



PROGRAM A: SAFE PREVENTION, PREPARATION AND SUPPRESSION OF BUSHFIRES

# THE EFFECTIVENESS AND EFFICIENCY OF AERIAL FIREFIGHTING IN AUSTRALIA PART 1

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# The Effectiveness of Aerial Firefighting in Australia

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## Executive Summary

- The aim of fire suppression is to minimise impacts from unwanted bushfire. Fire suppression resources include: ground personnel, incident management teams and technology (hand tools, ground transport, heavy equipment and aircraft). Ground personnel are the essential ingredient with technology offering options to increase their suppression capacity.
- The factors influencing the effectiveness of aerial firefighting include fire intensity, fuel characteristics, fire perimeter, aircraft specification and productivity.

Aircraft offer three major advantages over ground suppression resources; speed; access; and observation. These have been used to develop current aerial firefighting strategies and have led to the general consensus that the most effective use of aircraft is rapid attack on fires in their incipient stages.

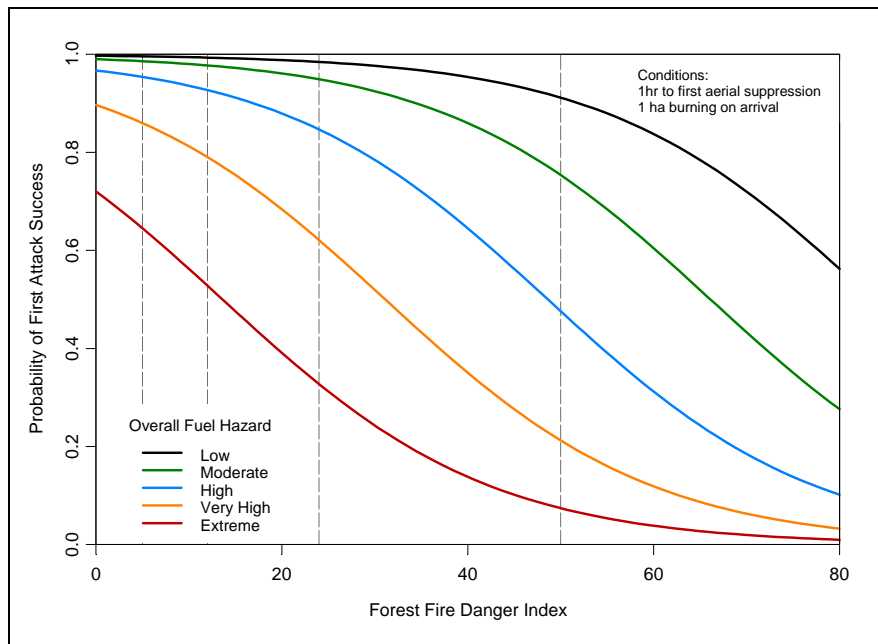
Listed below is a summary of findings and comments based on the suppression operational research data collected during the 2004/05 and 2005/06 fire seasons from state and territory rural fire and land management agencies in Australia and New Zealand and the current best practice from the literature.

- Data were collected from 284 fires that used aerial suppression. There were 76 and 32 fire reports from forest and grass fires respectively that were suitable for detailed analysis for this report. The forest fire dataset was suitable for limited statistical analysis. There were insufficient data to fully examine the effectiveness of aerial suppression on different fire intensities and in different fuel types. The collection of operational data will continue over subsequent fire seasons and researchers will continue follow up to complete data records.
- The operational data were analysed to determine parameters for predicting the probability of first attack success. In this study *first attack success* is defined as fire containment within 8 hours of detection. Area burning at time of arrival of first resources, forest fire danger index, time to first air attack and overall fuel hazard score were statistically significant on influencing the success of first attack.
- Interpreting probabilities can be difficult. The descriptions defined by Pollack<sup>1</sup> were used here:
  - <1% - extremely unlikely
  - 1 to 10% - little chance or very unlikely
  - 10 to 33% - some chance or unlikely
  - 33 to 66% - medium chance
  - 66-90% - likely or probable
  - 90-99% very likely
  - >99% virtual certainty.
- An example of the results from the analysis of operational data is illustrated in the chart below. This chart shows the probability of first attack success by forest fire danger index (FFDI) for different overall fuel hazard scores, if aircraft begin fire bombing on a 1 hectare fire an hour after detection. Up to FFDI 24 (HIGH) the probability of first attack success is likely to very likely when fuel hazard score is in the low, medium and high classes. Compared to long unburnt fuels of extreme overall fuel hazard score the probability of first attack success ranges from fair (medium likelihood) to some chance of

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<sup>1</sup> Pollack, H. N. 2003. *Uncertain Science...Uncertain World*. Cambridge University Press. 256 pp.

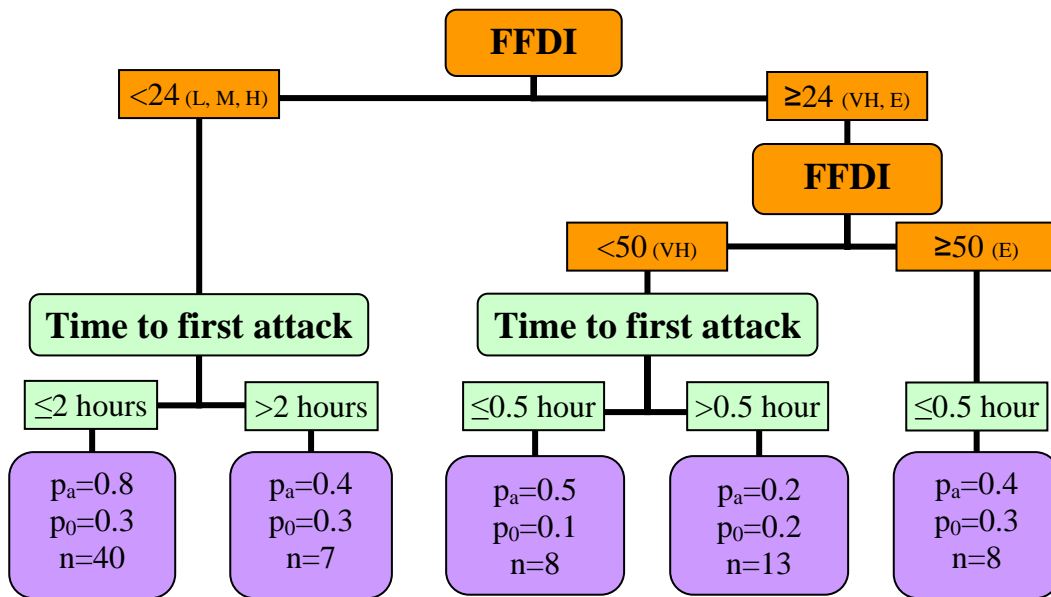
success. The probability of first attack success decreases as the FFDI and fuel hazard increases.



### The effect of overall fuel hazard and FFDI on predicted first attack success.

- The trends from this study show that aerial suppression alone is not sufficient to improve effective suppression and a combination of fuel management, ground crew support and aerial firefighting resources are all significant in increasing the probability of first attack success.
- Regression tree analysis and grouping data by forest fire danger classes and time to first attack (first resource on the fireline) was done to determine the probability of first attack success and to build the decision tree (shown below). If FFDI is in the low, moderate or high classes and arrival time to first attack is less than 2 hours the probability of first attack success is likely to very likely with aerial suppression support ( $p_a=0.8$ ) and unlikely without aerial suppression support ( $p_o=0.3$ ). If the FFDI is in the very high class the aerial suppression support provides medium likelihood ( $p_a=0.5$ ) but without aerial support there little chance of first attack success if arrival time is less than half an hour ( $p_o=0.1$ ).

The application of this decision tree can provide some general rules for determining the effect of aerial suppression on first attack of forest fires under different fire danger rating. However, because of the small dataset this is not a robust model. Additional information on fire behaviour and fuel conditions at the fire will improve the interpretation of the predicted probability of first attack success. The collection of additional data will enable the development of a better model accounting for other factors affecting first attack success.



$p_a$  = probability of first attack success with aerial suppression support  
 $p_o$  = probability of first attack success without aerial suppression support  
 $n$  = number of fires in each section

**Decision tree for defining first attack success using FFDI and time to first attack (any resources).**

- Aerial suppression can be effective in providing support to ground crews and improve the probability of first attack success by up to 50 percent or more if the FFDI is in the low, moderate and high classes. Aerial suppression can provide substantial support to the ground crews and increase the probability from little chance to medium likelihood when the FFDI is in the very high class and time to first attack is less than ½ hour.
- There were insufficient data to do detailed analysis on the effectiveness of aerial suppression on grass fires. The small dataset shows similar trends to the forest fires data with aerial suppression being most effective if time to first attack was less than ½ hour and grassland fire danger index was less than 20.
- The effectiveness of aerial fire suppression depends on many factors, including aircraft travel time, distance from fire, aircraft characteristics, drop characteristics, ambient conditions, availability of support ground resources, fire intensity, fire size, fuel type, pilot skill, suppressant agent used (retardant, foam or water) and organisational and infrastructure arrangements. Therefore, ‘for an aircraft to provide effective assistance’, it must be available at call, rapidly dispatched with minimal travel time, with logistical systems in place. Air operations effectively integrated into the incident management structure and competent personnel need to be available to direct the operation.
- This study has identified other factors which should be taken into account to determine the effectiveness of aerial firefighting. Additional data collection and further research is required to investigate these factors discussed below:
  - In this study there was very little data collected on aerial suppression providing direct property protection under very high to extreme fire weather conditions. There are a number of cases of anecdotal evidence that aerial suppression have saved homes.



