Background briefings on emerging issues for fire managers from AFAC and Bushfire CRC.

FIRE NOTE

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ASSESSING AERIAL SUPPRESSION DROP EFFECTIVENESS

Aerial suppression can be an important part of bushfire containment operations. It requires significant logistical support and can be expensive. It is important that aerial suppression drops are carried out in a safe and effective manner. The purpose of this Fire Note is to outline key criteria for assessing aerial suppression drops so that this can be achieved.

There are a large number of factors that influence the effectiveness of aerial suppression operations. These vary considerably depending on the conditions and resources available for a particular fire. This Fire Note concentrates on the main considerations for assessing single and multiple linked drops, which are: placement; coverage; and effect on fire behaviour. These aspects need to be considered in relation to the suppressant agents being used, the fire fighting tactics and strategies being employed, and the aircraft and delivery systems that are available. These issues are discussed in detail in this document and are used as the key topics in the list of considerations for drop assessment.

Aerial suppression drops should be directed in a way that is consistent with the overall fire fighting strategy. In nearly all cases, aerial suppression drops are of limited value without timely follow up from ground suppression resources. Unsupported drops that are quickly burnt around or spotted over are ineffective and will have a very limited influence on slowing the fire. Suppressant drops are often used to knock down flames ahead of ground resources that follow behind extinguishing residual flames and mopping up. This tactic can enable faster rates

ABOUT THIS PROJECT

Bushfire CRC Project A3.1 – Evaluation of Air Suppression Techniques and Guidelines.

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MAJOR CONSIDERATIONS FOR DROP ASSESSMENT

PLACEMENT

- On target — Yes → was this the most appropriate target?
  No → what is the likely reason for poor placement? (e.g. wind, visibility etc)
- Is the drop anchored and well linked?

COVERAGE

- Did the drop penetrate through the canopy and into fuels?
- Is there adequate coating of surface and near surface fuel layers?
- Are there gaps in the coverage?
- Is there enough coverage between linked drops?
- If the answer to any of these questions is no, provide a reason

EFFECTS ON FIRE BEHAVIOUR

- Is there a significant reduction in fire activity?
- Is the post-drop fire behaviour reduced to the level required?
- Is the drop holding? — Yes → monitor and note the duration
  No → Give reason(s) why (e.g. spotting, burn around, burn through)

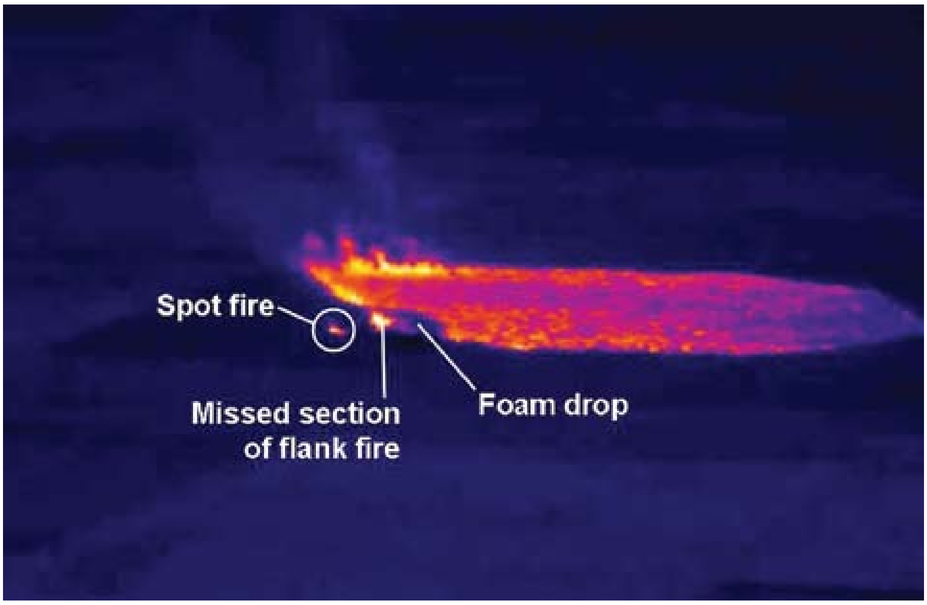
of line construction than either resource type working alone and may allow ground crews to work on sections of fire edge that would be too intense for them to safely suppress alone, though they should not rely on aircraft for safety. In the absence of ground crews, drops may slow fire spread but will not stop it. Aerial suppression cannot provide the detailed attention required to mop up burning and smouldering fuels, which can cause containment lines to fail. This task can only be achieved from the ground.

