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Feasibility of burning debris from wet eucalypt forests harvested to an aggregated retention prescription

Technical Report
10/2007

By Richard Chuter

Division of Forest Research and Development
Forestry Tasmania

20 July 2007

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About the author

Richard (Dick) Chuter worked for the Forestry Commission and Forestry Tasmania for 40 years until his retirement as head of the Fire Management Branch, in 2003. As a Forest Ranger in the early 1960s he assisted with research into improved methods of high intensity prescribed burning for eucalypt regeneration. He worked in the field for 25 years, during which time he acquired experience in all areas of fire management. He joined Fire Management Branch in 1992. He extensively revised all of Forestry Tasmania's fire management training material and was the principal instructor for fire management subjects. He has studied fire management issues in Canada and the United States and participated in the first international deployment of firefighters to the US in 2000.

Summary

Variable retention forest harvesting aims to retain a representative part of the original forest, interspersed with harvested sections, such that forest influence is maintained over the majority of the harvested area.

These harvesting systems present a challenge for effective regeneration treatment with fire. Traditional convection burning as practiced on clear felled coupes cannot be directly applied to retention harvesting without severely affecting the retained aggregates.

Twelve aggregated retention (ARN) coupes were presented for post-harvest burning in autumn 2007, with the aim of developing a method and prescriptions suitable for routine application.

Fuel dryness was identified as the key to a successful outcome. The drying of fine fuels occurs until the relative humidity reaches its daily minimum and starts to rise. This usually happens late in the afternoon. Propagation of fire in dry fuel, by slow progression, can be achieved if convection activity is moderated by a combination of the lighting method and rising relative humidity.

Aerial lighting with a helitorch is efficient and effective but depends on skilled operators applying fewer targeted ignition points to help in moderating the fire behaviour.

The design and preparation of variable retention coupes is integral to the facilitation of effective burning. Coupes should look more like golfing fairways and less like football fields. Narrower slash fields can be burnt out by single lines of sparsely applied ignition which, under the right conditions, will progress slowly.

Recommendations

Design: A ‘fairway’ design will provide better opportunity to moderate convection during burning. The ‘fairways’ need to be about 100 - 120 metres wide to facilitate safe lighting by helicopter. Length and alignment are not limiting factors. Winding ‘fairways’ may prove to be the most suitable, as they could interrupt any wind-tunnel effect.

If internal aggregates are needed, they should be at least 2 hectares in size. This will maintain a higher fine fuel moisture level around the core of the aggregate. Aggregates should incorporate any naturally fire-defensive features, such as swamps, marshes or streams. Aggregates must not be located in fire-prone zones such as dry mid-slopes or as isolated islands on ridge tops.

The design of ARN coupes should make the best use of natural fire boundaries such as vegetation types, watercourses and ridgelines. Difficult burning boundaries, such as mid-slope lines and adjacent flammable vegetation types must be avoided. Any feature or site to be absolutely precluded from fire, for whatever reason, must not be located within or adjacent to the burning area. To do so will add unreasonable costs for protection and may also compromise the integrity of the burn, resulting in an unsatisfactory outcome.

Preparation: Fuels, particularly the fine fuel component, must be arranged as an even, low profile cover. This must be an objective of the harvesting operation, realised through minimal traffic across fuel beds and use of techniques such as ‘shovel logging’ by excavators, with snigging restricted to the defined tracks. There will be training implications for harvesting contractors, not familiar with the ‘shovel logging’ technique.

Firebreaks should be surface raked in preference to scraping to mineral earth. This work should be integrated with the harvesting for cost savings and reduced fuel disturbance. Raked fuels should be evenly distributed adjacent to the perimeters, avoiding large windrows. Landing heaps should be similarly dispersed, with bark being transported back into the coupe, if necessary.

Monitoring: Data loggers should be used to monitor the onsite weather conditions for a month prior to the proposed burning period. The data should be used to determine drying trends and the distribution of rain events to calculate a local Soil Dryness Index and Drought Factor. While applicable to ARN coupes, it is anticipated that prescribed burning in general would benefit from a more rigorous approach to local weather observation. Leased equipment, which can be remotely monitored, is recommended. Apart from set-up costs, the weekly hire of $300 (currently) would be offset by the reduction in staff time and travelling to take weather readings at distant sites.

Lighting method: Satisfactory lighting of ARN coupes can be done with a helitorch, provided that the operators have been comprehensively briefed on the plan and the desired outcome. There should be further experimentation with lighting methods, particularly the use of spot ignition, to develop the best techniques. The aim will be to light less intensively and more strategically. A global positioning system (GPS) should be linked to the helitorch control switch in the helicopter to map the lighting flight path. This will be invaluable for post-burn analysis and the training of bombardiers.

Burning prescriptions: The following prescriptive advice should be considered as a starting point and further incremental refinement should be encouraged, as experience with this type of burning is accumulated.

- **Fuel** – The fine fuels must be dry; less than 13% fine fuel moisture content (FFMC) is recommended. The heavy fuel component should also be dry, as indicated by the local Soil Dryness Index which should be not less than 30 mm and up to 75 mm, to the end of March, with no upper limit during April and beyond. As a field check, the topsoil and litter should be dry, with the undersides of half buried logs still damp, during March.

- **Time of Day** – Burning should be done after 1600 Eastern Standard Time (EST), when the local relative humidity (RH) has reached its lowest point and is beginning to rise. Burning can be commenced up to thirty minutes after the rise is detected or up to one hour after, if fuels are very dry.

- **Temperature** – This will not be a limiting factor at this time of day and does not need to be specified.

- **Relative Humidity** – May be under 50%, but must be rising.

- **Tree Top Wind** – Beaufort 1 (0 – 5 kph). Ground measurements will be of little relevance unless the exposure is very good, in which case add half the ground reading again to get an equivalent wind speed at 10 metres above ground level, which is the Bureau of Meteorology standard. Better still, observe the tree tops and correlate with the Beaufort scale. If the wind is marginal late in the day, say above 10 kph at tree top level, the chances are it is not going to improve and conditions will be unsuitable for variable retention burning.

- **FFMC Difference** – A minimum difference of 7% between the moisture content of dry fuels and that of shaded forest fuels is desirable, if self extinguishment of perimeter fires is to occur overnight. The shaded fuels should not be under 18%, when the fire is started. It is important that the Fine Fuel Moisture Indicator (FFMI) sticks for the shaded forest reading are placed correctly, in a site representative of the driest of the surrounding vegetation and at least 60 metres from an exposed boundary to avoid an edge effect. Where fires persist in the surrounding forest, after burning, monitoring of the forest litter dryness must continue. This will help to determine if there is a continuing drying trend, in which case the fires in the surrounding forest must be suppressed, particularly during March and the first week of April.