- Aerial suppression and other use of aircraft have conveyed a very strong psychological message of “HOPE and CAN DO”. The use of aerial firefighting can be a morale boosting for the public and firefighters today, though these remain unproven.
- The data collected from the last two fire seasons is still limited for detailed analysis and the Bushfire CRC Aerial Suppression Evaluation Project (A3.1) will continue collection of operational data in collaboration with the state and territory fire agencies over the next two fire seasons.
- Operational assessment to identify the intensity of fires in different fuel types that can be contained by different suppression resources (i.e. ground, aerial) and different suppressant types was difficult due to access, personnel safety on the fire ground and other restrictions limiting the collection of scientific quality data from wildfires. Scientific quality data can be collected through field experiments. Field experiments are required to evaluate the effectiveness of different chemical suppressants (retardant, foam and gels) delivered by aerial and ground resources under a range of fire intensities and in different fuel types.
- Simulation models can be used for testing scenarios on resource types, combinations and locations. These models can provide an effective decision support system to help fire managers and planners to better determine the appropriate size, location, composition of suppression resources, as well as evaluate nationally shared aerial resource programs. Analytic scoping of existing resource allocation models should be investigated to determine if overseas models can be adapted to Australia suppression operations.

# 1. Introduction

## 1.1 Background

The role of aircraft in Australian firefighting operations has increased in prominence since the 1960s. In recent years it has received considerable attention from the national media, particularly when aircraft have been used on significant fires fringing metropolitan areas. In Australia the role of aircraft is now integrated within the overall task of managing wildfires. Supporting air fleets are comprised of both fixed wing (predominantly light agricultural planes and observational aircraft) and rotary wing aircraft (helicopters).

Recent severe fire seasons combined with increased media exposure have given rise to concerns regarding unrealistic community expectations and perceptions. While funding for aerial support and the popularity of large firebombing aircraft have increased dramatically, the question of how appropriate, useful and effective they are for fighting wildfires need to be clarified with scientific evidence.

This report documents the progress of work conducted by two Bushfire Cooperative Research Centre projects: (i) Part I: A3- Evaluation of suppression techniques and guidelines. This project was established to investigate the effectiveness and efficiency of suppression operations used on Australian bushfires, with its primary focus on aerial suppression effectiveness and efficiency.

Specific aims of the project include:

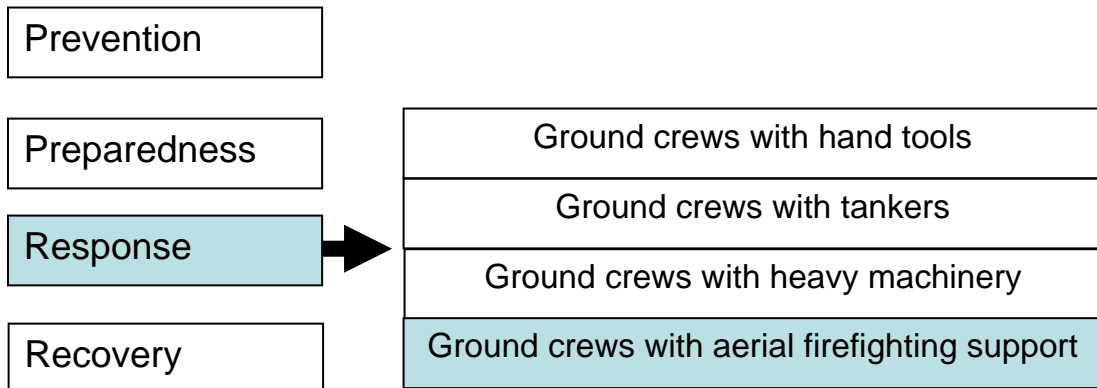
- To identify the intensity of fire in different fuel types that can be contained by different suppression resources (both ground and aerial).
- To define the rate of line construction (productivity) of different suppression resources and combination of suppression resources.
- To define the holding time of suppression lines, especially the holding time of aerial suppression drops (with different suppressants).

A number of inquiries were prompted by the severity of the 2002-03 fire season between May 2002 and April 2003, and its impacts (Ellis *et al.* 2005; Esplin *et al.* 2003; McLeod 2003; House of Representative Select Committee Report 2003). These inquiries made a number of recommendations related to firefighting resources and technology.

The four components of fire management (PPRR) as shown in Figure 1 are: Prevention (of bushfires), Preparedness (for Response), Response (also known as 'firefighting' or suppression) and Recovery (of fire damage).

These projects focus on the role of aircraft in "aerial firefighting". Therefore the areas highlighted in Figure 1 identify where firebombing aircraft can potentially play a role. In other capacities, apart from aerial suppression, aircraft can be used in prevention (e.g. fuel reduction, surveillance) and in preparedness (e.g. fire spotting, transport and patrolling).

## Fire Management



**Figure 1.** Four components of fire management Prevention, Preparedness, Response and Recovery.

Response is commonly referred to as ‘firefighting’, or fire ‘suppression’. The main objective of suppressing fires are firstly to stop fires from spreading and causing damage, and secondly to make them safe. Contrary to common belief, fires are rarely ‘put out’, but most often ‘secured’. The usual procedure is:

- Knocking down flames or reducing the fire progression and control of dangerous trees and vegetation likely to cause spot fires;
- Cutting off the extreme outer edges of the fire from access to new fuel by building a fireline (preferably to mineral earth), or extinguishing them;
- Extinguishing major fires in the interior of the fire perimeter;
- Mopping-up persistent fires, including smouldering hotspots in stumps and logs etc., along the outer edges of the fire perimeter.

Bushfire suppression activities aim to minimise the adverse impacts of wildfires on people, property and the environment. This is usually achieved by minimising the area burnt through aggressive early suppression activities. These are carried out in the early stages of fire development when the fire’s perimeter is small and the fire intensity is low. This aggressive first attack strategy maximises the likelihood of containment while minimising the area affected by fire and suppression costs (Parks 1964; Hirsch *et al.* 2004).

The rate at which bushfires accelerate and their intensity builds is highly variable and largely depends on the burning conditions including topography, fuel and weather particularly wind speed and direction (Cheney 1981). In their initial stages, bushfires will accelerate in their forward rate of spread and intensity until they reach a steady state. Having reached this steady state the average rate of spread remains constant relative to weather and fuel conditions (Cheney 1981).

In forest fires suppression efforts are most effective when initiated in the acceleration phase as up to 90 percent of the maximum rate of spread can be reached within the

first 30 minutes (Brown and Davis 1973; Luke and McArthur 1978; McAlpine and Wakimoto 1991). Grass fires can reach their steady state rate of spread within 12 minutes with longer acceleration phases occurring at higher wind speeds (Cheney and Gould 1995).

In order to halt the spread of fire and its growth, fire suppression activities focus on attacking the fire perimeter. Growing in proportion to the rate of spread, rapidly expanding fire perimeters are less likely to be quickly contained when their growth rates exceed line construction rates (Loane and Gould 1986). This is most evident in severe burning conditions such as those that occur during very high and extreme fire danger ratings.

First attack requires significant planning to maximise outcome success. Pre-attack planning is the process of collecting, evaluating and recording fire intelligence data in advance of fire occurrence. This aids decision-making and increases the chances of successful fire suppression during first attack. It also assists planning in large fire situations so that incident action plans are consistent with the fire management objectives for a given protection area (Alexander 2000).

## *1.2 Aerial suppression effectiveness*

The term ‘effectiveness’ as it relates to aerial suppression can be difficult to define and has received various interpretations and measures in previous studies. For example, Cumming (2004) defined effectiveness in terms of suppression outcomes as requiring ‘*only that burn rates with fire suppression be lower than they would have without it*’. This definition does not take into account the actual burn rates that were observed.

For the purposes of this project aerial suppression effectiveness is considered in two contexts: firstly, productivity and secondly, effect on fire behaviour (i.e. rate of spread, fireline intensity). Productivity is normally regarded in terms of line construction rates. Suppression effect on fire behaviour can consider fire intensity extinguished, fire progression slowed and suppression holding times. Cost efficiencies were not considered as part of aerial suppression effectiveness and is discussed in Section 6.

## *1.3 Aviation and bushfire suppression*

Combined aerial and ground suppression resources can form a suite of effective tools for agencies tasked with managing wildfires. Without ground crews and resources aircraft are limited in what they can achieve. They cannot perform all of the roles that are achievable with ground suppression resources. For example, rigorous mopping up can only be achieved by ground crews, as burning and smouldering fuels need to be fully extinguished or separated from unburnt fuels and left to burn out.

Aircraft offer three major advantages over ground suppression resources. These have been used to develop current aerial and ground firefighting strategies and include:

### **1. Speed**

Aircraft used for firefighting can travel at faster speeds than ground suppression resources and can also take a more direct path to a destination. This characteristic will often enable aircraft to reach a wildfire and begin suppression and/or observational activities before ground crews. Speed also enables aircraft to deliver greater quantities of suppressant to fires as they can often travel faster between the fires and nearby water sources.

## 2. Access

Aircraft are also capable of accessing remote areas, which ground suppression resources may only reach after unacceptably long travel times. Aircraft also have advantages where ground crew access is limited by safety concerns such as high fire intensity or falling limbs. This advantage is similar to that of speed, as fires that are difficult to access from the ground may still be accessed by aircraft relatively quickly. In situations where aircraft are able to reach the fire first, firebombing on fires of intensities up to  $3000\text{kW m}^{-1}$  can reduce intensity to a level where ground crews can safely work (Loane & Gould 1986). Even when flames are not completely knocked down by firebombing, this strategy can slow fire progression and buy time until ground crews can access the fire.

