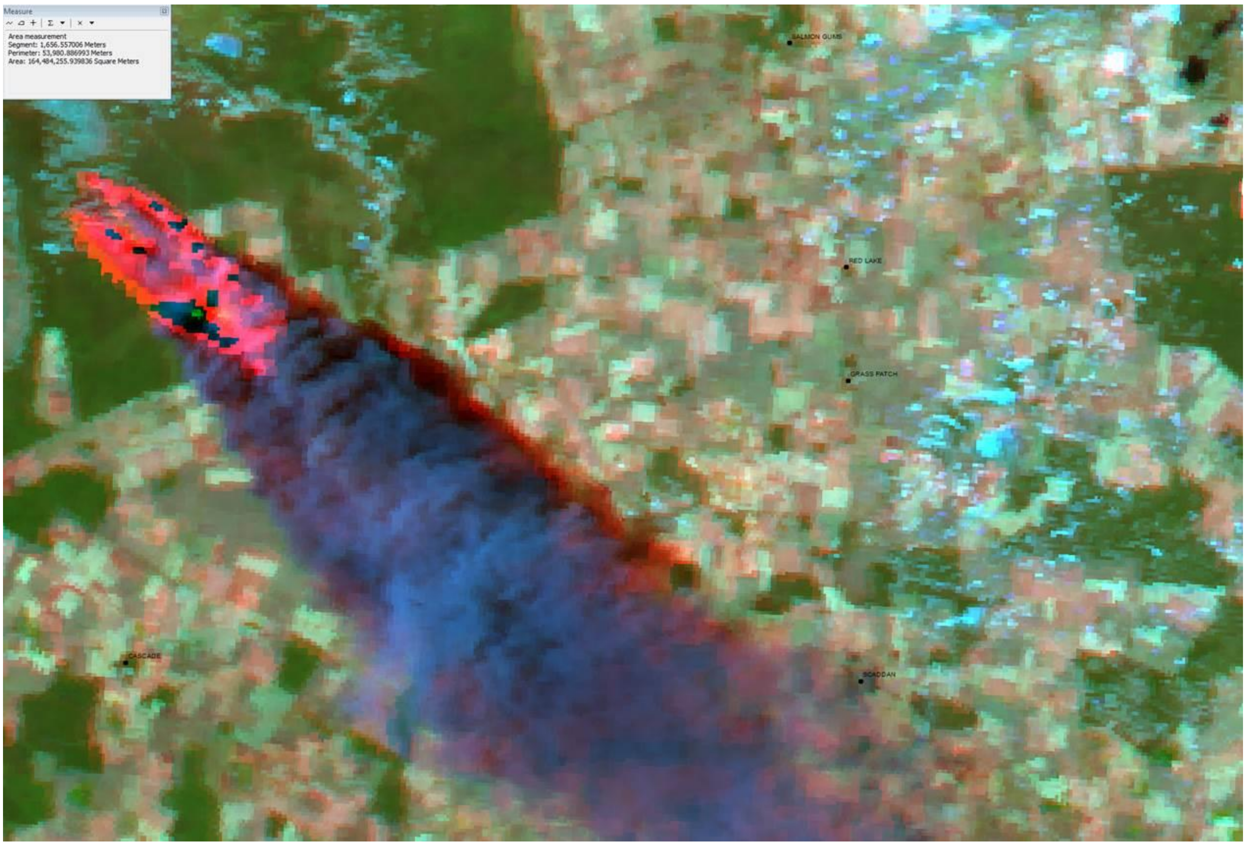

MODIS satellite image of the Scaddan fire at 1320 hrs on 17 November 2015

Introduction

On 15 November 2015, multiple bushfires started in the Esperance region (the Esperance fire complex) as a result of lightning strikes associated with the passage of a trough. On 17 November, extreme fire weather conditions inland of Esperance resulted in a CATASTROPHIC grassland fire danger rating and a dramatic escalation of the behaviour of the bushfires. One of the bushfires that started in Unallocated Crown Land (UCL) about 3.5 km south of Lake Mends (the Cascade fire) spread south-east into farmland and under the influence of a strong, hot and dry north-west wind, travelled some 70 km in about 5 hours through mostly unharvested, cured cropland. At its peak, this fire was unstoppable by suppression action. At around 1546 hrs, four people in two vehicles were trapped and killed when the fast spreading fire crossed Griggs Road, some 66 km from its origin. The fire burnt 128,000 ha, had a perimeter of 315 km and was 100 km long. In addition to the tragic loss of life, it unintentionally destroyed and damaged buildings, infrastructure, crops, stock and machinery, and pre-disposed topsoil to wind erosion. The monetary cost, including cost of suppression and recovery, will be many millions of dollars.

This report summarises aspects of fuel, weather, behaviour and path of the Cascade fire.

15 November 2015 - fire cause and origin

This fire was caused by a lightning strike in UCL bushland near 33.117^{o}S 121.023^{o}E at ~0930 hrs, 15th November 2015 (See Figs. 1 and 13). The origin as mapped by an aerial observer was about 2.7 km west of the location detected by the Himawari-H8 (H8) satellite. H8 is a low resolution (2 km pixel) weather satellite so the aerial observation is considered more accurate. The approximate location of the origin is 60 km west-south-west of Salmon Gums and 8.7 km north-west of cleared farmland. Evidence supporting the proposition that the fire was caused by lightning includes:

- Leading edge of a low pressure trough and associated unstable conditions (thunderstorms) in the area of the fire origin (Fig. 2).
- The origin was in remote, inaccessible bushland with the nearest vehicle access track being ~4.5 km away.
- Eye witnesses saw lightning in the general area. One witness (RT) claims to have seen lightning strike the ground in the general area at ~0930 hrs on 15th November.
- There are no other likely causes.

Early stages of fire development (15-16 November)

Following ignition by lightning, and for the next 48 hours or so, the fire burnt steadily in bushland fuels broken by a complex maze of playa lakes (Fig. 1). Satellite imagery (Himawari H8) and aerial observations during this period suggest fire growth was convoluted and slow, and fire behaviour was low to moderate due to the nature of the vegetation, the weather conditions and the natural barriers to fire spread. Some 48 hours after ignition, the fire is estimated to have reached a size of ~ 1,100 ha (Fig. 1).