Photo 1. Fine Fuel Moisture Indicator (FFMI) Sticks, placed correctly above the litter in surrounding forest.

Introduction

This report was commissioned under the Tasmanian Community Forest Agreement as part of the research program into alternatives to clearfelling in oldgrowth forests. Investigations and research were done to meet the specific project objective of developing prescriptions for the burning of post-harvest debris in aggregated retention coupes. Also examined were the effects of not burning these coupes and the likely outcomes in terms of fire management and regeneration.

The burning of logging residues (slash) to provide a seedbed for eucalypt regeneration has been routinely practised in Tasmania since the late 1950s. The process has not changed much since convection burning – initial intense central ignition with subsequent perimeter lighting - became the established method in the late 1960s.

The lighting was originally done by hand, taking up to several hours to complete a coupe.

In 1987 the first helitorch was used to light slash burns. Described as an 'aerial drip torch' using gelled petroleum for fuel, this machine out-performed all other lighting methods, although hand lighting continued to be used for small coupes. The helitorch is suited to large, regular shaped areas and with various refinements, has become the standard fire lighting tool for clearfelled and windrowed coupes.

Variable retention (VR) forest harvesting aims to retain a representative part of the original forest, interspersed with harvested sections, so that forest influence is maintained over the whole coupe. One form of variable retention is aggregated retention (ARN) (Franklin *et al.* 1997), which has been advocated for tall oldgrowth forest designated for wood production on public land (Forestry Tasmania 2005a). Under aggregated retention, representative patches of the original forest are kept among harvested sections so that forest influence is maintained over the majority of the coupe. As currently practised in Tasmania, half to one hectare aggregates of uncut forest are retained throughout a coupe, separated by 'fairways' of approximately two tree heights in width. The slash on the fairways is burnt to clear a receptive seed bed for eucalypt regeneration.

Convection burning, as practised on clearfelled coupes, is not suitable for aggregated retention. First attempts at burning VR coupes assumed that lighting damp fuels in marginal meteorological conditions would result in a 'low intensity' fire, removing sufficient fuel to create enough seed bed. This was not the case in practice, as too little fuel was burnt (Marsden-Smedley and Slijepcevic 2001).

Case Studies; Alternatives to burning harvested aggregated retention coupes

In researching the feasibility of burning ARN coupes, an alternative of not burning them was considered. This involved inspections of three areas of wet eucalypt forest, known to have been harvested and then left, either unburnt or partially burnt, for periods ranging from 12 to 31 years. To do the inspections, parallel strip-lines were laid out, 200 metres apart. Plots were established at 50 metre intervals along the strip lines. A subjective visual ground inspection was made of each plot for a radius of approximately 3 metres. Where remnants of the original harvesting slash could be identified, they were classified and rated for their contribution to the available fuel load. The presence or absence of eucalypts within a 3 metre radius was noted.

Photo 2. A plot point in the unburnt coupe survey showing 15 year old slash residues.

Black Bobs 006 – is a coupe of approximately 30 ha, harvested in 1992 and left unburnt (T. McCoy pers. comm.). Subsequent treatment involved drilling auger holes through the slash to mineral earth with a machine and planting seedlings. Eucalypts are now evenly dispersed across the lower slopes of this coupe, but sparse in the steeper sections, which were not treated. In 2007, 15 years after harvesting, no fine fuels from logging slash were observed but many small and large limbs remain, with an even scattering of logs.

About 20% of the plots inspected had recognisable and significant remnants of the original fuel bed, contributing to the current available fuel load.

Counsel 001A – is a small coupe of approximately 9 ha, clearfelled in 1995 and left with the slash unburnt (B. Warren pers. comm.). No fine fuels from the original felling were observed but many large logs and limbs remain. Clumps of eucalypt regeneration are associated with disturbance from snig tracks, but the coupe is otherwise under stocked, apart from sassafras, wattle and the occasional blackwood. A narrow strip along the western boundary is higher and more exposed, with a drier bracken understorey. More of the original slash remains in this section.

About 40% of the plots inspected had recognisable and significant remnants of the original fuel bed, contributing to the current available fuel load.

Arve 034F – is a coupe of 44 ha, harvested for sawlogs and pulpwood during the early 1970's. Poor utilisation resulted in many trees being left standing and some felling to waste was done, resulting in sections having a very heavy fuel load. Apart from patches which were clearfelled, the coupe looked as if it had been selectively logged. The area was burnt in 1976 with a patchy result due to the lighting method (electrical ignition circuits) and marginal burning conditions, in particular a high 70% RH, (1976 observation, R. Chuter).

Except for the areas which were either unburnt and / or had experienced no ground disturbance, the coupe is now well stocked and has recently been chemically thinned. There is a significant number of very large logs on the ground resulting from both the original felling and trees which have fallen during the 31 years since burning. The stocking distribution confirms the regeneration response of eucalypts to any level of burning or soil disturbance, particularly where there is an abundance of seed (from the standing trees) and protection from browsing (caging effect of partially burnt slash).

About 15% of the plots inspected had recognisable and significant remnants of the original fuel bed, contributing to the current available fuel load.

Conclusion – alternatives to burning

The inspections of three coupes, either unburnt or partially burnt, indicate that the fine fuel component, up to 25 mm diameter, will progressively decompose over several years, in wetter environments, where there is a canopy cover. There will be little significant natural eucalypt regeneration without some form of disturbance to expose a mineral earth seed bed (Gilbert and Cunningham 1972). Alternatively, coupes will have to be planted through the slash. A significant fine fuel load will remain for several years after harvesting.

Until the current residual biomass, particularly the coarse woody debris, can be substantially reduced through commercial utilisation, there is no prospect of economically regenerating harvested variable retention coupes without using fire. This refers to the mechanics of fuel removal to facilitate planting only, without considering the other potential benefits of fire for eucalypt seedling growth and vigour.