## 3. Observation

Aircraft are often used for detection and in observational roles during fire suppression activities as they are able to view the full extent of the fire conditions for access, fuel hazards and other potential hazards. This advantage has been used to develop the role of Air Observer (AOB) within the Incident Management System used by firefighting agencies. The AOB is responsible for obtaining and reporting accurate intelligence on fire activity and fire suppression effectiveness (NSW Rural Fire Service 2003; Department of Sustainability and Environment 2004). Collection and relay of information is not exclusive to this role. Sometimes important observations are relayed from firebombing pilots directly to ground crews. Occasionally aircraft have also been used to perform command and control services and to detect hotspots and spot fires.

### 1.4 *Types of aerial suppression resources*

In Australia there are four main types of aerial suppression resources. These aircraft are used for both attack and support in firefighting operations. Alder (1990) gave the following definitions for these roles:

**Attack** - tactical employment in direct suppression (e.g. firebombing, firefighter transport and aerial ignition);

**Support** - work that complements the direct suppression strategy (e.g. detection, intelligence gathering, reconnaissance, and command roles such as air attack supervision).

This report focuses on the work of attack roles, primarily suppressant bombing aircraft. Bombing aircraft working in attack roles normally deliver fire suppressants

including water, foam, gel and retardant<sup>2</sup>. Classifications for aircraft types have been agreed upon by all States and territories involved in the National Aerial Firefighting Centre (NAFC)<sup>3</sup>:

- Type 1 (Heavy) Helicopters - capacity >2650L
- Type 2 (Medium) Helicopters - capacity 1135 – 2649L
- Type 3 (Light) Helicopters - capacity 380 – 1134L
- Single Engine Air Tanker systems (SEATs) fixed wing firebombers

**Table 1. Firebombing aircraft types used in Australia**

| Type  | Roles  | Examples            | Lift Capacity (L) | Speed (km h <sup>-1</sup> ) |
|---|--|---------------------|-------------------|-----------------------------|
| Type 1 Helicopters (Heavy)                          | Firebombing, occasionally crew transport   | Erickson S64F,      | 9000              | 200                         |
|   |  | Bell 214B,          | 2900              | 200                         |
|   |  | Mil-8,              | 5000              | 240                         |
|   |  | Sikorsky S61        | 3000              | 200                         |
| Type 2 Helicopters (Medium)                         | Firebombing and remote area crew delivery (rappel/hover exit/ winch/ferry)   | Bell 204/205/212    | 1400              | 200                         |
|   |  | BK 117              | 1200              | 260                         |
| Type 3 Helicopters (Light)                          | Air attack supervision, firebombing, remote area crew delivery, reconnaissance, command & control, aerial ignition | Bell 206            | 400               | 205                         |
|   |  | Aerospatiale AS 350 | 500-1100          | 220                         |
|   |  | Hughes 500          | 400               | 250                         |
| Single Engine Air Tankers (fixed wing fire bombers) | Firebombing only   | PZL Dromader        | 2500              | 200                         |
|   |  | Air Tractor 802     | 3200              | 280                         |

There are two other firebombing aircraft types that are not used in Australia, large multi-engine fixed wing firebombers (e.g. Lockheed C 130, Douglas DC-6, Fokker F27) and water scooping aircraft (e.g. Canadair CL 215/415). These aircraft have been subject to trials in Australia with limited success.

<sup>2</sup> In this report retardant refers to long-term fire retardant chemicals that are mainly composed of ammonium-based phosphates and sulphates.

<sup>3</sup> National Aerial Firefighting Centre Standards PR001 and PR002 – adapted from USDA Forest Service.

### 1.5 Aircraft resource selection

The types of aircraft used for firefighting in Australia have typically been determined through experience. For example fixed wing firebombers have been found to be most suitable in situations where remoteness or lack of water dictates long turnaround times. Helicopters, by comparison, are most economical where turnaround times are short (<15 minutes) (Loane and Gould 1986; Alder 1990). There are many associated considerations when selecting the most appropriate aircraft for a given fire situation including:

- cost;
- capacity (e.g. larger capacity helicopters can deliver suppressant at more competitive rates than smaller ones in some situations - however they can also have exorbitant costs if not used effectively (Fogarty *et al.* 1998);
- airspeed (affecting response time and when combined with capacity determines productivity);
- coverage levels, drop patterns, and the ability to split loads;
- delivery system (e.g. flying restrictions in some areas limit the use of sling loads, while some water sources do not suit bellytanks);
- flying restrictions (e.g. some aircraft cannot fly in high winds);
- filling and airbase requirements (e.g. some aircraft require longer runways than are available, while others may require enlarged clearings);
- range and duration;
- logistical support requirements; and
- maintenance regimes.

There is often a trade off between these considerations. For example, cost may be a factor that limits the range of other selection criteria.

### 1.6 Fire suppressants and retardants

In Australia there are various suppression chemicals used for ground and aerial firefighting.

Suppressants, including water and Class A firefighting foams (e.g. *Phoschek WD881* and *Angus Forexpan S*)<sup>4</sup>, which are applied directly to flames to reduce fire spread. The foam concentrate added to water reduces the amount of water required for suppression, as the foam contains a surfactant that increases retention on fuel and reduces evaporation. Gels (e.g. *AquaGel-K* and *Thermo-Gel*) are a new type of suppressant that are added to water in a concentrate form. The additive has been designed to slow evaporation and increase adherence to fuels. Gels have been trialled operationally in some areas of the United States (California Department of Forestry and Fire Protection 2005), but have not been used operationally in Australia.

Retardant mixtures (e.g. *Phoschek D75R* and *Fire-Trol 931*) are normally applied ahead of the fire edge. Long term retardants remain effective after the water contained in them has evaporated. They leave a coating on the surface of fuels with ammonium salts of sulphate and phosphate which, by chemical reaction, are

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<sup>4</sup> The use of trade, firms and corporation names in this report is for information and convenience to the reader. Such use does not constitute an official endorsement or approval by Ensis-CSIRO and the Bushfire CRC of any products or services to exclusion of other that may be suitable.

converted to sulphuric and phosphoric acid. It is this reaction that suppresses complete flammability and promotes charring and carbonisation. As part of the aerial first attack strategy, they can provide an effective barrier to fires of up to  $3000\text{kWm}^{-1}$  in intensity and contain the fire for many hours until ground crews arrive (Loane and Gould 1986). Retardants are generally used where longer term retarding properties are required, such as indirect attack or where there is significant delay in getting ground crews to fires (Alder 1990).

### 1.7 Aerial suppression strategies

The strategies used in aerial suppression primarily depend on;

- fire conditions including fire behaviour, fuel, terrain and weather
- location restrictions including remote access and proximity to assets; and
- resource availability.

Suppression strategies commonly employed by aircraft include:

#### 1. Direct Attack

*This is suppression action aimed directly at slowing or stopping the flaming edge of a fire.* For aerial suppression this is attack on the flaming edge. Direct attack from aircraft is most effective when fires are small, with lower flame heights and smaller perimeters (McCarthy 2003). Direct firebombing on high intensity fires may only have a damping effect on fire progression. This however, may buy time until ground crews can safely support the aerial drops, and/or there is a change in weather to more favourable conditions for direct attack

#### 2. Crew Support

*This is aircraft use to improve the safety and effectiveness of ground crew operations.* It is in 4 types:

- a. Direct firebombing, crew protection and evacuation.* Firebombing can be used to reduce fire intensity near ground crews. This can assist these crews in establishing either a mineral earth fuel break, or wet line, to stop advancement of a fire. Aircraft may also be used to reduce fire intensity where ground crews are in direct danger from the fire. Crew evacuation using aircraft may be used in critical situations.
- b. Remote area special crew transport.* Aircraft can transport special crews to remote fires where ground access is difficult and then support these crews with direct firebombing, observation and transport out.
- c. Command and Control.* Fireground observation from aircraft can be used to improve the overall fire strategy and resource allocation.
- d. Intelligence.* Aircraft can provide indirect support to ground crews through provision of hand drawn maps, maps produced with global positioning systems (GPS), and infra-red linescan maps, of fire edges. They can provide direct support with Forward Looking Infra-Red (FLIR) for real time identification of hotspots on the fireground.



### 3. Line Construction/Line Holding

*Line construction is the establishment of a mineral earth fuel break to stop fire spread. Temporary line holding is the use of water, foam or retardant to provide a temporary barrier to fire spread.* In Australian fuels, all wet lines, or retardant lines, are regarded as temporary fireline holding methods. This is principally because wet lines dry out and retardant lines can be removed by rain. Thus firebombing can only provide a temporary fireline.

### 4. Indirect Attack

*Indirect attack is suppression activity some distance away from the flaming edge of a fire, with the intention that this action will slow or stop the flaming edge of the fire at a later time.* Indirect attack is often used where fires are too big and too intense to be attacked directly. Indirect attack often includes "back burning", where fuels between an established fireline and the fire edge are deliberately burnt out to provide a wider fuel break. Aircraft can assist indirect attack by the application of fire retardants on fuels ahead of the fire. Aircraft may also be used to help control back burning, by direct firebombing to reduce back burn intensity, or for aerial ignition of fuels to widen back burns.

### 5. Property/Asset Protection

*This is where the aim of suppression activity is to safeguard property or assets at risk of being burnt by a fire.* Aerial suppression, with its advantages of speed, observation and access, can assist ground forces in protecting assets such as buildings and plantations. Asset protection may be the most effective work for aircraft in situations where rate of spread, fire intensity, and fire size make direct or indirect attack futile.