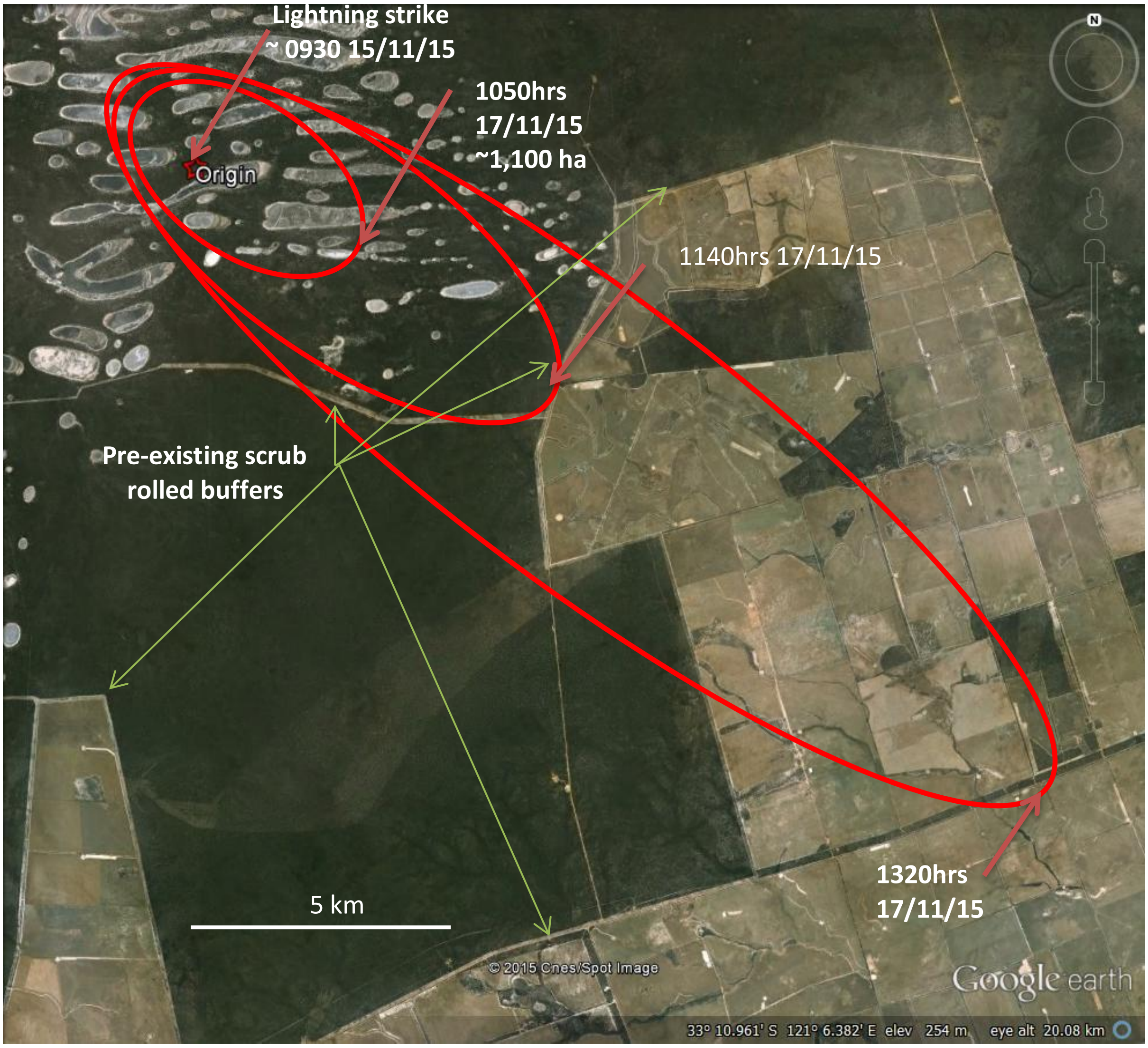

Figure 1: Approximate location of a lightning strike (origin) in a maze of lakes as mapped by an air observer, and approximate (smoothed) shape of the fire at various times based on satellite imagery. The fire crossed into farmland at about 1140 hrs on 17 November (Himawari- H8 imagery). Note pre-existing scrub rolled buffers.

While the region experienced above average winter rainfall, spring rainfall was below average (Fig. 3). This pattern resulted in good crops with high potential fuel loads on grassland / cropped land, but earlier than average spring drying of bushland fuels and crop curing. Weather conditions recorded at Salmon Gums for 15 and 16 November are shown in Figs. 4 and 5. During the ~48 hour period between ignition and prior to escalation in fire weather conditions on the 17th, the diurnal peak of Grassland Fire Danger Index (GFDI) was 23 (VERY HIGH) and 19 (HIGH) for the 15 and 16 November respectively. The vegetation (fuel) in the UCL surrounding the fire's origin comprised a mosaic of long unburnt shrubland, mallee-heath and occasional patches of woodland. There is no record of when the area was last burnt but local knowledge suggests it was >50 years ago. The complex maze of lakes is an impediment to fire spread, enabling bushland between the lakes to escape fire for long periods. Fig. 6 shows a number of relatively small 1980s fire scars in UCL closer to farmland

and south and east of the lakes system. These had no noticeable impact on the fire's behaviour. Predicted (McCaw mallee-heath model) maximum rates of spread in the UCL bushland during peak daytime conditions on 15 and 16 November range from 1,200-1,800 m/h with little or no spread occurring overnight when winds were light and relative humidity was high (Figs. 4 & 5). Although the fire's initial development was slow, its steady growth in bushland over the two days prior to the escalation in fire weather conditions was an important factor in determining head fire width and subsequent damage potential of the fire when it finally burnt out of bushland into farmland on 17 November.

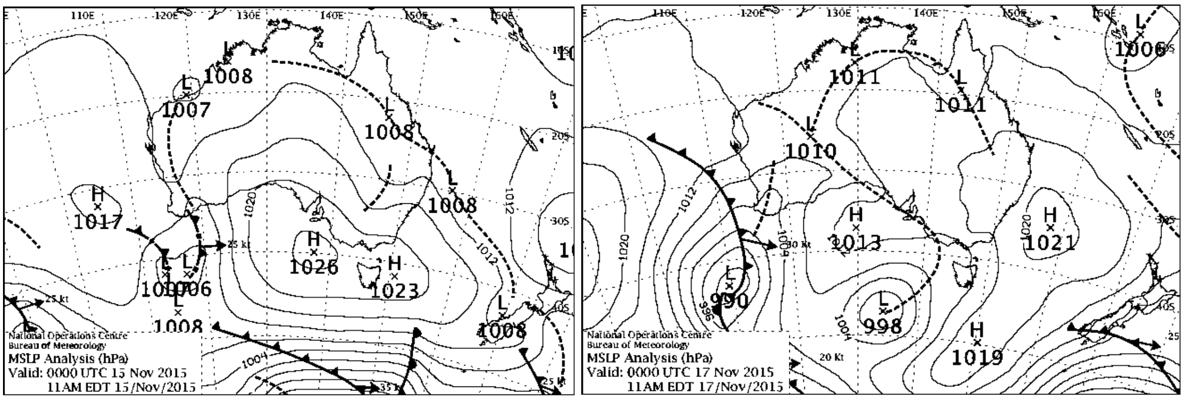

Figure 2: Left: Synoptic (weather) chart showing the position of the trough (dashed line) at 0000UTC (0800WST) 15 November 2015. Lightning associated with the trough started the Cascade and other fires in the Esperance / Salmon Gums area. Right: Pressure gradients on the weather chart for 17 November do not indicate strong winds at the surface in the Esperance region.