Burning aggregated retention coupes

Fuel must be dry if it is to burn unassisted by wind or slope. Slash fuel in wet forest is comprised of up to 85 tonnes per hectare of surface fine fuels under 25 mm diameter (Marsden-Smedley and Slijepcevic 2001). Since the amount of fine fuel is a principal determinant of fire intensity (Luke and McArthur 1978) it is readily apparent that even with zero rate of spread, fires in heavy slash release huge amounts of energy as heat. There is no likelihood of an effective 'low intensity burn' in wet forest type harvesting slash. An 'effective' burn is currently (2007) defined as one which removes a minimum of 85% of the fuel over 85% of the area (Minutes, Burning of ARN Coupes Derwent District Meeting March 13 2007). If it is accepted that burning to this standard is required to adequately regenerate ARN coupes, then these coupes must be planned with this burning objective as an absolute priority.

Coupe planning and design

The reliance on convection burning throughout the 1970s and 1980s was reflected in coupe design, large uniform shapes with a central elevated section being preferred (Prescribed Burning – High Intensity, Forestry Tasmania 2005b). The increasing use of helicopter lighting during the 1990s encouraged the planning of this type of coupe design. Since then, the size and shape of coupes has been progressively affected by required reservation: riparian, wildlife, scenic and karst for example, making safe, efficient convection burning a more technically difficult operation. Variable retention is another layer being added to this standard design template.

In planning future ARN coupes a landscape-level approach needs to be considered, in preference to planning at coupe-level. This will consider much larger areas of production forest. All mandatory reservation, plus any additional site needs, determined during intensive ground inspections, will be mapped first. Only after the net area available for harvesting has been determined will ARN coupe planning be considered. This will use natural features to determine the best design for ARN, which must facilitate its specific burning needs. The length to width ratio of coupes is important, with extended, rectangular coupes being preferred over the more equilateral shapes, to reduce the opportunities for convection fires from central ignition. By extending streamside reservation or aligning with reserved type boundaries, there may be opportunities to reduce the reliance on internal aggregates. Coupe alignments which minimise edge shading and increase airflow, as might occur when orientated with the local prevailing wind direction, should be considered.

Burning of ARN coupes must be compatible with broader fire management plans. These will at least identify proximity issues, such as specific special values sites and high risk vegetation, prior to commitment to road construction and harvesting.

By taking a pre-emptive approach, part of the cost and effort currently needed for post-burn fire suppression will be shifted to pre-harvest planning, with potential benefit.

The planning maps shown here illustrate the effect of reservation and exclusion zones on net area available for harvesting. A single coupe, taken in isolation, may be considered as a standard clearfall (A). A composite of several coupes, including intermediate reserves, may meet the criteria for variable retention, with additional retained aggregates, if required, (B, C, & D).

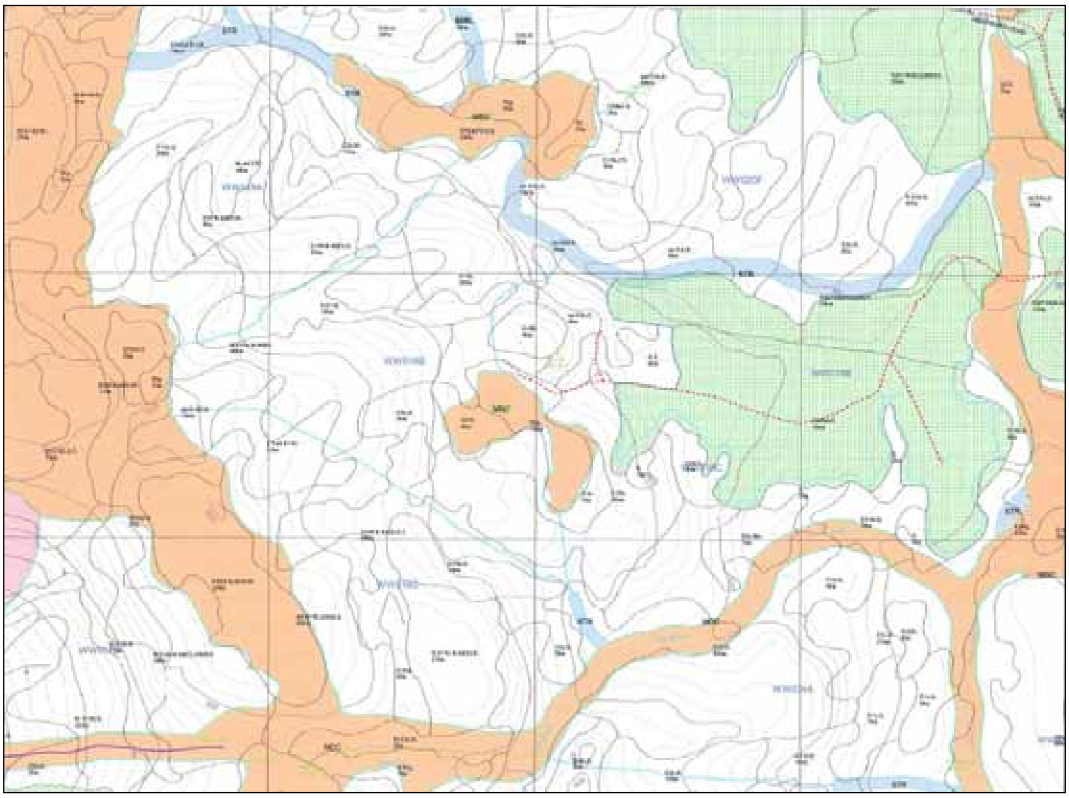

Figure 1. Planning map prior to special values assessment.