### 6. Mop Up

*This is suppression of smouldering fuels - after the flaming edge of a fire has passed - to reduce the chances of re-ignition and fire escape.* Typically smouldering fuels are extinguished by ground crews, using wet or dry methods, for up to 20 m inside a fire control line. In most cases it is regarded as an uneconomical, and, most importantly, an *unsafe practice*, to use aircraft for mop up (Biggs 2004b). Aircraft should only be used for limited mop up where ground access is extremely difficult, and the chance of fire escape without mop up is very high.

## 2. Previous Suppression Research

This section gives a brief overview of existing literature related to the evaluation of the effectiveness of bushfire suppression. This includes operational and scientific evaluations.

### 2.1 Major studies

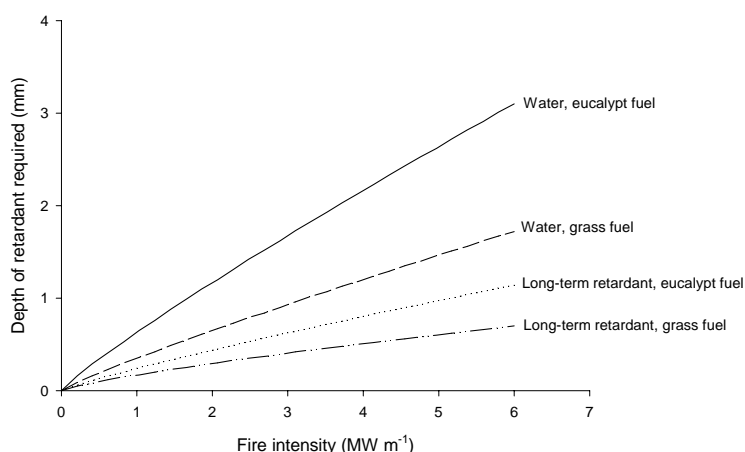
The USDA Forest Service Intermountain Fire Science Laboratory (Hardy 1977; George 1981; Anon. 1982; Blakely *et al.* 1982; George 1982; George and Johnson 1990; George 1990) has conducted most of the research on the performance of air tankers. Research on performances and effectiveness of aerial suppression in Australia was mostly done in the 1980s (Cheney *et al.* 1982; Rees 1983; Rawson and Rees 1983; Loane and Gould 1986), with a more recent study by McCarthy (2003). Annual evaluation of aerial suppression in Western Australia has been conducted in the outer metropolitan region of Perth since 1997 (CALM and FESA, 1998, 1999, 2000, 2001, 2002, 2003, 2004).

Wide ranges of fixed-wing aircraft are available for the delivery of long-term fire retardant. In Australia, the main aircraft are single-engine fixed-wing agricultural aircraft (e.g. Air Tractor AT802, PZL Dromader) which can carry loads of between 2500L and 3200L depending on the aircraft and operating conditions. Suppressant foams (Class A firefighting foams) which enhance both the wetting and lasting abilities of water are applied from rotary and fixed wing aircraft as well as ground tanker units.

The effectiveness of the application of suppression chemicals depends on:

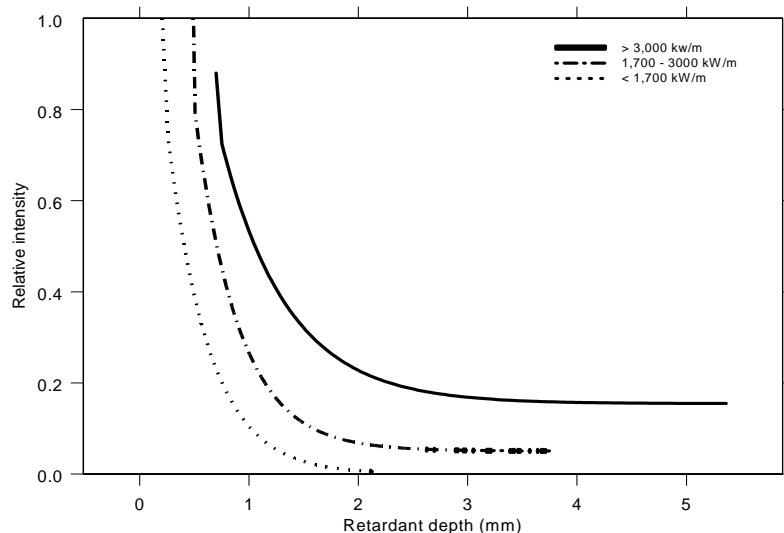
- the amount of suppressant or retardant actually needed on the critical fuel;
- the interception of suppressant or retardant by the forest canopy above the critical fuel;
- the pattern of the suppressant or retardant drop; and
- the chemical characteristics of the suppressant or retardant reaching the fuel.

One of the prime aims of Project Aquarius (Loane and Gould 1986) was to gather evidence of the effect of fire retardants on the behaviour of moderate to high-intensity fires in dry eucalypt forest. The depth (application rate) required to stop a fire burning through retardant-coated fuel in a drop zone is shown in Figure 2. The Aquarius studies indicated that unsupported retardant drops in stringy-bark forests were ineffective when fire intensities were  $>2000\text{kW m}^{-1}$  due to heavy spotting across the drop zone. If a ground crew supports the retardant drop within one hour, the effective limit is around  $3000\text{kW m}^{-1}$  (Loane and Gould 1986).



**Figure 2.** Depth of water and long-term retardant required to hold a fire at different intensities in grass and *Eucalyptus* fuel. 1mm is equivalent to 1L m<sup>-2</sup>. (Source: Loane and Gould 1986)

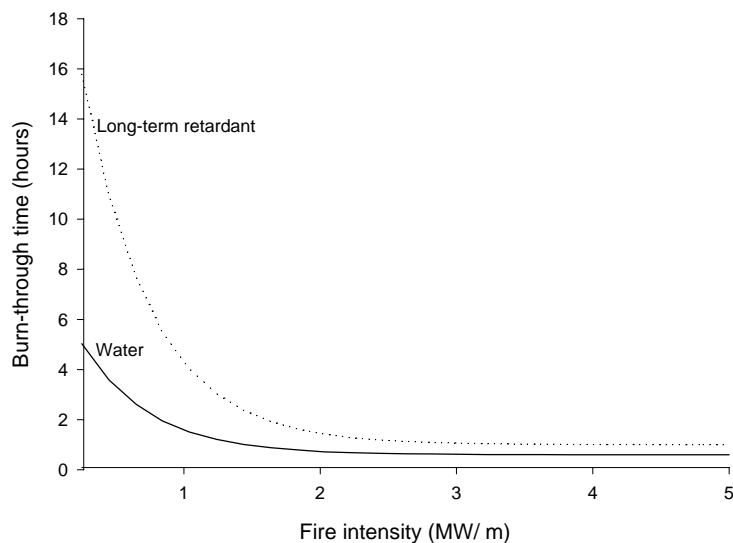
Loane and Gould (1986) concluded that there is no useful retarding effect for forest fire intensities  $>5000\text{kW m}^{-1}$ , i.e. rate of spread around  $700\text{m hr}^{-1}$  in a forest litter fuel load of  $15\text{t ha}^{-1}$ . Although the retardant drop may have a temporary dampening effect on the flames and fire intensities as shown in Figure 3, the fire may throw numerous spot fires across the drop zone which rapidly reform a new fire front. Thus even if the retardant coated fuel remains unburnt the progress of the fire may be delayed by only a few minutes.



**Figure 3.** Proportion of the original fire intensity remaining after the first retardant drop. (Source: Loane and Gould 1986)

Low-intensity fires may be completely extinguished by a retardant drop, or be held until fire weather conditions improve. Long-term retardant provides a retarding effect

even after drying out. However, fire controllers expect the fire to creep through gaps in the retardant line where coverage is low, for example in the lee of large logs. The time taken for the fire to burn through a drop depends mainly on fire intensity, suppressant type, concentration, width of the drop zone and fuel type. The burn-through time is shown in Figure 4 for water and long-term retardant for different fire intensities.



**Figure 4.** Water and long-term retardant burn-through time based on 30m wide drop zone. (Source: Loane and Gould 1986)

The application of firefighting chemicals is accomplished using a wide variety of aircraft equipped with different delivery systems. This results in a wide range of drop patterns. Drop patterns are also dependent on drop height, retardant type, canopy interception, relative humidity, temperature, and wind speed and direction. Although there has been a substantial effort to improve the performance of fire-retardant delivery via fixed-wing aircraft (George and Johnson 1990; George 1992) it is still difficult to quantify the effectiveness of retardant drops delivered to a fire. Most of these early studies were done on fixed-wing aircraft and there are only a few recent studies on helicopters for aerial firefighting (e.g. Biggs 2004a; Milne and Abbott 2005).

Operational studies from Victoria in the 1990s included a study of first attack effectiveness by both air and ground forces (McCarthy and Tolhurst 1998), and also a specific study into the effectiveness of firefighting aircraft (McCarthy 2003). Both studies highlighted the necessity of getting adequate ground and/or aircraft resources to a fire in the early phase so that containment is achieved before fire size and intensity builds to insurmountable levels.

In Western Australia, inter-agency annual reports on aerial firefighting operations have been compiled since the commencement of aerial suppression operations in 1996 (Lancefield Consultants 1997; CALM and FESA 1998, 1999, 2000, 2001, 2002, 2003, 2004). The reports describe the resource usage over each fire season and evaluate operations with case studies used to give examples of aerial firefighting successes. These reports contain estimates of the reduction in area burnt by wildfires due to aerial suppression, based on expert opinion, along with estimates of financial and resource savings. The reports have been a valuable tool for communicating the cost effectiveness of aerial suppression on these fires. Through recommendations the reports have subsequently influenced decisions to increase the number and types of aircraft and the regions in which they operate.