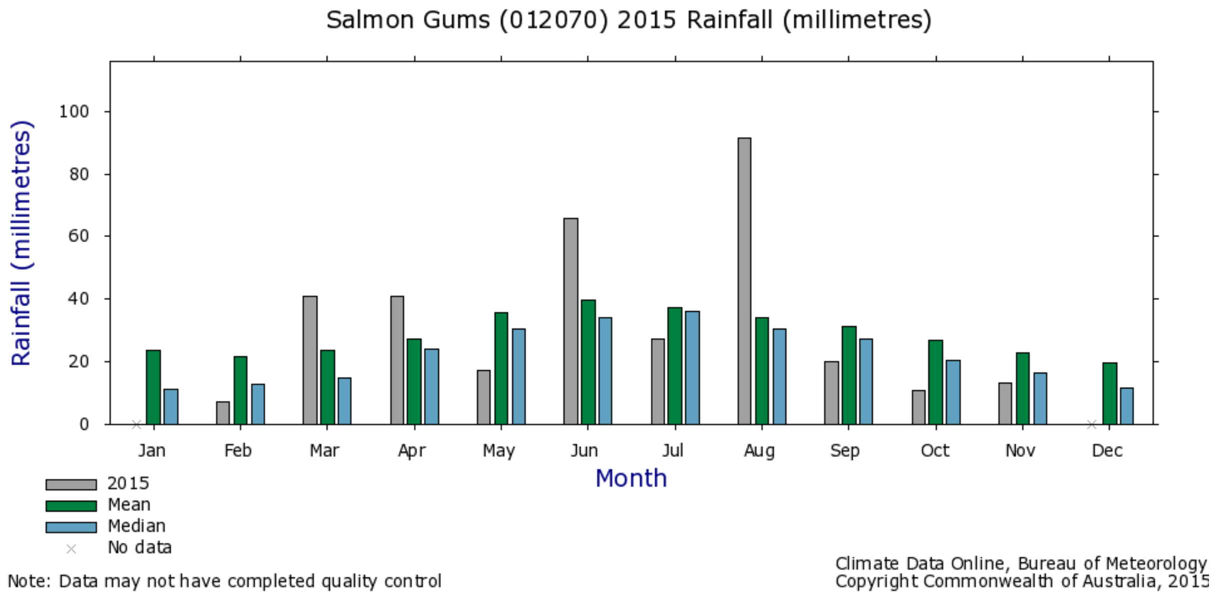

Figure 3: Monthly rainfall for Salmon Gums – long term average, median and 2015 values. Note above average winter rainfall and drier than average spring.

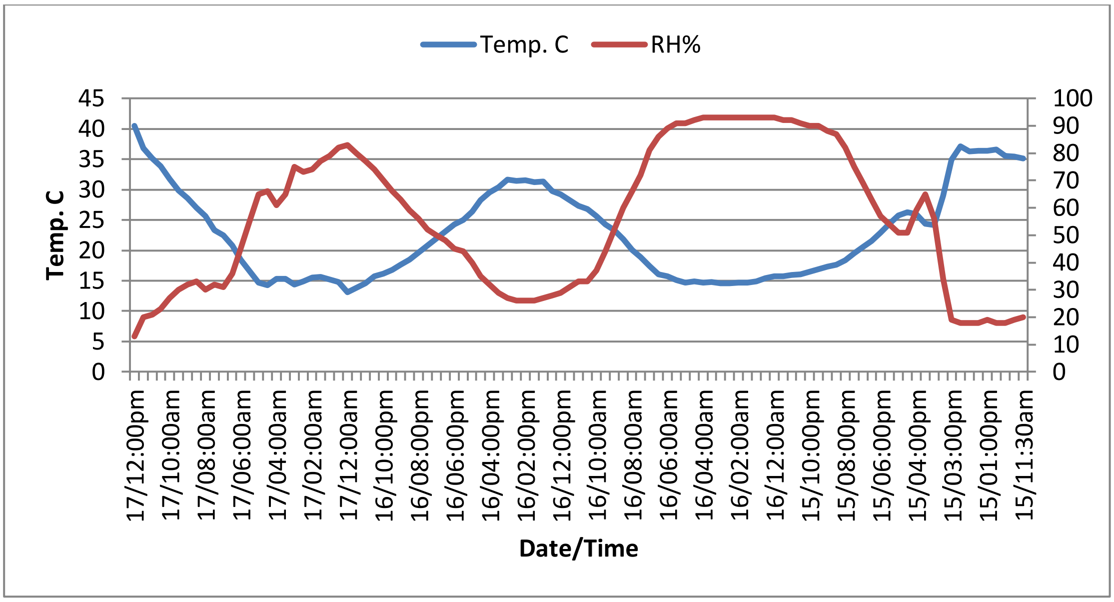

Figure 4: Temperature and relative humidity recorded at Salmon Gums (~56 km east of the ignition point) for the period 1130hrs on 15 November to 1200hrs on 17 November 2015.

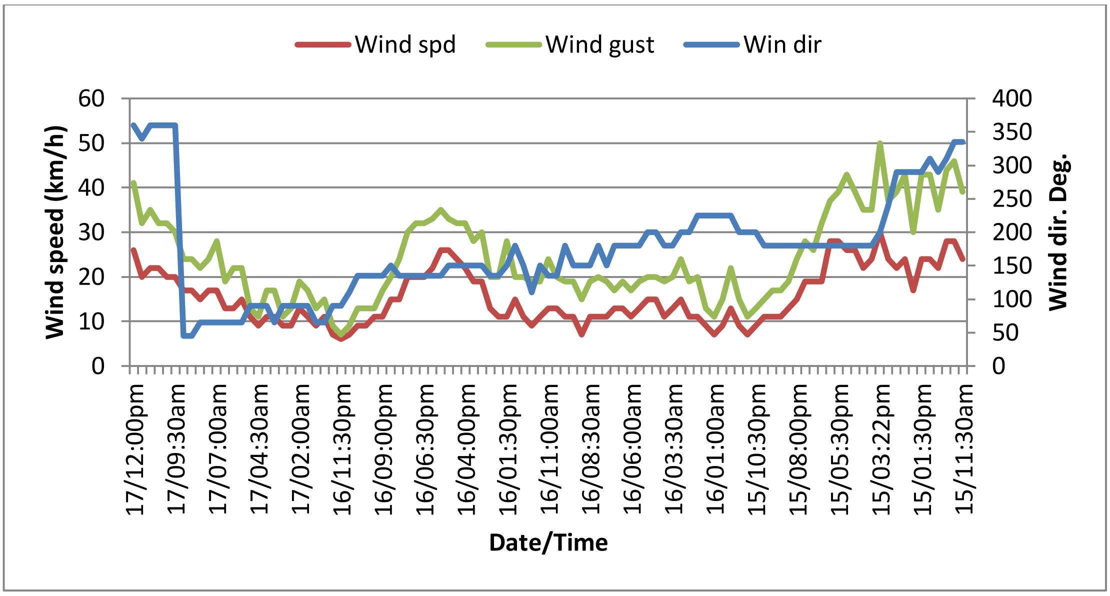

Figure 5: Wind speed and direction at Salmon Gums (~56 km east of the ignition point) for the period 1130hrs on 15 November to1200hrs on 17 November 2015.

The nearest (spatial and temporal) available atmospheric sounding was from Albany airport at 00Z (0800hrs) on 16 November 2015 (Fig. 6). It is likely that similar atmospheric conditions occurred further east in the Esperance region on 17 November. A significant feature in Fig. 6 is the wedge of very dry air at 900 – 700 hPa (~1,000m – 3,000m) with dew point reaching -40.0^{o}C and RH at 2%. Wind speed and direction just above the dry slot (~550 hPa) are NNE at 40-50 knots (~70-90 km/h). These conditions are similar to those recoded at the surface in the afternoon of 17 November, so it is likely that this dry air mass aloft mixed to the surface as the ground heated. The c-Haynes Index calculated using the data in Figure 6 was >10, which is very high.