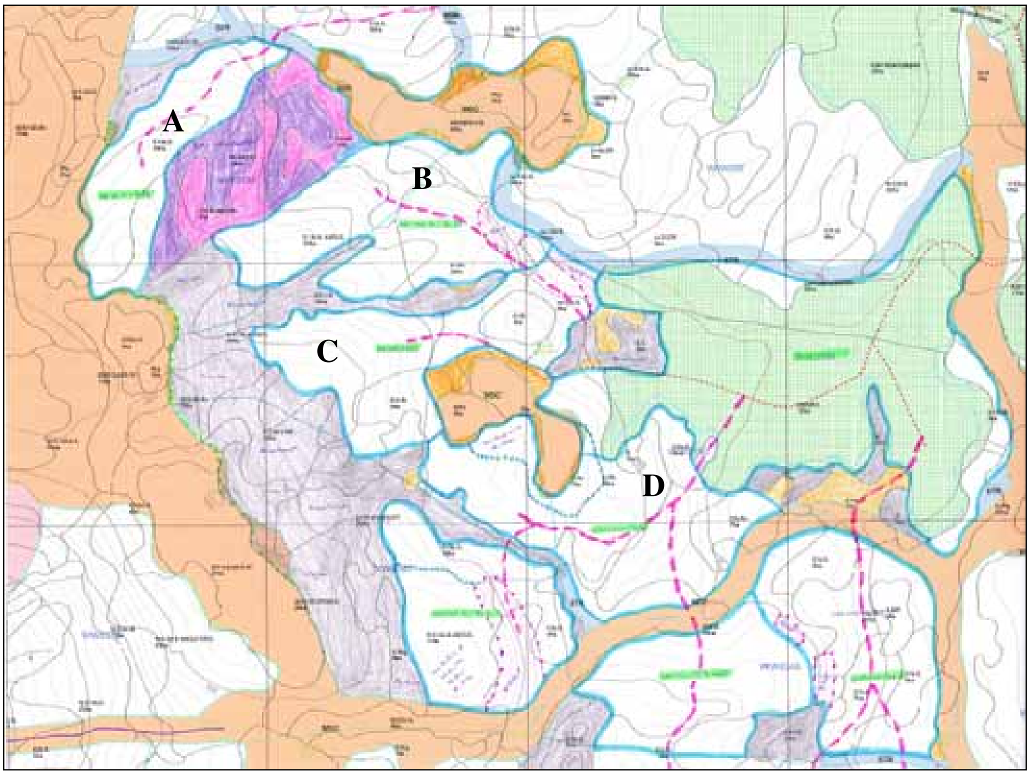

Figure 2. Planning map showing small clearfell (A) and possible VR approach (B, C, D).

Harvesting and preparation

Examination of current practice reveals opportunities to improve conditions for burning and to save site preparation costs at the same time. Since the condition of the fuel, particularly the near-surface fine fuel, is a significant factor in the burning strategy, this fuel must be presented in the best condition for lighting. Low profile, evenly distributed fuel beds are important for promoting fuel dryness, fire propagation and effective burnout. This is not the case with unevenly distributed and heaped fuels, large windrows or fuels which are mixed with earth and humus. The aim should be to minimise machinery damage to fuels by limiting passes across fuel beds and restricting traffic to major access tracks. This may require a fresh approach to harvesting, with more use of 'shovel logging', where wood is passed across the surface with an excavator, rather than being dragged by a wheeled or tracked machine.

Photo 3. An example of an ideal fuel array, SX04B.

The need for and type of firebreaks should be examined. Where aggregates are retained as 'islands', mineral earth firebreaks should not be put around them. Not only will such breaks not prevent fires spreading into the aggregate, but the radiant heat from the burning of the adjacent windrows of cleared fuel will increase the rate at which the aggregate perimeters dry, facilitating the spread of fire into the aggregate. Instead, use excavators during the harvest to rake fuels away from the aggregate perimeters. It is important that this is done while the wood is being extracted, to minimise cost and subsequent machinery traffic across the fuel bed.

The same argument is offered for perimeter firebreaks. These may be justified in convection burning, where a clearly delineated perimeter is needed for the edge lighting when convection is drawing all edges inwards, but there is little evidence to support the proposition that mineral earth firebreaks prevent escapes. At best, they facilitate access for subsequent fire suppression. Mineral earth firebreaks need to be considered in terms of their construction costs, potential environmental damage and loss of productivity compared with their effectiveness, particularly when the vegetation community adjoining the boundary is one of the less flammable types, such as wet forest or rainforest.

Photo 4. Example of a firebreak with a large windrow of fuel adjacent to a small aggregate, AR023E.

Photo 5. Example of a raked edge against a wet forest type boundary, SX018E.

Burning method

As described, convection burning is widely practised for clearfelled coupes, where the rapid propagation of fire within the coupe is a desired outcome. The resultant convection column draws air in from all edges, thus facilitating perimeter lighting and rapid burnout. Where this occurs and there are no large smouldering heaps of fuel on the edges, the fires can be considered as 'relatively safe' within an hour or two of lighting.

Aggregate retention coupes require a different strategy. This will be termed 'slow' burning, where convection is avoided and fires spread slowly, relying on fuel dryness and radiant heat for propagation, as occurs with 'backing' or down slope-fires.

It must be acknowledged that this is a higher risk burning strategy, with high reliance on fires self-extinguishing as they meet progressively damper surrounds overnight. Persistent creeping fires will have to be suppressed if the surrounding forest begins to dry out or the burning is being done before the end of March. In any case, continual monitoring of forest dryness by routine measurement of the fine fuel moisture indicator (FFMI) sticks must become part of the procedure, until fires are extinguished.

'Slow' burning for ARN coupes will depend on:

- the shape of the area to be burnt,
- the fuel dryness,
- the time of day, and
- the lighting method.

Shape

Avoiding the development of a convection column depends on limiting the opportunities for more than a single fire or line of fire to interact with other fires, resulting in junction zone effects. In convection burning, the shape of the coupe is important, as a large symmetrical area allows multiple ignition spots to be placed at a central point. These generate intense heat, causing fresh air to flow inwards to replace that being pushed aloft.

This effect can be avoided in a narrow 'fairway', where a single line of fire or spots can be placed along the centre with no opportunity to create a focal point other than to funnel along the corridor. Without wind effects, the fire will tend to spread slowly outwards towards both perimeters. The precise width of the fairway needs to be determined by field experience. Helicopter pilots have said that they prefer a minimum width of 100 – 120 metres in tall forest.

It was noted that a 60 metre 'fairway' was successfully negotiated by a helicopter in placing a single centre-line of lighting at EP081B. The width of the 'fairway' must not exceed the distance which can be travelled during the burning period (which may extend overnight) by the fires arising from the initial lighting line. This is something yet to be determined, but is probably in the order of 100 – 150 metres.

Photo 6. A long narrow corridor lit with a central line of fire, EP081B.

Fuel Dryness

The dryness of plant material plays an important role in determining fire behaviour (Slijepcevic & Anderson 2006). Contrary to previous opinion, AR burning may actually require drier fuel than convection burning. Convection burning depends on mass fire effects with resultant inflow winds. This airflow rapidly dries out any residual dampness in fine and medium fuels and promotes the spread of fire by both internal spotting and accelerating headfire advance. ‘Slow’ burning is an extended process. Convective activity is present in ‘slow’ burning but it is not as focussed nor as strong. The brake on fire behaviour is this circumstance is a rising RH which limits spotting distance and the opportunity for spot fire propagation, particularly in forest outside the coupe.

Photo 7. An example of fires spreading in dry fuel under conditions of high relative humidity, without strong convection present. EP081B (Don Riddell).