Another recent Western Australian study examined the effectiveness of helicopters undertaking suppression around Perth (Milne and Abbott 2005). This study concentrated on data related to the response time of helicopters, and recommended that helicopters be supported by ground suppression in order to be effective. Milne and Abbott (2005) also stressed the importance of further ongoing data collection and research relating to dispatch and deployment strategies and the operational strategies used by helicopters.

## 2.2 *First attack studies*

The role of first attack<sup>5</sup> is to quickly contain and thereby minimise the cost and damage that results from bushfires. With first attack being a primary focus of aerial suppression operations, it is not surprising that much of the research into aerial suppression effectiveness has been on this topic. Early publications on first attack discussed the benefits of suppressing small fires compared to larger ones. A recent paper by Cumming (2004) compared changes in management strategies that improved preparedness levels and first attack aggressiveness, associating improvements in first attack effectiveness to these.

Some of the Australian work mentioned previously (McCarthy and Tolhurst 1998; McCarthy 2003; Milne and Abbott 2005) have also highlighted the advantages of rapid first attack. McCarthy and Tolhurst (1998) developed a model to predict the probability of first attack success for various forest danger indices and overall fuel hazards levels. The authors based the first attack success on “*normal first attack resources*” of six crew members, one or two slip units and one D3 or D4 bulldozer with an average response time from ignition to first suppression work of 110 minutes. The probability of first attack success declines rapidly as the fire danger increases with increasing fuel hazard. McCarthy (2003) concluded that aircraft response time has an increasing influence on first attack success up to FFDI 30.

Substantial research has been conducted on topics relating to maximising the effectiveness of first attack. Some work has been conducted to improve detection systems (Kourtz 1967; Kourtz 1968; Kourtz 1987; Rego and Catry; 2006). However the majority of research in this field has been focused on optimising the locations of

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<sup>5</sup> First attack (initial attack)- (i) The first action taken to suppress a fire whether it by ground or air (ii) Resource initially committed to an incident.

bases in order to minimise travel times (Kourtz 1968; Bratten 1970; Greulich and O'Regan 1975; Simard 1977; Hodgson and Newstead 1978; Martell 1982; Kourtz 1984; Mees 1986; Fried and Gilles 1988; Islam and Martell 1997; Fried and Gilles 1999; Greulich 2003). The majority of this research has been conducted in North America. One Australian study by Gould (1987) looked at optimising base locations on southeast South Australia and southwest Victoria. Some of the more recent publications on base locations have also considered the effects of multiple ignitions on resource location and redeployment (Greulich 2005, Rachaniotis and Pappis 2006, Fried *et al.* 2006). Other work on first attack issues have aimed at assisting the determination of appropriate preparedness levels (Anon. 2003).

### 2.3 *Resource allocation modelling*

The current trend in research related to first attack is the development of resource allocation models. These can be used to aid planning decisions, such as resource selection and to develop deployment rules. Resource allocation modelling utilises research findings incorporating both suppression resource effectiveness and economic efficiency fields, as well as historical data, such as fire occurrence and weather records, for a given study area. Resource effectiveness data is lacking, but it is critical for resource selection, and for determining the limitations of different suppression resources. Effectiveness studies such as those presented here (Section 3) will provide user-defined rules that related fire environment to suppression effectiveness as input parameters to the resource allocation models.

Resource allocation models can be an important tool for planning for suppression operations and several models have been developed or enhanced (e.g. McAlpine and Hirsch 1999; Wiitala and Wilson 2005; Fried *et al.* 2006). Given the increasing complexity and cost of suppression operations fire managers need to consider techniques to examine the operational and performance characteristics of their suppression capabilities. This would assist in planning appropriate preseason protection and help evaluate nationally shared aerial resource programs. For example, Wiitala and Wilson (2005) developed a Wildfire Initial Response Assessment System (WIRAS) with intent that the model would closely represent the dynamics of fire occurrence, fire behaviour and suppression resource deployment characteristics of multi agency wildfire protection programs. The aim of this model is to provide a close correspondence to reality so it can be used as effective decision support system to help fire managers and operational planners better determine the appropriate size location, composition and use of locally controlled first attack resources. The model has also been used to evaluate nationally shared aerial resource programs.

### 2.4 *Drop patterns and coverage levels research*

Substantial research has been conducted to determine coverage levels and drop pattern characteristics for a large number of aircraft and delivery system combinations. This work has built on previous studies focused on the design of delivery systems (e.g. George and Blakely 1973). Most drop pattern studies have been conducted in open areas, such as airport runways, in low wind conditions. The term 'bare ground pattern studies' was used by Robertson *et al.* (1997a) to describe this type of work. Drop patterns are determined using a grid of evenly spaced containers to catch samples of the suppressant on the ground and thereby determine the drop pattern. These studies

have been described by a number of authors (George and Blakely 1973; Robertson *et al.* 1997b; Suter 2000; Biggs 2004a; Lovellette 2004; Plucinski *et al.* 2006). Factors that have been found to affect the drop pattern shape and coverage levels include aircraft speed and height, wind speed and direction, the flow characteristics of the delivery system and suppressant viscosity. A few studies (Rawson 1977; Newstead and Lieskovsky 1985; Robertson *et al.* 1997a) have also considered the effect of canopy interception on drop patterns and have conducted trials under a variety of canopy types.

The wide range of aircraft delivery systems can be modified to deliver similar amounts of suppressants (Rees 1983). Effective retardant coverage levels range from  $<0.5\text{L m}^{-2}$  for grass fires to  $>1.5\text{L m}^{-2}$  for eucalypt forest (providing a holding time up to 2h) (Loane and Gould 1986).

Theoretically the coverage level required for suppressing fires in heavy fuels or logging slash may be as high as  $4.0\text{L m}^{-2}$ , but in practice the effective coverage levels are considerably lower. An extensive operations study of the use of aerial suppression in the United States of America found that an average coverage level of  $0.5\text{L m}^{-2}$  (range  $0.3 - 0.8\text{L m}^{-2}$ ) was effective on fires with flame lengths up to 2m (intensity approximately  $2000\text{kW m}^{-1}$ ) in a wide range of fuel types. (George *et al.* 1990).

The drop pattern of a typical Australian firebombing aircraft (e.g. PZL Dromader, Air Tanker 602/802) is such that maximum ground level retardant coverage under canopy rarely exceeds  $2.5\text{L m}^{-2}$ . Within any given drop it is estimated to be less than 10% of the total area would be covered at this level.

## 2.5 Fireline production rate studies

Production of either *constructed* or *holding* fireline by suppression forces has been defined as follows in this study (after McCarthy *et al.* 2003):

**Constructed fireline:** this is fireline constructed down to mineral earth by either machines or hand tools, and provides a permanent fuel gap to inhibit fire spread.

**Temporary holding fireline:** this is fireline where the fuel has been physically or chemically treated - with water, foam, or retardant - to temporarily restrict fire spread.

In this study, the application of all suppressant and retardant agents by aircraft has been treated as producing *temporary holding fireline* only. While it may be argued that the application of retardant to fuels in front of a fire can produce an effective barrier to fire spread, this effect is not permanent. Rain rapidly renders retardants ineffective by washing the fire retardant chemicals off the fuel surface. Fires can burn through deep fuel beds that have retardant on the surface.

McCarthy *et al.* (2003) produced an operational guide for resourcing and fireline construction/holding based on 103 operational fires. Temporary holding fireline productivity for aircraft were based on very few observations at operational fires.

This operational guide suggested that rate of construction of temporary fireline was determined mostly by aircraft drop length and turnaround time.

## 2.6 *Suppressant and retardant research*

Studies into suppressant and retardant effectiveness have been conducted throughout much of the 20<sup>th</sup> century, with early work aiming to improve the effectiveness of water as a suppressant. The majority of the work that has been conducted has considered the effectiveness of long term retardants. Much retardant effectiveness research has been conducted in the laboratory (George and Blakely 1970; George and Blakely 1972; George *et al.* 1976; George *et al.* 1977; Blakely 1983; Blakely 1988) with this work focussing on reduction in flammability and combustion rates of different retardants during indirect suppression. Most of the recent research into retardants has focussed on their environmental impacts, these include some Australian studies (e.g. Bradstock *et al.* 1987; Adams 1999; Bell *et al.* 2005). Some comprehensive reviews of retardant research have been published recently that cover use, effectiveness and environmental effects (Gould *et al.* 2000; Giménez *et al.* 2004).

Long-term retardants are around 3 times more efficient than plain water when applied directly to burning slash fuels (Luke and McArthur 1978). When applied from the air, long-term retardants are required to hold a fire for some period. The USDA Forest Service has devised a relative rating for long term fire retardants called a “superiority factor”. The superiority factor is based on a combination of factors including the retardant effect on rate of spread and combustion rate of a fire burning in a standard test bed after the water carrying the retardant has evaporated (Celia Johnson *pers comm.* in Gould *et al.* 2000). To be accepted for use by the USDA Forest Service as a long-term retardant, any formulation is required to have a superiority factor of 60 or above, which means that the formulation is at least as effective in reducing combustion characteristics as a 10.6% solution of diammonium phosphate (the USDA Forest Service standard). Plain water has a superiority factor of zero.