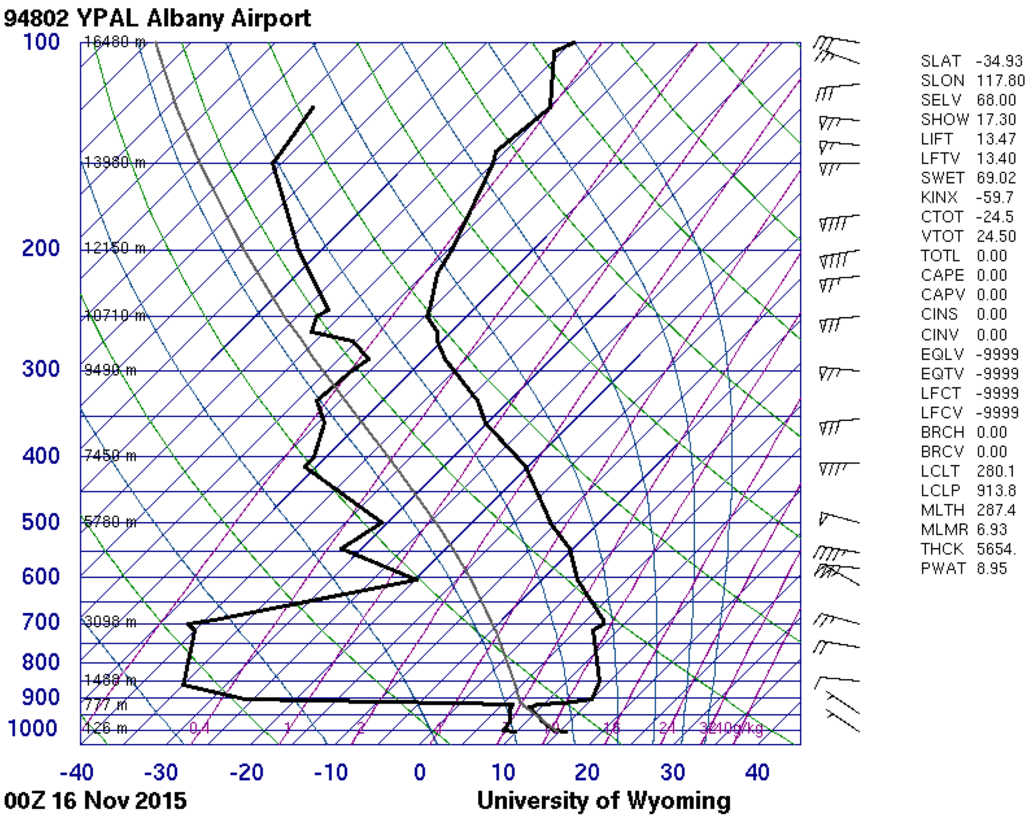

Figure 6: Aerological diagram from a Bureau of Meterology (BoM) ballon flight from Albany airport on 16 November (no data for the 17th). This reveals a warm, dry wedge of air at 900-700 hPa with dew point as low as -40^{o}C and RH of 2%.

Pre-fire mitigation measures

The Department of Parks and Wildlife and its predecessors have carried out bushfire mitigation measures along the interface with the UCL bushland and cleared farmland in the region at least since 2004/05, as shown in Figs. 1 and 7. Shrubland and mallee heath vegetation form a discontinuous fuel, so fire spread is only sustained under warm, dry and windy conditions (McCaw and Broomhall 2011) usually when the fire danger rating is HIGH or greater. Such fuels are often referred to as 'go – no-go' fuels on account of fuel moisture and wind speed thresholds, or tipping points, that must be exceeded for fire to spread. The structure of the fuel means that under LOW to MODERATE fire danger ratings, conditions when it is safer to conduct prescribed burns, these fuels are unlikely to sustain fire spread. Implementing prescribed burns under higher fire danger ratings when fire spread is likely, increases the risk of the prescribed burn escaping. Therefore, rather than broad-acre prescribed burning as is done in continuous forest fuels further west, the preferred mitigation strategy is to create buffers by mechanically modifying the fuel first, then burning it under milder weather conditions. Scrub rolling / chaining is the most common form of fuel modification. Once the vegetation has been scrub rolled and allowed to dry, it can be burnt under mild conditions when the surrounding untreated vegetation is unlikely to carry fire, creating a barrier to fire spread, or a buffer.

It is neither feasible nor environmentally appropriate to treat broad areas by scrub rolling and burning, but a network of strategically located strips or buffers can be very effective at stopping or slowing a bushfire in these landscapes. In addition to field experience of the benefits of scrub rolling in wildfire control, research trials demonstrated that an 18-month old, 100 m deep scrub-rolled and burnt buffer was able to stop a high intensity fire burning under VERY HIGH fire danger rating conditions (McCaw and Broomhall 2011). Even though flames were 10-14 m long, the buffer stopped the fire, which did not spot over the buffer. Research and operational experience shows that 100 m wide buffers should contain all but the most extreme fires in mallee heath vegetation for 8-10 years before requiring re-treatment. This knowledge and experience underpins the prescriptions for implementing buffers in mallee heath vegetation to stop the spread of most bushfires.

In the vicinity of where the Cascade fire crossed from UCL into farmland there had been prior bushfire mitigation measures taken by way of the installation of a network of scrub rolled / chained buffers between the UCL bush and cleared farmland. The buffers are mostly 100 m deep (narrower in woodlands) bounded by a road on the 'farmland side' and a mineral earth fuel break on the 'bushland side'. The location and condition of the scrub-rolled buffers at the time of the Cascade fire are shown in Fig. 7. Most buffers were installed, i.e., scrub rolled and burnt, in 2005, although some sections were scrub rolled but not burnt, and some sections scrub rolled again in 2009 and burnt in 2010. Where the ~5.5 km wide head fire crossed from UCL into farmland, most (~70%) of the buffer was scrub rolled and burnt in 2005 and re-scrub rolled in 2009 but not burnt; the remainder (~30%) was scrub rolled in 2009 and burnt in 2010 (Fig. 7). Under CATASTROPHIC fire danger rating conditions, the fire readily burnt through the buffers, including the buffers burnt in 2010, which, under less severe fire weather conditions, would be expected to stop the fire.

On Monday 16 November, the day before the fire crossed into farmland, fire containment measures included widening the pre-existing 100 m buffers by scrub rolling, but not burning, an additional 80 m to create a 180 m wide buffer. Where this activity was carried out against buffers that had been scrub rolled in 2009 and burnt in 2010, it was very effective at stopping the wildfire, which burnt through the new 80 m scrub rolled fuel, but stopped at the 2010 treatment (see plate 8). However, limited time and resources meant that only about 5 km along Ned's Corner Road could be treated and of this, only about 1 km was in the path of the fire. However, it demonstrated that the strategy may have stopped the fire if there was sufficient time and resources to treat a larger area.