Time of Day

Escapes from prescribed burns and breakouts from wildfires occur most frequently in the late afternoon to early evening. This is when the relative humidity is likely to be lowest and consequently fine fuels are likely to be at their driest. To confirm this, five automatic weather stations (AWS) were located in AR coupes from Salmon River in the far northwest to the Arve Valley in the south, including two in the upper Derwent Valley (Styx).

From February 6th 2007 through to April14th 2007, these machines logged RH readings hourly to determine the time of day when the lowest RH most commonly occurred. This is assumed to be the time at which fuels stop drying out and after allowing for a short time lag, begin to take up moisture from the air, as the RH rises.

The AWS data showed that across the State, on a majority of days, the lowest RH was recorded between 1500 and 1700 (EST). The recognised time lag for fuels to respond to RH is considered to be about 1 - 2 hours, although recent research indicates that this time may be considerably shorter (Slijepcevic & Anderson 2006). On a majority of fine autumn days, fuels are at likely to be at their driest at around 1630 (EST). The data indicated a rapid rise in RH from about 1900 (EST).

This suggests that on suitable burning days, lighting is likely to be most successful between 1600 and 1700.

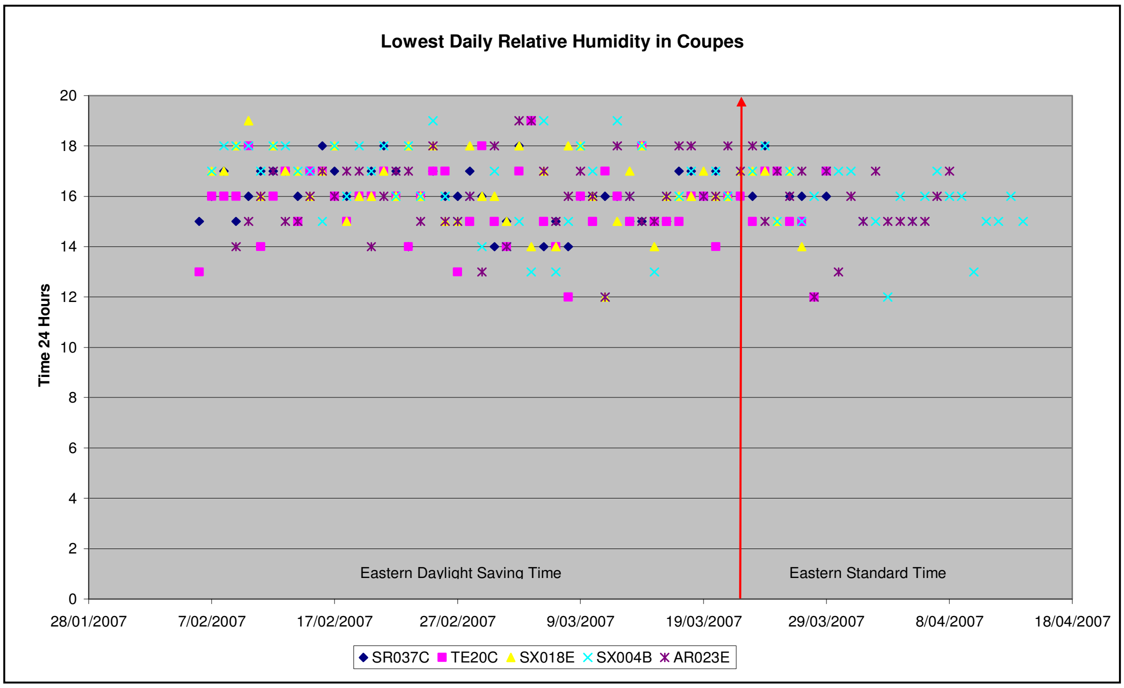

Chart 1: Relative humidity at five locations, February to April 2007

Lighting method

Previous experience with ARN burning indicated that hand lighting was considered likely to be more successful than lighting with a helitorch because of greater control over the pace of lighting and the intensity of the fires (Knox 2005). There are significant issues with hand lighting, however. The most obvious is the time and labour required. While labour adds to cost, the time factor is critical because of the fuel moisture cycle. Experience indicates that between 1 and 2 person hours per hectare are needed for hand lighting and up to 5 hours may be required to burn a 30 hectare coupe. This means starting the burning well in advance of the fuel being at its driest, with difficulty in getting fires to burn during the early hours and then burning too fiercely in the latter part of the day.

Two Styx coupes of comparable size were burnt on the 27th March 2007, SX007A (40 ha) and SX018E (30 ha). The former was lit by hand. Nine personnel commenced at 1430 and finished at 1830 (36 person hours). SX018E was lit with a helicopter at the best time of the day, relative to fuel dryness and a rising RH, and took only 20 minutes to complete. In terms of results, quality of burn and extent of aggregate damage, no appreciable benefit was observed to have been gained by hand lighting SX007A.

A significant issue with the helitorch is the practice of bombardiers, particularly the inexperienced, to over-light the fuel. This can result in firestorms within coupes, particularly when the fuels are very dry. Resultant convection wind accelerates the drying of the perimeter vegetation and small, internal aggregates.

Variable retention burning requires skilled bombardiers with enough knowledge and discipline to put down a minimal number of ignition points in the pre-determined pattern and to not be tempted to light more points when they do not get an immediate response. Once additional lines or spots are introduced, the opportunity for convection development increases, as the separate fires meet.

From observation, it is estimated that ARN coupes, at the fuel dryness and arrangement specified will require much less lighting than broadcast burning. For this reason, it is recommended that the GPS tracking of lighting lines is routinely used as a training and evaluation tool for all future helitorch operations.

Case studies from the 2007 burning season

The burning of four VR coupes during March and April of 2007 was monitored. The results support a burning strategy which aims to avoid convection by lighting dry fuel, late in the day with a rising relative humidity.

EP081B

This coupe of 45 hectares is located south west of Dover, in the Huon District (48770E 521300N). The design does not favour the type of burning which will offer the best chance of preserving aggregates. Those aggregates on the western side of the coupe are less than a hectare in area, located on rocky knolls near the top of a ridge. A large, centrally-located swamp effectively divides the coupe into two sections, with two larger aggregates and another small clump of trees in the eastern half. A corridor, approximately 60 metres wide, along the northern boundary links the two sections and provides an opportunity to compare 'fairway' burning with the more conventional shapes presented by the two main parts.