The most comprehensive reference on foam suppressants is the proceedings of the International Wildland Fire Foam Symposium and Workshop (Ramsey 1996), which contains papers covering foam properties, effectiveness, application and environmental impacts. Foam suppressants are a special category of short-term suppressant which contain foaming and wetting agent. The advantages of Class A foam are (NWCG Fire Equipment Working Team 1993):

- Increase the effectiveness of water;
- Extend the useful life of water;
- Provide short term fire barrier;
- Effective on fire in all type of class A fuels (vegetation fuels);
- Reduce suppression and mop-up time;
- Relatively easy to use (mixing and handling);
- Visible from ground and air.

There is limited information available on the use of gel type water enhancers as suppressants. An anecdotal report on some operational testing of gel suppressants by the Californian Department of Forestry and Fire Protection (2005) conveys positive results, suggesting further evaluation. A preliminary Australian trial of gel



suppressants (Taylor *et al.* 2005) has found that they have slower evaporation rate than water or foam and suggested it that they could be used as an effective short term retardant. The trials in this study were limited and the authors recommended that further testing be done.

### **3. Operations Study**

#### *3.1 Introduction*

The aim of the operations study was to collect suppression response and outcome data from a large number of Australian wildfires that used aircraft for suppression. Data were collected for this purpose over the 2004/05 and 2005/06 fire seasons and is proposed to continue over subsequent seasons.

#### *3.2 Methodology*

Data were collected from operational personnel using two data forms; the Air Attack Supervisor (AAS) report form and the Suppression Operation Report (SOR). These forms were designed to collect information on fire location, size, and behaviour, fuel types, weather, topography, suppression resources deployed, timing of detection, deployments and containment, as well as, overall outcome and performance measures. Data were only collected from fires that used aircraft for suppression.

The AAS report was designed to be filled by those directing aerial bombing operations. The AAS report was based on that used by the Victorian State Aircraft Unit, who have used it in various formats for a number of years and have made it mandatory for all AAS suppression deployments in Victoria. An example of this form is attached as Appendix 1 along with the accompanying page of instructions.

The SOR was designed to be filled by ground personnel who had closely observed the suppression effect by both aerial and ground forces. It covers the majority of points on the AAS report, but also seeks more detail on fuels, fire behaviour, ground suppression resources, timing and suppression outcome. This extra information makes the SOR data more valuable for analysis. Although efforts were made to get SOR reports completed for all of the fires that had AAS report data, this was not always possible. An example of the SOR form and instructions is given in Appendix 2.

The questions on both of these data collection forms represent a balance between the desired data for analysis and information that could be easily obtained using this method. The forms were designed to cover as many situations as possible, regardless of fire size, fuel type, or suppression strategies. Only one version of each form was used in order to minimise confusion amongst those providing data.

The data collection forms were distributed as widely as possible in order to maximise data quantity and also to cover a large range of different fire types and deployment conditions. The reports were distributed to each state and territory fire agencies through a series of workshops and also by contacting fire control officers soon after fires that utilised aerial suppression. The workshops were usually held in conjunction with other meetings of fire aviation specialists. The intended data providers for SOR forms were more widespread than the aviation specialist groups, making them more difficult to contact and brief before fires. Thus the majority of the SOR forms were sent out soon after fire events. Not all requests for data were realised and many of the people contacted needed considerable prompting to provide data.

Respondents providing data on SOR forms were also asked to provide additional information. This included information such as incident reports, maps (including sketch maps showing the location of flame front and aerial suppression drops), weather reports, radio logs, and photographs (particularly of fuels and fire behaviour) that would add value to the data entered on the report forms.

The report form data was entered into a database and prepared for analysis. The data were divided into two groups, forest and grass, based on the fire danger index (FDI) system applicable to the majority of vegetation across the area of the fire. The forest fire danger index (FFDI) group included vegetation types such as forests, woodlands, scrublands, and heathlands. The grass fire danger index (GFDI) dataset consisted of fires that predominantly burnt grasslands. The data were divided into these groups because of the differences in fire behaviour and the associated influence on suppression strategy. The most obvious difference between the two groups was the area burnt on arrival. Grassfires often burnt much larger areas in the period before the arrival of suppression resources. This was particularly the case during elevated fire danger conditions (i.e. high to extreme GFDI). The FFDI data was not split into vegetation type categories because there was not enough data for most of these vegetation types to be analysed alone.

The data were analysed with respect to the success of first attack. First attack was declared to be successful when fires were contained within 8 hours. This definition is based on that used previously by McCarthy and Tolhurst (1998) and McCarthy (2003). This typically meant that the final fire area in forest FDI fuel types was less than 10 hectares, though in some cases it was more. The grassland fire dataset was too small to analyse using this method. This definition produced a binary distribution of suppression outcomes, enabling a probability of first attack success to be determined.

The data were analysed using logistic regression modelling and regression tree analysis. Logistic regression modelling can be used to estimate the probability of an event occurring, in this case fire containment in less than 8 hours. The basic model is of the form:

$$\ln\left[\frac{p}{1-p}\right] = b_0 + b_1 f_1 + \dots + b_n f_n$$

where  $p$  is the probability of first attack success,  $b_0$ ,  $b_1$ , and  $b_n$ , are regression constants, and  $f_1$  and  $f_n$ , are predictor variables. Potential predictor variables tested for inclusion in a model included those related to fire behaviour, fire size, weather, fuels, terrain, and deployment delay time (aircraft and ground crews). The statistically significant variables included in the model were decided using the Chi square test (Dobson 1990). Variables that were highly correlated with those already in the model could not be included.

Regression tree modelling was also used for the analysis of results, so that a decision tree could be developed.

### 3.3 Results

Data were collected from 284 separate wildfire events. Not all of the data received were able to be used for analysis. Many of these operational reports had missing information. Data from fires that had AAS report information only (i.e. no SOR data)

were not used because they lacked crucial information on timing, fuels, and weather. Follow up data collection will occur where possible to increase the total dataset. Many operational reports from Western Australia could not be used in the analysis because of missing information needed to calculate FFDI. This information is currently being obtained from the Bureau of Meteorology which will allow completion of these reports for future analysis.

There were 76 and 32 completed reports in forest FDI fuel types and grass fuels respectively that had sufficient data for analysis. These met the criteria of being discrete fire events and not being escapes from previous fires or prescribed burns. A summary of the data used, sorted by state of origin, is given in Table 2. This table also shows the range of Forest Fire Danger Index (FFDI) and Grassland Fire Danger Index (GFDI) for the current dataset.

**Table 2.** Summary of data collected for Operations Study.

|       | <b>Total data collected</b> | <b>Forest FDI fuel types</b> |            | <b>Grassland fuels</b> |            |
|-------|-----------------------------|------------------------------|------------|------------------------|------------|
|       | Number (%)                  | Number (%)                   | FFDI range | Number (%)             | GFDI range |
| ACT   | 3 (1)                       |                              |            | 3 (9)                  | 8 – 16     |
| NSW   | 91 (32)                     | 31 (41)                      | 8 – 67     | 28 (85)                | 8 – 128    |
| Qld   | 20 (7)                      |                              |            |                        |            |
| SA    | 9 (3)                       |                              |            |                        |            |
| Tas   | 15 (5)                      | 8 (11)                       | 8 – 25     | 1 (3)                  | 43         |
| Vic   | 63 (22)                     | 33 (43)                      | 1 – 64     | 1 (3)                  | 70         |
| WA    | 81 (29)                     | 3 (4)                        | 15 – 25    |                        |            |
| NZ    | 2 (1)                       | 1 (1)                        | 8          |                        |            |
| Total | 284                         | 76                           | 1 – 67     | 32                     | 8 – 128    |

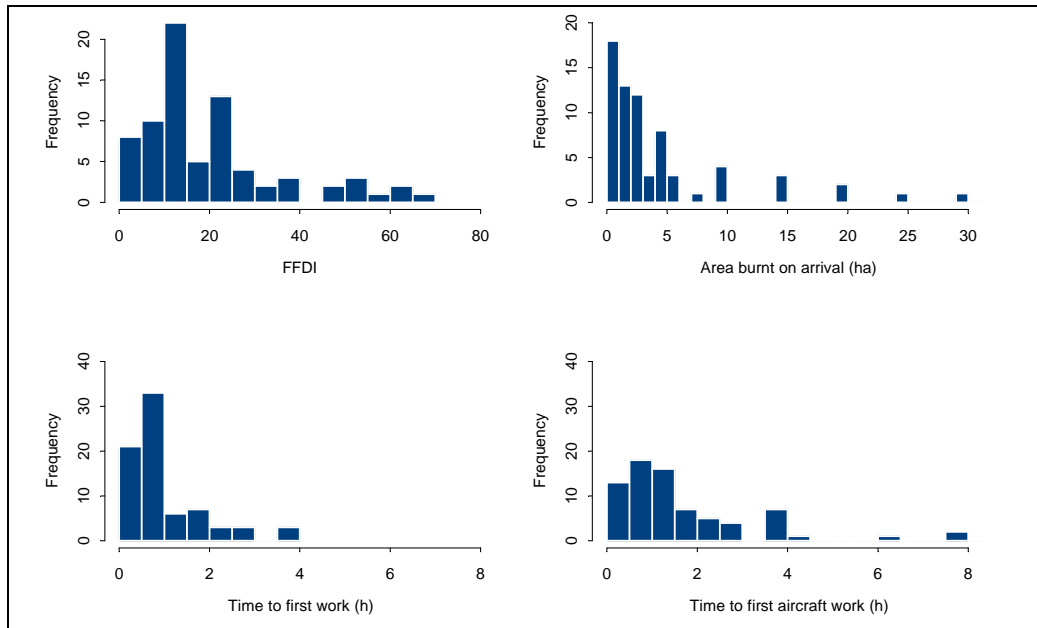
While the Forest FDI fuel type dataset contained enough data for logistic regression modelling, the grassland data did not. The distributions of data variables in this dataset are given in Figure 5. The variables found to be significant for inclusion in a logistic regression model (Equation 1) were: area burning on arrival; FFDI; time between detection and first aircraft work; and overall fuel hazard score. All of these were significant at the 95% confidence level, and had acceptable levels of cross correlation. Table 3, shows coefficients standard errors and probability ( $p$ ) values for the variables included in logistic regression modelling. The correlation coefficient ( $R^2$ ) value for this model is 0.51.