UNDERTAKING A DROP ASSESSMENT

A drop assessment needs to consider the drop objectives and whether it is part of a direct or indirect tactic. The objective for a drop may be to slow or stop fire spread, or reduce fire intensity for ground crews. The tactics used to achieve the objectives should be compatible with those being used by other resources.

Suppression drops are best assessed on the ground. This allows for detailed observation and monitoring at the site of impact. Drop assessment from aircraft is limited, especially when there is a canopy present, because drop areas can be difficult to identify and close inspection of the drop areas is usually not possible. Infrared cameras, which allow fire to be seen through smoke and light canopies, can greatly assist evaluation of drops. Some infrared images from the Project FuSE aerial suppression experiments are used as examples here.

Ground crews can advise when drops are being ineffective or could be improved. However ground observers need to be aware of hazards, such as falling limbs and slippery ground when working in and around drop areas and should be away from the drop area as it impacts. It is not always possible to get drops assessed at ground level, as crews may not be available or conditions may not be safe for drop areas to be accessed. Air operations need to be clear when communicating requests for information. Ground crews should clearly describe the location, drop time, and aircraft responsible as well as other drop effects including limb dislodgement and adverse rotor wash effects when relaying information on drop effectiveness.



▲ **Figure 1:** Infrared image of a misplaced foam drop, Project FuSE Aerial Suppression Experiments. A section of flank fire and a spot fire are located in front of the drop. This drop had a very minimal effect on slowing that section of fire edge and was therefore ineffective.

FURTHER READING

Plucinski M., Gould J., McCarthy G., Hollis J. (2007) *The Effectiveness and Efficiency of Aerial Firefighting in Australia*, Part 1. Bushfire Cooperative Research Centre, Australia. Report A.07.01.

MAIN CONSIDERATIONS

1) Drop placement

During assessment, drop placement should be considered both in terms of the intended target and the best target. If the intended target is not the best place for a drop the reasons for this should be relayed to air operations personnel and pilots. Drops may not reach their intended target if they are affected by unexpected wind drift, made in poor visibility conditions, or have been dropped from too high due to difficult terrain.

Suppressant drops

The location of the drop with respect to the fire edge is critical for direct attack. Direct attack drops should have their area of highest coverage impact along the intended section of fire edge. Suppressant drops that land in areas that are already burnt are wasted (Figure 1, above).

Suppressant drops that land ahead of the fire in unburned fuels may eventually slow the fire, but have a high risk of being burnt around or spotted over when the fire reaches them.

The placement of suppressant drops should be part of the overall strategy for the fire, with sequences of drops linked together and with breaks in the fuel. Fire will spread through gaps between drops and areas of light coverage.

Retardant drops

Retardant drops are normally laid ahead of fires with the intention of stopping their spread or protecting assets in their path. They are often laid in areas with limited ground access. The placement of retardant drops also benefit from alignment with and anchorage to existing features. Retardant is often laid in lines of multiple drops. These need to have a consistent coverage along their whole length (Figure 2, next page).

SUPPRESSION CHEMICALS

Most aerial suppression drops contain chemical additives. Drops containing only water are occasionally used for direct attack, particularly when fires are near waterways or there are concerns about the environmental impacts of chemicals.

Suppression chemical additives can make drops more effective. They fit into three classes: foam surfactants, water enhancers and long term retardants. Foam surfactants and water enhancers are primarily designed for direct attack and are only effective while wet. These are termed suppressants and are sometimes called short term retardants. Foams aid the wetting of fuels by lowering the surface tension of the water and assisting saturation. The proportion of foam concentrate in aerial suppression drops has a large influence on the drop characteristics and the ability to penetrate through dense canopies. Water enhancing gels contain substances that slow evaporation and increase adherence to fuels. Gels are currently being trialled in some parts of Australia, and are coloured with a blue dye.

Long-term retardants are designed to be laid ahead of the fire as they remain effective after the water they originally contained has evaporated. They are usually coloured red. Retardants work by inhibiting flaming combustion.