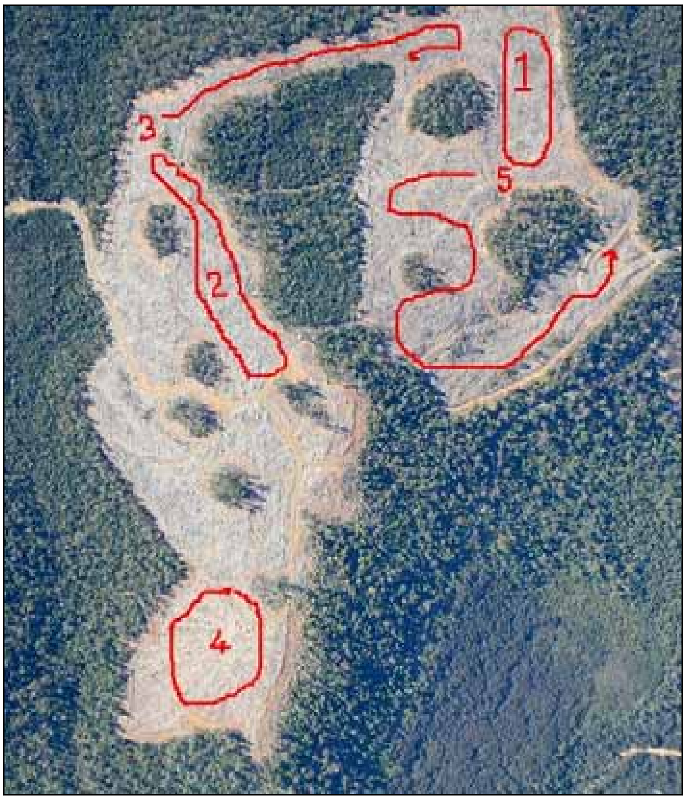

Photo 8: Aerial view of EP081B showing lighting sequence.

Very dry conditions prevailed throughout the summer and early autumn, with below average rainfall being recorded for the Dover area, (43% of average for March). The Soil Dryness Index for EP081B, interpolated between Dover and Hastings, was 70 mm on March 26th, when the coupe was burnt, indicating that the large diameter fuels were dry. In Table 1 below, the weather and fuel dryness recorded on the burning day indicates that conditions were close to ideal for a burn of this type, with fine fuels dry enough to kindle the heavy fuel component and a high RH being maintained over the coupe by a moist south easterly airstream. Following 5.6 mm of rainfall in the previous week, the FFMI sticks in the uncut forest were too wet to properly record with the standard field scales which weigh only to 25% moisture level. The aggregate FFMI sticks were located in an exposed ridge top clump of trees.

Table 1. Weather and fuel dryness for EP081B on March 26th 2007.

Time	Dry Bulb	Wet Bulb	RH	Wind	Open Sticks	Aggregate Sticks
1230	16	12	63	0-5 E	15	23
1300	16	12	63	0-5 E	14	
1330	15	11	62	0		
1400	15	11	62	0	13	22
1415	16	12	63	0		
1430	15	11.5	67	0		
1445	15	11.5	67	0-7 SE		
1530	13	10.5	74	<5 SE	12.5	
1600	12	10	69		13	

The lighting of the coupe commenced at 1430 in section 1. A widely spaced lighting pattern was employed, taking about 15 minutes to complete.

This was followed by limited ridge top lighting in section 2 and lighting of the northern corridor (3) with a single line of ignition. With a rising RH (74%), a steep section of cable harvesting in the southern part of the coupe (4) was lit at 1530. This produced an intense but localised fire which did not influence the sections already alight and at 1600 it was noted that discrete fires were spreading slowly in the different sections of the coupe which could be seen from the observation point and separate small columns were observed above areas of most intense fire activity. The fire in the western half spread down-slope overnight, burning through all the small ridge top aggregates. The remaining section of the coupe (5) was burnt on March 27th.

The burning of this coupe confirmed that development of convection can be retarded by using an appropriate lighting pattern and that a rising RH has a moderating effect on fire behaviour, as observed in section 4. It also showed that dry heavy fuels are necessary for burning to be effective in these conditions, allowing fuels to continue to burn out under mild conditions overnight. The benefits of this are offset by the increased risk of escapes if the surrounding forest is also dry or there is a risk of severe fire weather occurring some time after the burn when the edges are still smouldering. During this burn, the surrounding uncut forest was significantly wetter than the exposed coupe fuels.


Photo 9. Aggregate burnt by overnight fire, EP081B.

SX018E

This coupe of 30 hectares is located south-east of Maydena in the Derwent District (478283E 5258858N).

The design of this coupe was better for ARN burning than EP081B, with larger retained aggregates and more fairway-style corridors around the perimeter. However, a large centrally-located ‘football field’ of dense fuel and large bark heaps would cause a centralised convection if lit intensely. This coupe had sections of well-prepared fuel and some raked, rather than constructed, firebreaks.

A Soil Dryness Index on March 27th of about 80 mm indicated that heavy fuels were dry. In this regard SX018E was similar to EP081B described previously.

Conditions were close to ideal, with a consistent north-easterly wind under 10 kph at tree top level, falling away to a calm afternoon. A stable relative humidity of 49% was maintained until late in the afternoon. Exposed fine fuel dryness peaked at 11.5% with shaded fine fuel at 16%. Normally, this would be considered too dry for safe burning but it was noted that the shaded FFMI sticks had been located only 30 metres from the forest boundary and were drier than litter at the recommended distance of 60 metres from the forest boundary. It was estimated that this edge effect had reduced the equivalent shaded fine fuel moisture by about 2%.

The aggregate FFMI sticks were placed in a small, centrally-located patch of forest, shown by the red arrow in Photo 10. The sticks indicated a drying rate of about half that of the exposed fuels, over the three hours from noon. The top soil was dry, confirming the locally high Soil Dryness Index. A final recording of fine fuel dryness of 14% in the aggregate at 1500 indicated that the aerial fuels within the aggregate were likely to burn. Lighting commenced at 1730, as the RH rose from 49% to 63%.

Photo 10: Coupe SX018E.

Table 2: Weather and fuel dryness for SX018E on March 27th 2007.