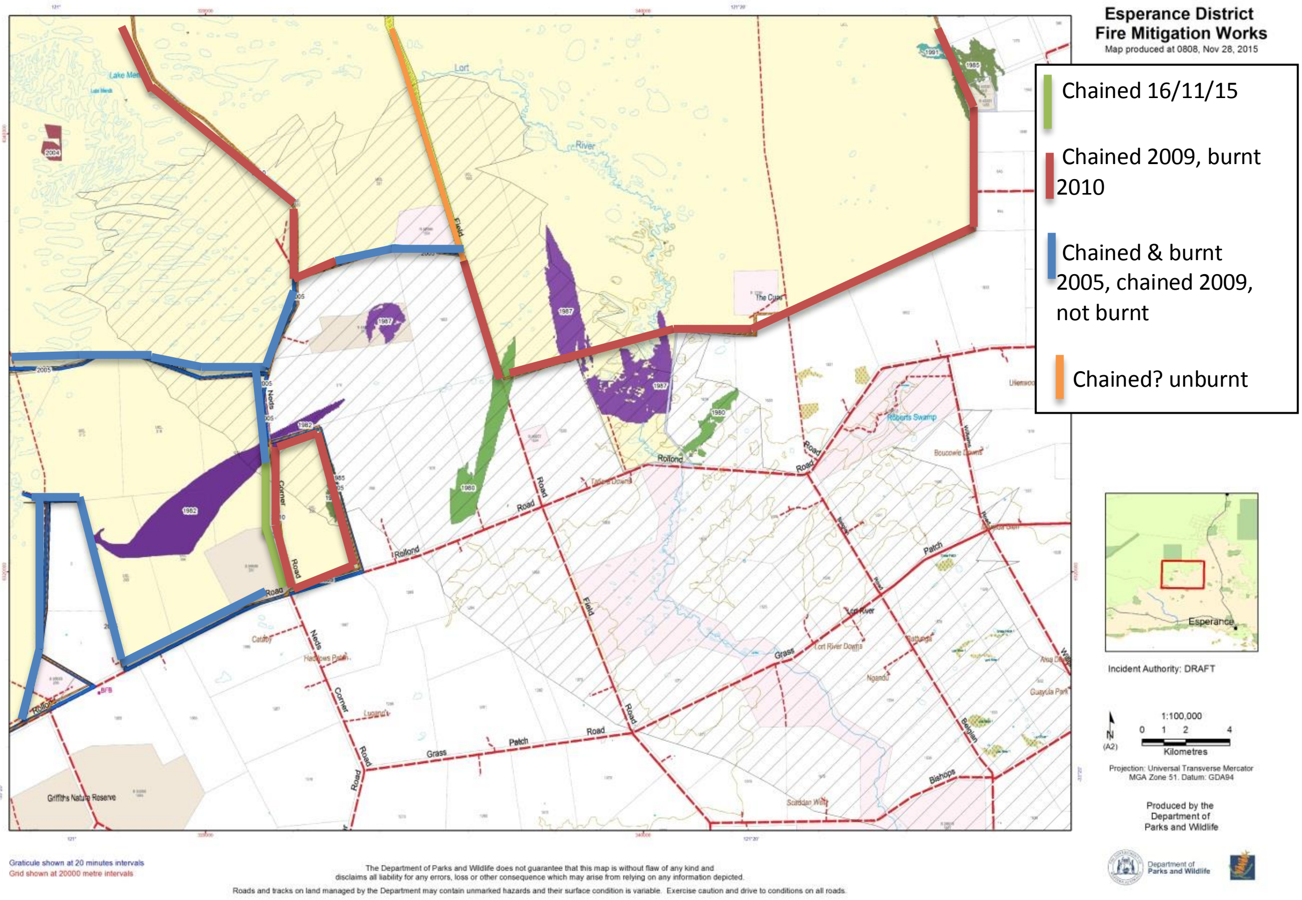

Figure 7: Parks and Wildlife fire mitigation works prior to the Cascades fire. Some chaining was carried out on 16 November against areas that were chained in 2009 and burnt in 2010. The fire did not burn through this combination of fuel treatments, but burnt through other treatments. Note scars from small fires in the 1980s

17 November

Based on H8 imagery, the fire was burning in bushland on UCL at 0100 hrs 17 November and under the influence of a strong NW wind, crossed into farmland paddocks at about 1140 hrs on a wide front, the centre of which was near the junction of Ned's Corner and Pyramid Roads (Fig. 1). At this stage, AWS data show that the wind backed from NE to NW at about 1000-1015 hrs, driving the fire towards farmland (Figs. 9 and 10). Because it had developed a significant perimeter while burning in bushland since 15th, the head fire was ~5.5 km wide when it reached the paddocks. Predicted rate of spread in bushland at 1030-1140hrs is 3.9 km/h (Table 1). Although there was substantial pre-existing scrub rolling and other fuel treatment at the UCL-farmland interface to prevent fires crossing this boundary, under these extreme fire weather conditions, these treatments were largely ineffective. Over the next 2 hours, mean 10-minute wind speed increased from about 30 km/h to over 55 km/h with gusts to 76 km/h recorded at the Cascade AWS, and up to 93 km/h at Salmon Gums. Mean wind speed remained consistently 50-60 km/h from about 1300 hrs to 1650 hrs with maximum speed (gusts) between 70-80 km/h (Scaddan and Cascade AWSs - Fig. 9). On entering farmland, the fire was burning in mostly unharvested crops. Fuel load is estimated at 4-6 t/ha (average yield on harvested paddocks in the region was ~4.2 t/ha). Following a dry spring, the crop/grassland was 100% cured.

Weather conditions from about midday to 1700 hrs on 17 November were extreme, with the temperature peaking at ~42°C and RH falling to 3.5% (Fig. 8). Mean hourly changes in the GFDI are shown in Fig. 11. With wind speed averaging ~54 km/h from NW backing WNW (Fig. 10), this resulted in the mean hourly McArthur Grassland Fire Danger Index (GFDI) peaking at 222 (CATASTROPHIC). In McArthur's original system, an index value of 100 represents the worst possible fire weather conditions so conditions on 17 November are among the most severe ever experienced in southern Australia. Throughout the day, wind gradually backed from NW to WNW and at about 1700 hrs, then backed abruptly to SW and abated to 20-30 km/h. With the winds in the SW and easing, temperature decreased and RH increased (Fig. 8). By 1900 hrs the GFDI had fallen to 17 and the fire's shape had stabilised by about 2000 hrs. While there was a slight expansion of the 100 km northern flank on the SW wind change, the falling GFDI prevented this flank from becoming a 100 km wide damaging head fire.