$$p = \left( \frac{1}{1 + \exp(-[7.65 - 0.15f_1 - 0.07f_2 - 0.49f_3 - 1.21f_4])} \right) \quad \text{Equation 1}$$

Where  $p$  = probability of first attack success  
 $f_1$  = area burning on arrival (hectares)  
 $f_2$  = FFDI  
 $f_3$  = time between detection and first aircraft work (hours)  
 $f_4$  = overall fuel hazard score

**Table 3.** Coefficients, standard errors and  $p$ -values for first attack logistic regression model in FFDI vegetation types.

|  | Value | Standard Error | $p$ value |
|--|-------|----------------|-----------|
| (Intercept)  | 7.65  | 2.15           | 0.00      |
| area burning on arrival                            | -0.15 | 0.07           | 0.02      |
| FFDI   | -0.07 | 0.02           | 0.00      |
| time between detection and first aircraft work (h) | -0.49 | 0.23           | 0.02      |
| overall fuel hazard score                          | -1.21 | 0.48           | 0.01      |



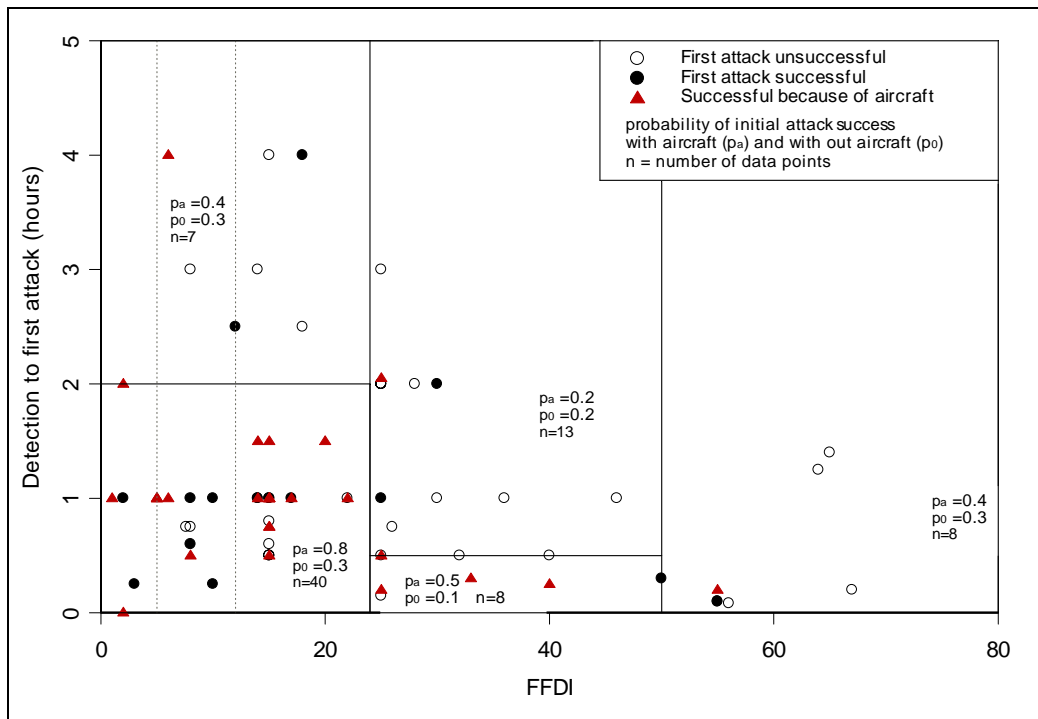
**Figure 5.** Distribution of FFDI, area burnt on arrival, time to first attack (any resources) and time to first aircraft work data.

A decision tree was developed for the Forest FDI fuel type dataset. This was based on regression tree analysis that using FFDI and time to first attack as predictor variables and first attack success as the response variable. These variables were chosen for decision tree analysis due to their ease of operational prediction. That is, fire managers could use them operationally to rapidly predict the likelihood of first attack success. The variable “time to first attack” is independent of resource type (i.e. ground or air), and gave a better fit than the variable “time to first aircraft attack”, which was used in the logistic model (Equation 1).

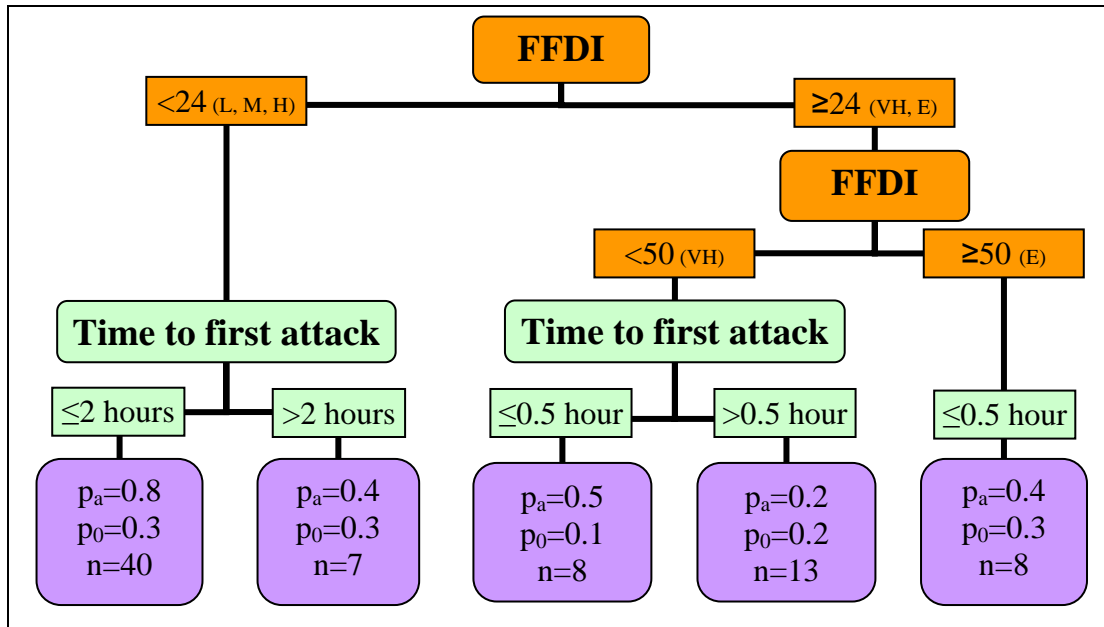
A scatter plot showing the distribution of first attack success, based on FFDI and time to first attack is given in Figure 6. This figure also shows the distribution of fires where first attack success was attributed to combined aerial and ground suppression - and essentially could not have been achieved without aircraft contribution. Data on probable first attack success without aircraft (first 8 hours) were used to derive this. The lines partitioning sections of this plot correspond with the branches of the decision tree (Figure 4). The cut off points from the regression tree analysis were adjusted to fit the FFDI values used to define the fire danger classes. The probabilities given in the bottom boxes of the decision tree are the probability of first attack success ( $p_a$ ) and probability of first attack success without aircraft ( $p_o$ ). The boxes also indicate the number of data points used to calculate the probabilities. A general interpretation of probabilities (Pollack 2003) is given in Table 4.

**Table 4.** Description of probability ranges (Pollack, 2003).

| Probability range      | Description                    |
|------------------------|--------------------------------|
| < 0.01 (<1%)           | extremely unlikely             |
| 0.01 – 0.10 (1 - 10%)  | little chance or very unlikely |
| 0.10 – 0.33 (10 - 33%) | some chance or unlikely        |
| 0.33 - 0.66 (33 - 66%) | medium likelihood              |
| 0.66 - 0.90 (66 - 90%) | likely or probable             |
| 0.90 – 0.99 (90 - 99%) | very likely or very probable   |
| > 0.99 (>99%)          | virtual certainty              |



**Figure 6.** First attack success in forest FDI fuel types with forest fire danger indices (FFDI) and time between detection and first attack.