Time	Dry Bulb	Wet Bulb	RH	Wind Speed	Wind Directn	Open Sticks	Aggregate Sticks	Shade Sticks
1200	17	12	56	<5	NE	14	15	
1230	18	12	49	<5	NE	14		
1430	17	11	48	5-10	NE	11.5		17*
1500	18	12	49	5-10	NE	11.5	14^	
1530	18	12	49	<5	NE	11.5		16*
1600	18	12	49	<5	NE	11.5		
1700	18	12	49	<5	NE	11.5		
1730#	16	12	63	0				16*
1740	16	12	63	0		11.5		
1800	17	12	56	0				
1820						12		
1840	15	12	71					

= Light up time Shade surface litter moist (50m inside topsoil dry)
* = Shade sticks only 30 metres from edge & not representative of inner dryness add approx 2%
^ = aggregate surface litter damp topsoil dry

The increase in relative humidity coincided with a 2°C drop in temperature, as the sun went below the tree line. The central ‘football field’ was lit initially (1), followed by a single pass lighting pattern along the ‘fairways’ (2) and then edge lighting.

At first, the fire appeared to develop convection driven behaviour over the ‘football field’, where the initial lighting of bark heaps was more intense, but the southern section was soon influenced by a north-easterly drift and a convection wind funnelling down the main access road. By 1840, the RH had risen to 71%, but convection winds were gusting to 21 kph from the north east, blowing sparks into the surrounding forest.

Subsequent inspection revealed that the small central aggregate had been burnt through with a surface fire as predicted and that other aggregates had been affected by fire to various degrees. Fires had also crossed the coupe boundary in several locations on the southern and western perimeters. These had progressed only 10 to 20 metres before self extinguishing.

Photo 11: Aerial view at about 1830 shows sections of SX018E burning as separate fires. (Eddie Willis)

This coupe demonstrated several points:

- small centrally located aggregates less than 1 hectare are too prone to drying out to avoid being burnt by surrounding fire,

- the efficacy of aerial lighting, which can take advantage of a precise ‘window’ of optimal fuel dryness, compared with the hours required for hand lighting,

- the need to avoid creating large open areas of fuel, where multiple ignitions will cause convection effects,

- the need to limit the amount of lighting and number of passes to a level below even that being currently used,

- the effect of high RH in preventing spot fires, with wind up to 20 kph,

- the effect of overnight fine fuel wetting, which caused most perimeter fires in forest to self extinguish only 10 – 20 metres from the boundary, and

- a significant suppression force had to be deployed to protect a small reserve, adjacent to the southern boundary.

Photo 12: Central aggregate where fine fuel moisture content (FFMC) prior to burning was 14% - this was the most severely burnt aggregate.

Photo 13: Narrow fairway showing minimal edge impact by fire.

AR023E

This coupe of 50 hectares is located north west of Geeveston in the Huon District (485383E 5222709N). It is comparable with SX018E, being tall E. regnans mixed forest but at a lower elevation and on a drier site. The design was remarkably similar to SX018E, with a number of small aggregates around the perimeter and a large ‘football field’ of slash, centrally located around a landing complex.

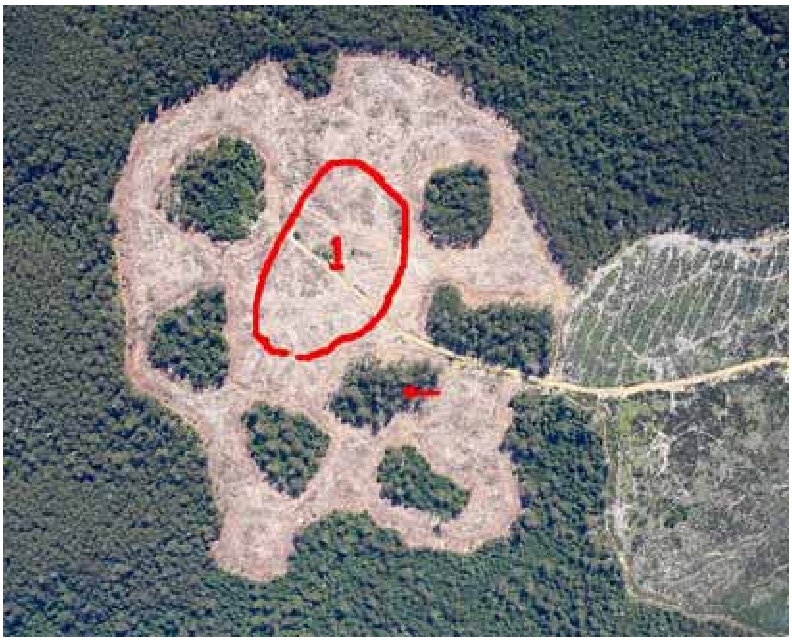

Photo 14: Aerial view of AR023E.

The coupe was burnt on April 9th 2007. The SDI was 93 for the nearest station at Geeveston and estimated to be slightly lower at the coupe, about 10 kilometres further inland.

Between March 26th and April 2nd, the coupe had received a significant rainfall of 33 mm and a further 1.4 mm between April 2nd and April 8th.

At 1030 on April 9th, the fine fuel on the coupe was damp (17%) with the effects of heavy dew. The litter in the surrounding forest was also damp (21.5%) and FFMI sticks in a small aggregate were 20% at 1145, although the topsoil was noted as 'dry', confirming a high SDI and the potential for the dewfall dampness to dissipate quickly during the day.

Table 3: Weather and fuel dryness for AR023E on April 9th 2007.

Time	Dry Bulb	Wet Bulb	RH %	Wind Kph	Open Sticks	Aggregate Sticks
1030	12.8		88.7	3.5 NNW	17	
1145						20
1200	16		76			
1230	18		65			
1240	19		66	10-15 W	14	
1300	20		59		13.5	
1315	21		53			
1415	22		47			
1430	22		47	30 W		
1500	24		44			
1645	21		53			

As expected, fuels dried out throughout the morning under the influence of rising air temperature, falling relative humidity and a fluctuating north-westerly wind. The decision was made to light the coupe at 1240 on the basis that conditions were within prescribed limits (at the limit for the 10 m wind) and there was concern that winds would be likely to strengthen later in the day ahead of a predicted front, which might bring further rain and end any hope of burning this coupe in the current season.

This was a reasonable assumption, given the time of year. It was considered that the dampness of the surrounding forest would hold the fire in the event that the wind increased during the afternoon. Making the decision to burn in less than ideal conditions is a common dilemma for forest mangers attempting to complete large burning programs before a season ends. It is something which must be factored into the planning requirements for specialist operations, such as ARN burning, when ideal conditions will be the exception rather than the norm.

The burning plan specified that the central cleared area (1) would be lit first as a high intensity burn and allowed to die down, before strip lighting around the aggregates – a similar strategy to that employed at SX018E.