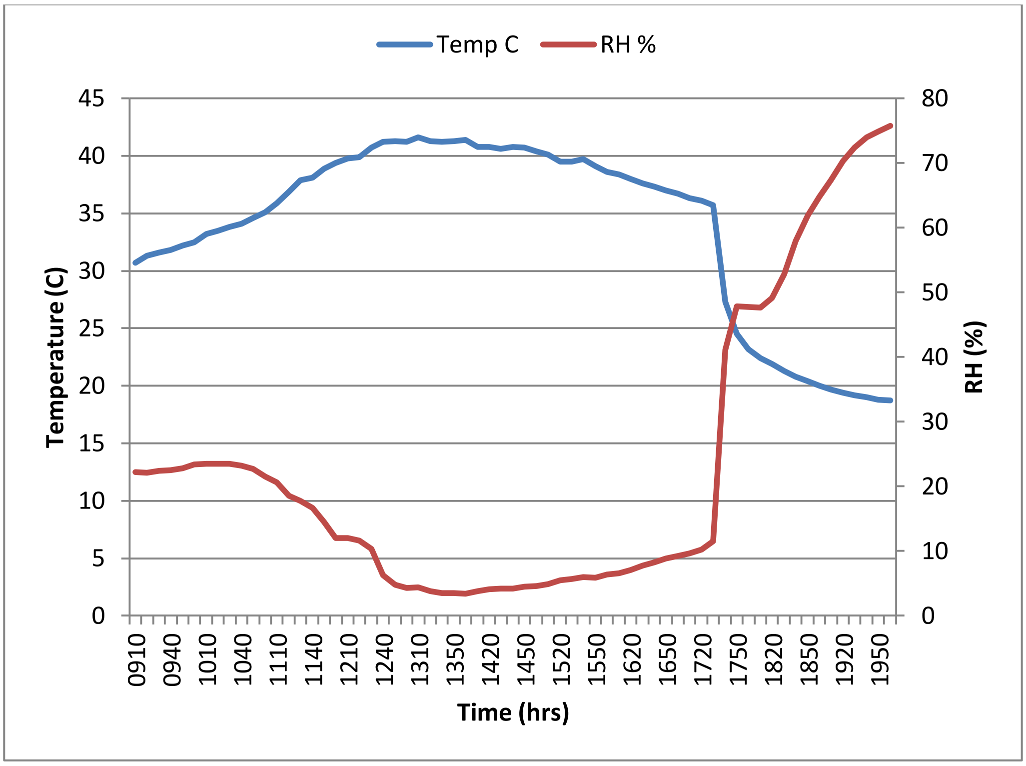

Figure 8: Temperature and relative humidity recorded at the DAFWA Cascade AWS for 17 November 2015. The minimum RH (3.5%) is among the lowest ever recorded. Note the sharp decrease in temperature and increase in RH when the wind backed to the south-west at around 1720 hrs.

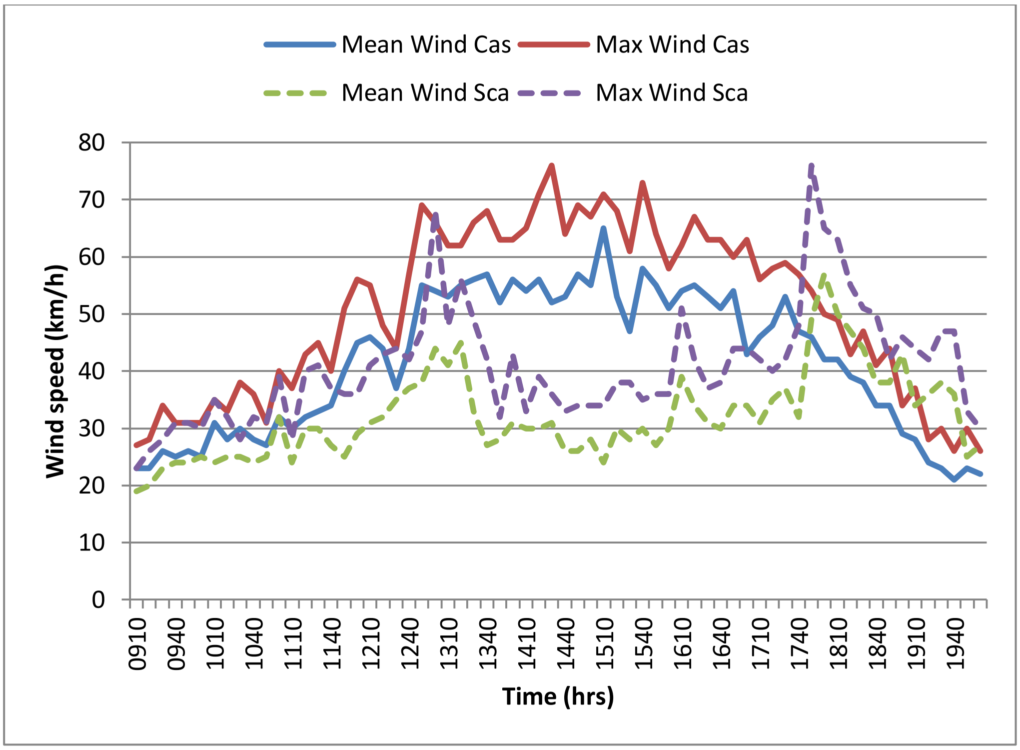

Figure 9: Mean and maximum wind speeds recorded at the Cascade (Cas) and Scaddan (Sca) DAFWA AWSs 17 November 2015 (note: anemometers at 3m so correction factor of 1.3 x applied to adjust for 10 m open wind speeds).

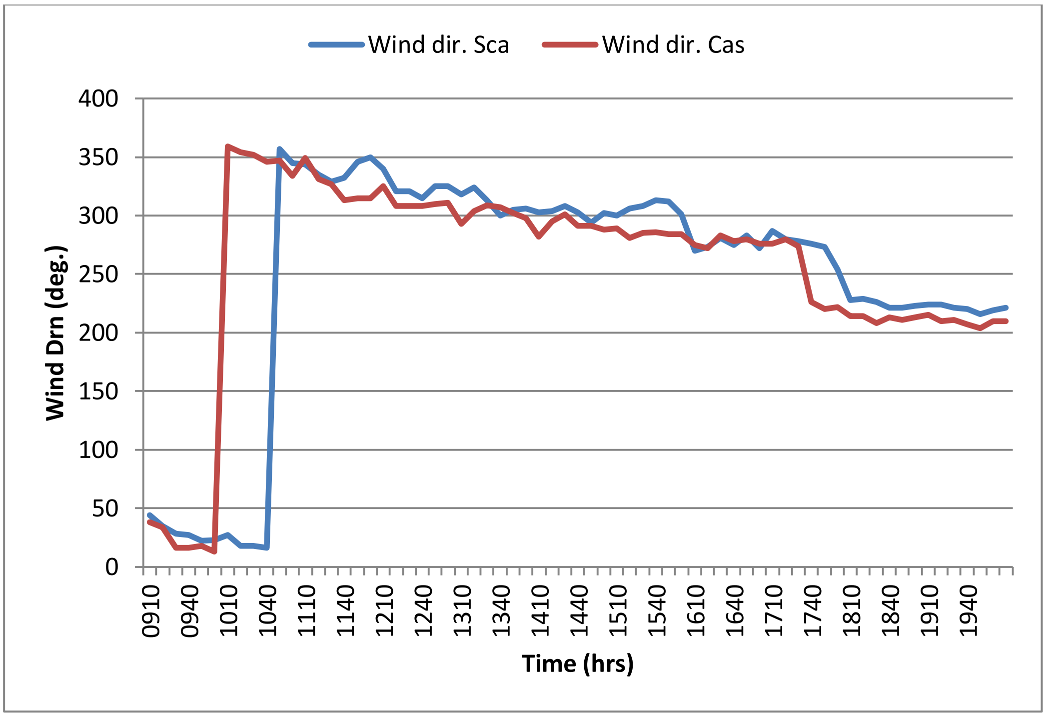

Figure 10: Wind direction recorded at DAFWA AWSs at Scaddan (SCA) and Cascade (Cas). Note i) abrupt change from NNE to NW ii) gradual backing from NW to WNW and iii) abrupt change to WSW-SW.