2) Drop coverage

Assessors need to determine if there is a sufficient amount of suppressant or retardant reaching the fuels. Coverage levels will vary across drop patterns. The highest coverage level is usually located in the centre of the drop, with areas of lighter coverage surrounding. The coverage level required to extinguish flames increases with fuel load and fire intensity. High intensity fires burning in heavy fuels may require coverage levels beyond what can be delivered with even the largest aircraft. Drops on such fires will only temporarily subdue flames.

It is important that drops coat fuels on and just above the ground and penetrate them. It is also important that a consistent coverage is achieved within the drop and where drops overlap. Breaks in coverage can be caused by shadowing from overlying vegetation and other obstacles such as logs and rocks (Figure 3, below right). Generally, drops that rain down vertically are less affected by shadowing. To achieve this, drops need to be made at a height that allows the drop mass to lose forward momentum at or above the top of the canopy. A disadvantage of this is that drops may be exposed to wind drift and may have a wider footprint with a lower coverage level. Drops made during peaks of fire activity are particularly prone to this problem. When possible, drops of retardant for strategic lines ahead of the fire edge should be made at times when wind speeds are low.

The ability of a drop to penetrate a canopy can be affected by its viscosity and surface tension. Thick or highly viscous mixes of suppressants

AIRCRAFT AND DELIVERY SYSTEMS

A large range of aircraft and delivery systems are used for aerial suppression in Australia. These have evolved through operational experience and are selected for a range of reasons including cost, carrying capacity, ability to access water, travelling speed and drop patterns. Not all suppression chemicals can be used in all delivery systems. Drop patterns are influenced by a number of properties related to aircraft and delivery systems. Crucial factors include the speed and height of the drop and environmental variables, such as wind speed and canopy interception. The most important attributes of drop patterns are coverage levels on surface fuels and the consistency and dimensions. Different levels of coverage are required for different fuel types and fire intensities.