Seen from the ground, the lighting of the initial stage was very intense. Certainly, the amount of ignition along the flight lines was excessive. The fine fuels were still in a drying cycle and had reached 14% at the time of lighting, falling a further 0.5 % in the next 20 minutes. The effect on the ground became apparent within that time as the ambient 10 -15 kph westerly flow was initially overpowered for a short period by strong convective winds in the opposite direction. Fifteen minutes after lighting, it was observed that the perimeter fire was again under the influence of a strengthening westerly wind and impacting on the eastern boundary. Fire storms were observed.

The relative humidity continued to fall during the afternoon, reaching its lowest point of 44% at 1500, by which time the prevailing westerly wind had again become dominant, gusting to 30 kph. Crown fires were observed in the eastern aggregates and spot fires were starting in the adjacent eucalypt plantation. At the same time, an aerial observer noted that fuels which had not been lit on the western side of the coupe, around the aggregates were still unburnt. This indicates the strength of the wind, initially convective and then ambient, which was pushing the fire away from fuel which might otherwise have burnt.

Photo 15: AR023E April 9th 2007, 1326.

A subsequent inspection of AR023E on April 12th revealed that three small aggregates on the eastern side of the coupe and closest to the 'football field' of high intensity burning had been burnt through with severe scorching to 60 m on the mature trees. Aggregates on the western side were least affected although a small section of the coupe not burnt in the main fire was lit the following day, and subsequently burnt into the adjacent aggregate, which would have been much drier as a consequence of the drying effects from the previous day's burning.

Photo 16: Western aggregate where the fine fuel moisture indicator (FFMI) sticks were 20%, 1 hour before the adjacent area was lit.

This coupe confirms several key observations:

- Planning of the burning of VR coupes, particularly those containing small aggregates should not incorporate conventional convection burning in the burning strategy.

- Burning late in the day is preferable, as the onset of milder evening conditions will moderate fire behaviour.

- Over-lighting of dry fuel leads to unnecessarily intense fires, with the potential for escapes.

- The ambient 10 metre wind should be less than 5 kph (Beaufort 1) for VR burning.

- Dewfall can cause FFMI sticks to give deceptively high readings early in the day. Stick readings should always be considered along with other factors, particularly the lower litter layer and top soil dryness.

SX04B

This coupe is included as it provides further evidence in support of the burning strategies and prescriptions which have been proposed.

The 18 ha coupe lies south west from Maydena and north of the Jubilee Range and the World Heritage area (WHA) (478283E 5258854N). The harvesting boundary borders the highly flammable button grass vegetation type which runs directly into the WHA. This coupe was considered too high a risk for the burning strategy applicable to VR coupes and a decision was made to burn it as a conventional convection burn, without attempting to preserve the aggregates.

On April 4th 2007, data from the AWS established in the coupe showed that 11.5 mm of rain had fallen in the previous fortnight. At 1200 the FFMI sticks in the coupe were showing 20% FFM while in the adjacent forest it was off the scale at more than 25%.

Over the next 10 days, only 1.1 mm of rain was recorded so by of April 14th, the coupe was very dry. The Soil Dryness Index at Maydena was then 125 mm.

A single FFMI stick reading in the open was 7.5% at 1420 while the reading in the surrounding forest was over 25%. The automatic weather station, which was located about 500 m south of the burn, recorded a steady decline in relative humidity from 91.7% at 0900 to an incredibly dry 26.8% at 1500. It should be noted that readings taken by observers at the burn site, using whirling psychrometers (WP), recorded 35% at 1455. This suggests that the AWS' relative humidity sensor was under-recording. Treating the AWS record as a trend indicator only, shows that there was a significant decline in relative humidity over the 6 hours to 1500. It is reasonable to assume that there was a corresponding reduction in FFMC.

By 1630 the relative humidity on the coupe had risen to 43% (WP) and 64% (WP) by 1648. Lighting by helicopter of the central landing area commenced at 1645 in virtually calm conditions. The FFMC at the time of lighting was still an incredibly low 7.5%, 2 hours 25 minutes after the first recording (R. Hill pers.comm.). The relative humidity in the meantime had increased by 27%. The reading of 7.5% FFMC is questionable. It should be noted that this indicator was first placed in the field on February 7th and had been exposed for 10 weeks prior to the burn. It was well beyond the recommended usage time of about 4 weeks and had probably weathered to such an extent that it was unreliable. The relative humidity figure is however, consistent with the abnormal fuel dryness for this time of year.

There is no doubt that the very high FFMC in the surrounding uncut forest and presumably the inner parts of the aggregates helped to preserve them from burning. These conditions would be exceptional in most burning years.

Photo 17: Aerial view of SX04B showing lighting sequence

Table 4: weather and fuel dryness for SX04B on April 14th 2007.

Time	Dry Bulb	Wet Bulb	RH %	Wind Kph	Open Sticks	Aggregate Sticks
1420	21	12.5	36	0	7.5	>25
1435	22	14	41	Light & V	7.5	>25
1455	22.5	13.5	35	0		
1510	18	11	42	0		
1530	17.5	10.5	39			
1545	21	13	39	2.7		
1600	20	12	38	<1		
1615			41	<1		
1630	19	12	43	<1		
1648	16.5	12.5	64	<1		

Fire observation notes indicate that an intense fire developed around large bark heaps in the vicinity of the landing: “1655 diffuse brown smoke; 1658 fire drawing to centre; 1712 central landing well alight, fire drawing in from all edges, sun low and off the coupe.”

Less than half an hour later, it was noted that, in the absence of sun and with the relative humidity at 60% (WP) “fire spread slowed considerably”.

It is significant that with the fuels being so dry, fire activity actually moderated at this time and subsequently other sections of the coupe were lit but very conservatively and with spot ignitions, rather than lines of fire (R.Hill pers. comm.). Burning continued with supplementary hand lighting until 1900 when the relative humidity was recorded at 68% (WP).

The coupe was inspected four days after burning with 7.4 mm of rain having fallen in the intervening period. The results were surprisingly good, with only the smallest aggregates severely burnt and others having various levels of edge penetration and scorch.

Photo 18. Post burn view of SX04B.

This coupe confirms several key observations:

- Burning late in the day can be successful if the fuels are dry enough to light, even as fine fuel wetting is in progress.

- Fire activity is moderated by rising relative humidity, even when the relative humidity is low to begin with.

- Spot lighting can be a useful alternative to traditional strip ignition.

- Night burning with hand lighting may extend the opportunity for variable retention burning in some circumstances.

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