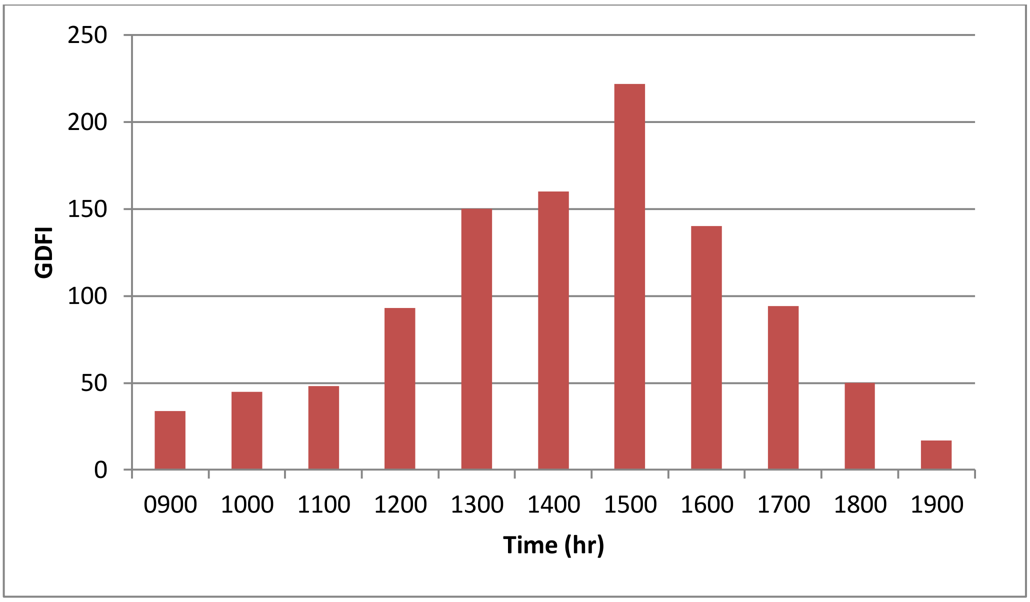

Figure 11: Mean hourly Grassland Fire Danger Index at Cascade, 17 November 2015. An Index > 100 is a Fire Danger Rating of CATASROPHIC.

Table 1: Summary of mean fire behaviour 17 November 2015. Intensity calculations are based on 5 t/ha (grassland) and 8 t/ha (mallee heath) fuel consumption. The grassland meter does not have harvested or unharvested crop fuel categories, so the 'grazed grass' category was used.

Source/fuel	ROS (km/h)	Flame ht (m)	Intensity (kW/m)
Predicted mallee-heath (McCaw model) (1030-1140 hrs)	3.9	3-6	15,500
Predicted CSIRO Grassland (grazed grass) (1140-1600 hrs)	15.8	1.5-2.5	39,500
Estimated from H8 hotspots (grassland paddocks)	14.1	1.5-2.5	35,250
Estimated from time at known locations (grassland paddocks)	14.4	1.5-2.5	36,000

Fire behaviour at the victim impact site

Four people in two vehicles were trapped by the fire on Griggs Road and lost their lives. The first vehicle (V1) containing one occupant was ~850 m east of the western edge of the fire and the second vehicle (V2) containing three occupants was ~1,190 m east of the western edge (Fig. 8). Having burnt through a (harvested) paddock north of Griggs Road, the fire burnt into a ~9 m wide road verge of smooth-barked mallees up to 8 m tall. Unburnt road verge vegetation west of the fire comprised a light patchy ground cover of eucalypt leaves, bark and twigs (~3.5 t/ha), cured grass (mostly wild oats) to 1 m (~1.5 t/ha), scattered low native shrubs to 1.8 m (~1.5 t/ha) and patches of coarse woody debris (CWD) comprising fallen trees, cast limbs and prunings from road verge maintenance that had accumulated over time. The distribution of CWD was patchy, but where it occurred, comprised a significant fuel load. The road verge had not been burnt for a long time – the mallee stem diameters ranged from 15-23 cm, some of the CWD was weathered and decomposing and there were no signs of charcoal.

Figure 12: Location of victim's vehicles (V1 – one occupant; V2 – 3 occupants) on Griggs Road in relation to the passage of the fire (red). Victims were heading east on Griggs Road when they were trapped.