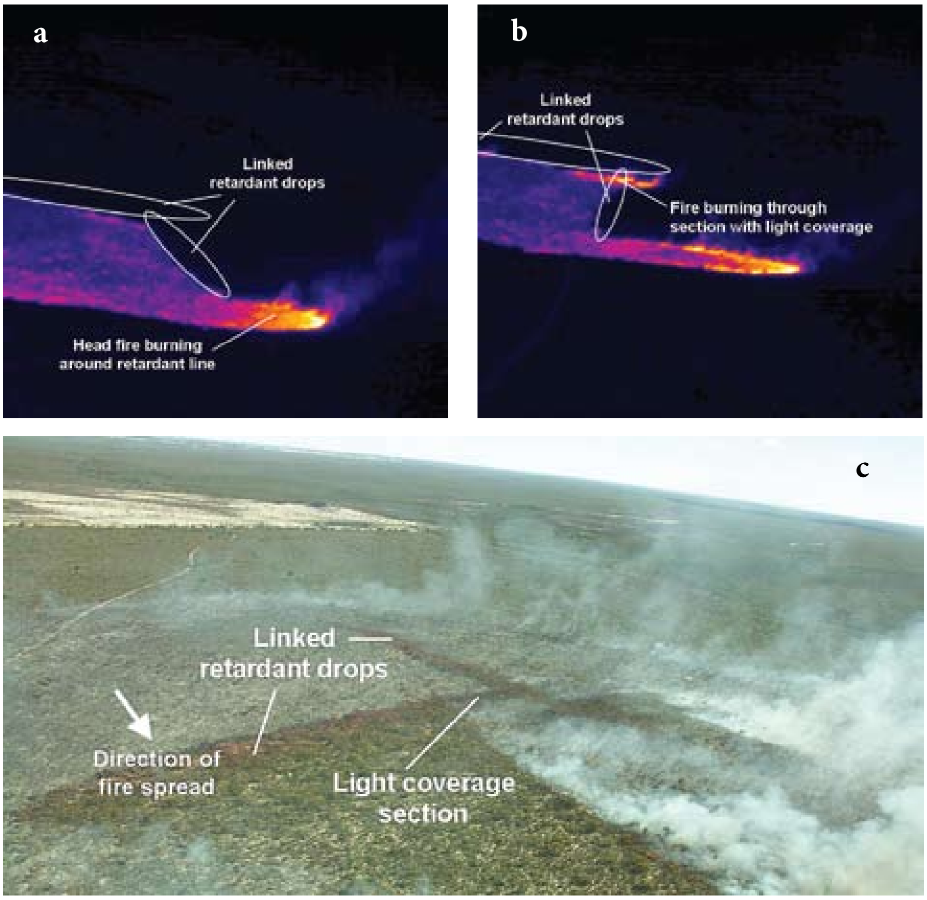


Figure 2: Sequence showing fire burning through section of light retardant coverage from the Project FuSE Aerial Suppression Experiments. a) Fire holding on retardant line and burning around one end. b) Fire burning through section of light coverage in retardant drop. c) The resulting burn pattern.

Figure 3: This retardant drop held the fire despite being penetrated in some sections that were shadowed by the trees. Drops can be breached by fires trickling through sections of light coverage like this.

END USER STATEMENT

"Accurate assessment of drops is absolutely fundamental to ensuring that aerial firefighting resources are used effectively and that fire agencies are properly accountable for the delivery of a vital but high-cost, highly specialised capability. Consistent, accurate drop assessment will ensure that collectively we can continue to improve the efficiency and effectiveness of aerial firefighting. As well as providing a valuable consolidation of relevant information, this work represents a very significant advance on the topic and provides a solid foundation for more rigorous approaches to assessing drop effectiveness and improving performance."

– Richard Alder, General Manager, National Aerial Firefighting Centre Ltd

▲ **Figure 4:** High foam concentration drop adhering to a tree canopy. Drops like this will not penetrate thick canopies.

and retardants hold together well when dropping and are more resistant to wind drift. However, they have a high adherence to the canopy and limit the proportion of the drop that drips through. Such drops may also have difficulty penetrating into litter layers. Similarly, foam drops with high proportions of foam concentrate (>0.04%) may adhere to canopies due to the high surface tension (Figure 4, above). High concentration foam drops also mix with air when dropping and are more prone to wind drift.

The table (above right) outlines some of the compromises that should be considered when balancing drop coverage and effectiveness. The effects listed are generic and the range of the effects will vary depending on products and delivery systems. Finding an optimal balance between these effects may require some assessment of effect and adjustments within a given operation.

3) Effects on fire behaviour

The ultimate test of drop effectiveness is the effect on fire behaviour. The best way of assessing this is to compare pre- and post-drop fire behaviour (Figure 5, above right) and determine how long the drop impedes fire spread. When drops are breached the reasons should be investigated and fed back to those determining the tactics.

Drop success depends on the availability of ground suppression support. If ground crews are present, drops may only need to reduce fire behaviour to manageable levels to be effective. If ground support is delayed, then drops need to hold fire spread until ground resources arrive.

There are three causes of drop failure: spotting; burn around; or burn through. Drops can be breached by more than one of these causes.

Embers that carry for distances greater than the effective drop width will prevent the drop from holding fire spread. If the density of spot fires beyond the drop is high, or spots develop quickly, then drop effectiveness is greatly reduced.

Drops can be burnt around if there is a problem with their placement. This can occur when turnaround times are too slow for the rate of perimeter growth. Such a result should prompt a revision of tactics.

If drops are burnt through then their coverage may be inadequate for the fire intensity and hold time required. All suppressant drops are at risk of eventually being burnt through, as the duration of their effectiveness is always determined by the rate of evaporation of their water content. For this reason, when possible, the duration of drop holding time should be estimated for suppression drops that are burnt through.

BALANCING DROP COVERAGE AND EFFECTIVENESS

	Too high	Too low
Drop height	More prone to wind drift	Intercept canopy at an angle resulting in shadowing
Foam concentration	More prone to wind drift Low penetration of canopies and fuel layers	Low adherence to fuels
Retardant / gel viscosity	Low penetration of canopies and fuel layers	More prone to wind drift Lower concentration of retardant salts

▲ **Figure 5:** The effect of a direct suppressant drop on fire behaviour as indicated by pre (a) and post drop (b) images taken during the Project FuSE Aerial Suppression experiments. Flames that were up to 2 metres were knocked down to less than half a metre and extinguished in some places. Although this drop had a large influence on this section of fire perimeter, it was not anchored and the fire quickly burnt around it, making it ineffective.

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