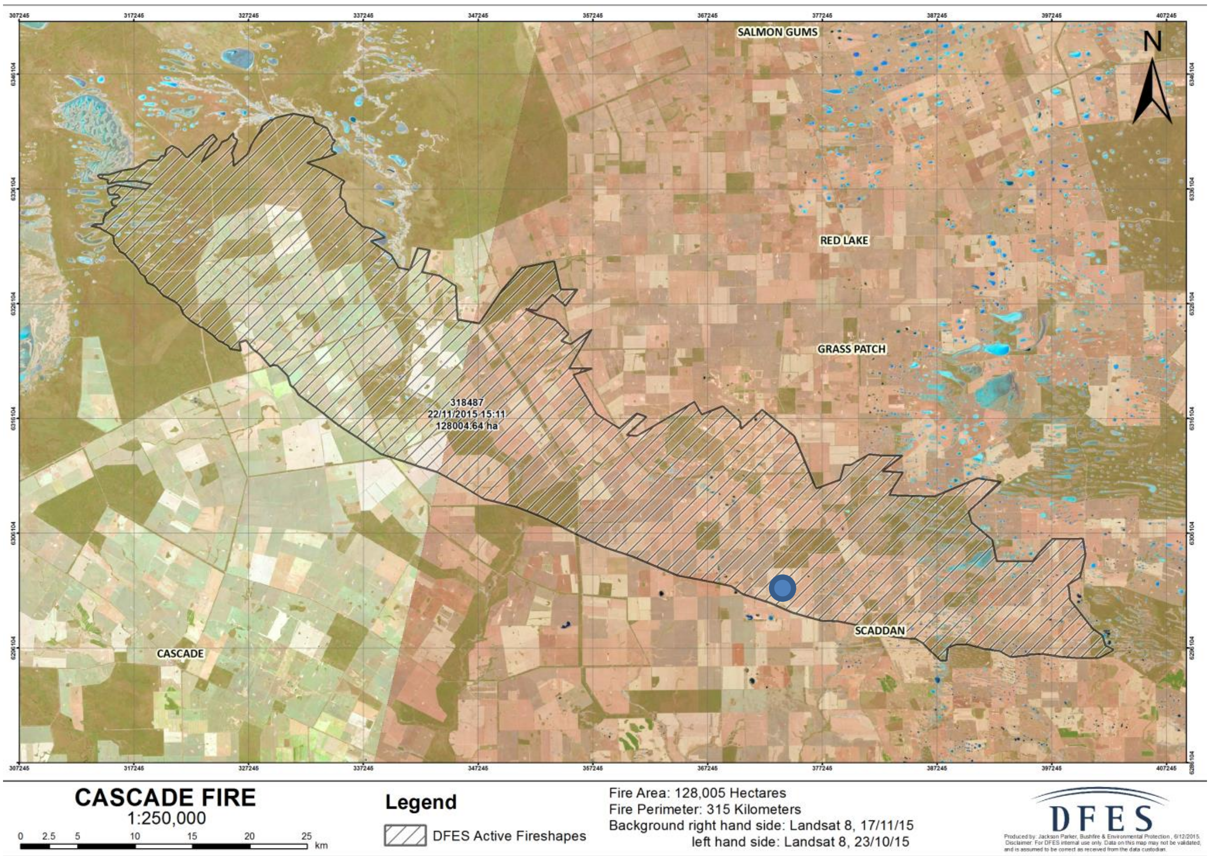

Figure 13: Fire shape as at 1700 hrs 17th November; Area ~ 128,000 ha, perimeter ~ 315 km, length ~100 km, mean width ~ 12.5 km. Note the curved shape of the southern perimeter as a result of wind steadily backing from NW to W, then finally SW (courtesy Jackson Parker, DFES). Location of 4 fatalities on Griggs Road (blue) about 6 km west of the Coolgardie-Esperance Highway.

The fire crossed Griggs Road, which runs east-west, from the NW. Its rate of spread at this point was about 14 km/h, and based on plant defoliation levels, flames were mostly 1.5 m to 2 m high, flaring to 7 m as occasional mallees torched. The mallees were mostly fully scorched but a few were defoliated. The length of carbon deposit (staining) across the sealed road, measured from the road /vegetation verge and indicative of flame length, was mostly 4-5 m with intermittent flaring to 10-12 m at intervals, so flames were low and long. The road width, from verge to verge, is ~23 m. Fire intensity in the bushland road verge at this location is estimated to be very high at ~30,000-35,000 kW/m.

Orientation of road stain was 310°-320°, indicating the fire crossed the road from the NW. However, road verge vegetation freeze was 250°-260°, indicating that freeze set under the influence of a W-WSW wind. This suggests that the wind change occurred soon after the fire crossed Griggs Road and before the vegetation had cooled and set under the influence of the NW wind. Data in Figure 10 (Scaddan AWS, ~6.7 km ESE of impact site) suggests the wind backed to the W by 1610 hrs, then to the SW by 1750 hrs.

The fire was probably opposite the Campbell farm house at around 1535-1540 hrs (based on witness accounts (LC;LM)). The farm is ~2.7 km WNW of the victim impact zone, so based on these times, and assuming a fire rate of spread of 14 km/h, it is estimated that the fire crossed Griggs Road, impacting the victims, at around 1546-1551 hrs. However, H8 hotspots imagery, although coarse, suggests the fire crossed Griggs Road near the victim impact site later, at around 1620 hrs, and was burning on a ~6 km wide front. That the fire crossed the road from the NW (road stain) and that the wind backed to the W at about 1610 hrs, after it had crossed Griggs Road, is further evidence that the fire probably impacted the victims closer to 1546-1551 hrs.

Concluding remarks

This fire was started by a lightning strike in bushland in UCL and burnt for two days before it developed extreme behaviour on 17 November, during which 4 people lost their lives. Weather conditions and the GFDI during this incident were among the most severe ever experienced in southern Australia. Similarly, the speed of the fire was among the highest ever recorded. The extreme fire weather conditions likely mixed down from a dry slot aloft. Dry slots can be detected from aerological diagrams constructed from balloon flights ex Perth and Albany airports and this data should be used by fire behaviour analysts to assist with interpreting and forecasting impending fire danger rating in the south-west. As is often the case with extreme fire weather events, the c-Haynes index was very high (>10) as a result of very low dewpoints aloft (min. -40.0^{o}C).

There is an opportunity to improve bushfire danger and impact forecasting by further developing and utilising the automated bushfire spread simulator Aurora, managed by DFES and Landgate. The simulator has the capacity to use satellite hotspots detection of fire ignitions and 4 day weather forecasts to predict and from this, rapidly map potential speed, path, shape and size of a bushfires, or multiple bushfires, burning anywhere in the State. This intelligence will enable better suppression response planning and prioritising and better community preparedness. For example, the path and behaviour of the Cascade fire, and other fires in the region, could have been quickly predicted, within reasonable limits, from the time the ignition was detected by satellites in the morning of 15th November through to the evening of 17th November. Aurora requires further development and testing before it can be reliably used in this capacity, but used in an appropriate structure, it has great potential so such investment by the State could be life saving.

While the CSIRO Grassland Fire Behaviour Model does not have ‘cereal crop’ as a fuel category, using ‘grazed grass’ fuel and on extrapolation to CATASTROPHIC fire weather conditions, it performed well in predicting the rate of spread of this fire.

Extensive pre-existing fire mitigation works, including the construction of scrub rolled and burnt buffers, failed to stop the Cascade fire under these extreme fire weather conditions. Scrub rolling a 80 m wide strip against a pre-existing 100 m scrub rolled and burnt (in 2010) buffer did stop the fire, but the treatment was of insufficient length to contain the ~5.5 km wide head fire. However, it demonstrated that scrub rolled and subsequently burnt buffers out to 200 m wide, if maintained regularly (treated every 8-

10 years) can be effective even under severe conditions. However, with some 700 km of interface between cleared farmland and bushland in the Esperance region, this would require about 100 km (~2,000 ha) to be treated every year. Parks and Wildlife currently does not have sufficient resources in the District to meet this target, so either additional resources will need to be made available, or the area of interface treated will need to be prioritised using a wildfire threat analysis or similar risk-based approach.

Acknowledgements

I acknowledge the following people who have contributed to this report: Andrew Duckworth and Jackson Parker (DFES), Ian Foster (DAFWA), David Turnbull, Greg Mair, Lachie McCaw and Paul Rampant (Parks and Wildlife) and Linda Campbell, Robert Tonkin and Lorraine Major (citizens of Esperance).

My condolences go to family and friends of those who lost their lives in this fire.

Appendix 1: Photos

Plates 1 & 2: Unburnt and burnt mallee-heath vegetation/fuel near where the fire crossed from UCL into farmland.

Plate 3: Griggs Road near where 4 people lost their lives. The fire crossed from left to right – note the carbon 'staining' on the bitumen indicating flame flash (length).

Plates 4 & 5: Variable fuel condition of the road verge along Griggs Road west of where the fire crossed the road. The road verge was long unburnt.


Plate 6 Left: Pre-existing (unburnt) 100 m buffer along Ned's Corner Road – chained in 2009, burnt in 2010 and re-chained just prior to the arrival of the fire. Plate 7 Right: The same buffer but further down the road where the head fire crossed. Under less severe fire weather conditions, this buffer would have most likely stopped the fire.

Plate 8: A section of Ned's Corner Road that had been chained just prior to the fire (Monday 16th November). The additional 80 m of chaining (burnt by the wildfire - left) was added to the pre-existing 100 m of buffer (right) that was chained and burnt in 2009/2010. Although the fire burnt through the recent 80 m of chaining, the combined treatment stopped the fire (coming from the left).