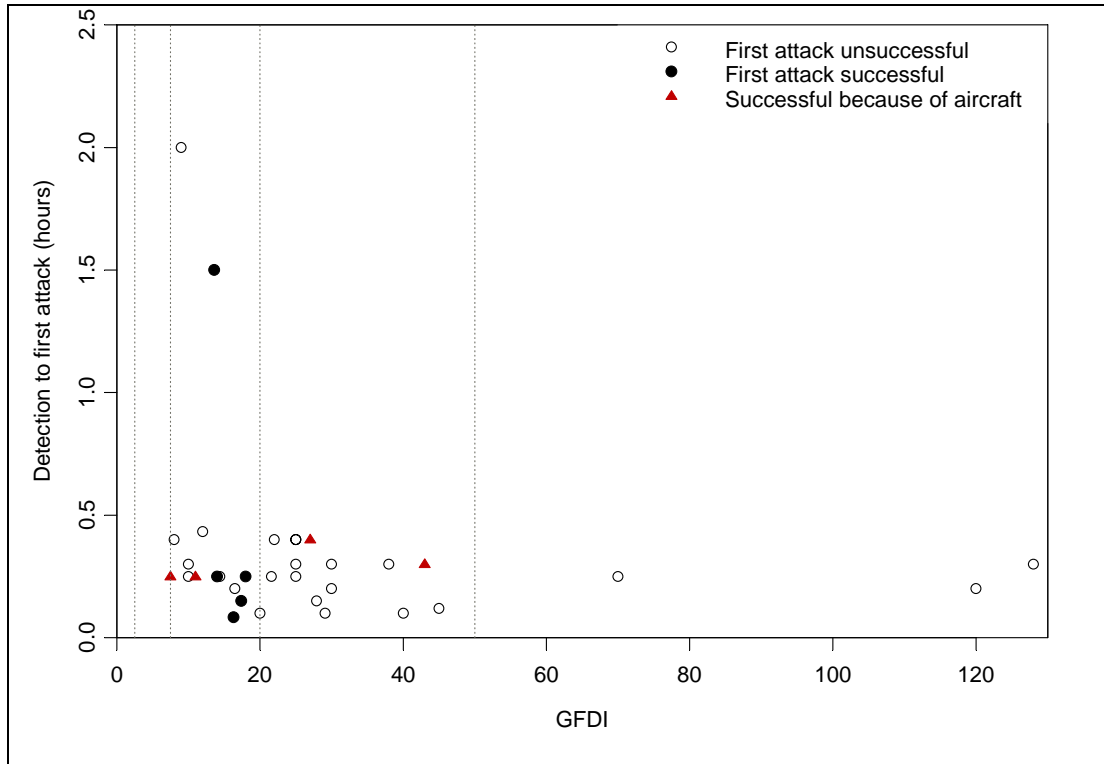


L, M, H, VH, E = low, medium, high, very high and extreme categories of FFDI  
 $p_a$ = probability of first attack success with aerial suppression support  
 $p_0$ = probability of first attack success without aerial suppression support  
 $n$ = number of fires in each section

**Figure 7.** Decision tree for defining the probability of first attack success, using FFDI and time to first attack (any resources).

A plot of response time (detection to first attack) and GFDI, for the grassland dataset, is shown in Figure 8. This figure shows that with the exception of two fires all grassfires in the dataset were attacked within half an hour of detection. Only three grassfires in this dataset were in the extreme GFDI range ( $GFDI \geq 50$ ). Figure 8 also shows that most grassfire first attack successes occurred at GFDIs <20, with all but two of the grassland first attack success fires occurring in this range. More data are required to further quantify this relationship and examine the importance of other factors to grassfire containment.





**Figure 8.** First attack success in grassfires with Grassland Fire Danger Index (GFDI) and time between detection and first attack.

### 3.4 Discussion

#### 1. Discussion of methodology

The SOR and AAS operational survey methodology provided sufficient data for valid preliminary statistical analysis within two fire seasons. This proved to be the only methodology capable of collecting sufficient data for this preliminary analysis. The strengths and weaknesses of this method of data collection are outlined in Table 5. The major weakness of this method is that some aspects of the data are subjective and therefore subject to observer bias. Thus conclusions reached may not be as scientifically valid as those obtained from quantitative field measurement or experimentation. Survey methods have been used to collect operational information for bushfire related research in the past (Hodgson and Little 1970; Simard and Forster 1972; Robertson *et al.* 1997a; Fogarty and Robertson 1997; McCarthy 2003; Canton-Thompson *et al.* 2006). These authors similarly accepted the weakness of subjectivity in the interests of collecting sufficient data for analysis.

**Table 5.** Strengths and weaknesses of data collection using surveys (Plucinski *et al.* 2004)

| Strengths   | Weaknesses  |
|---|---|
| <ul style="list-style-type: none"> <li>• Data relatively cheap to acquire</li> <li>• Potential to collect a large set of data</li> <li>• Can include all state and territory fire agencies</li> </ul> | <ul style="list-style-type: none"> <li>• Subject to observer bias</li> <li>• Qualitative data, limited in application</li> <li>• Limited quantitative data on effectiveness of drops in fires of different intensities</li> <li>• A limited amount of information can be asked for in a survey</li> </ul> |

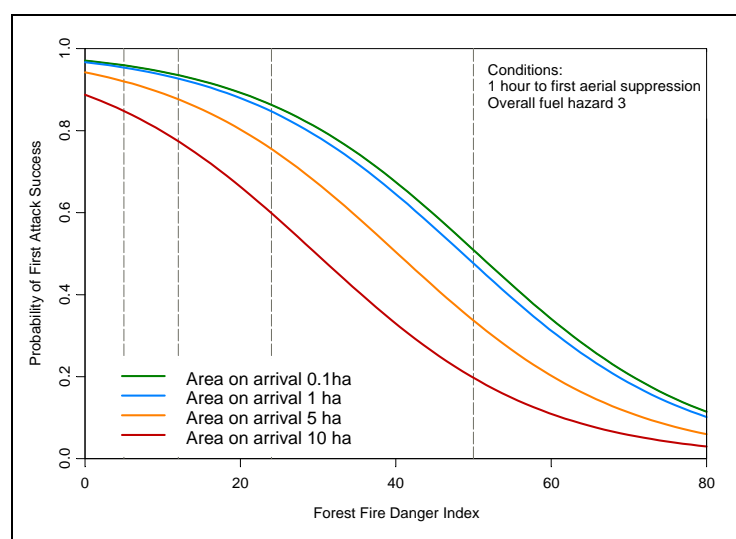
This study defined first attack success as fire containment within 8 hours of detection, based on that used by McCarthy and Tolhurst (1998) and McCarthy (2003). These authors had the additional criterion that final fire area did not exceed three times that of the initial fire area. Large variations between final and first attack fire size are due to fuel types, fire weather conditions and accessibility, particularly between the forest and grassland fires, meant that it was not useful to apply an area criteria for defining the probability of first attack success. Many of the grassland fires in the data were substantially larger than 10ha at the time of first attack. Nearly all of the forest fires where first attack was successful were kept under 10ha in size.

Two other definitions of first attack success from Canadian studies were final fire size not exceeding 3ha (Cumming 2004) and fire being contained by 10:00 am on the day following detection (Quintilio and Anderson 1976).

## 2. First attack success logistic regression model

The logistic regression model for first attack in FFDI vegetation types is shown in Equation 1 and Table 3. Area burnt on arrival was found to be the most important factor for inclusion in the model. This factor is a good measure of the suppression task on hand. Fire perimeter on arrival may have provided a better measure of the initial suppression task. However estimation difficulties, and a probable greater margin of error, meant that initial perimeter was not used as an input variable. The precision of estimates of area burnt on arrival was also limited in many cases. Most operational reports probably rounded initial area estimates to the nearest hectare for fires <10ha and to the nearest 5ha for fires >10ha.

Figure 9 shows predicted probability of first attack success with changes in area burnt on arrival and FFDI. This figure shows that the greatest differences in the probability of first attack success related to area burning on arrival are in the very high fire danger class (FFDI 25-49). In this range fires of 1 hectare or less have probabilities of first attack success ranging from 0.9-0.6, where as fires that are 10 hectares when the first suppression crews arrive have probabilities of only 0.6-0.2.

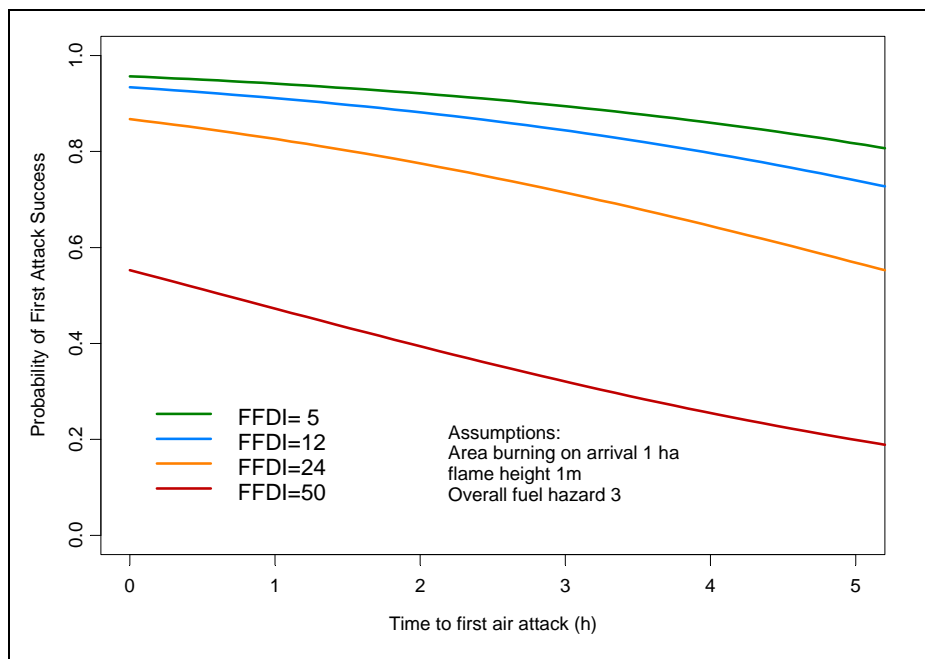


**Figure 9.** The effect of FFDI and area burnt at first attack on predicted first attack success.

FFDI was the second most significant factor for inclusion in the model. FFDI combines the principal fire weather variables (wind speed, temperature, relative humidity, and drought factor) into a single measure. Although FFDI was more significant than any of its component weather variables, minimum relative humidity and maximum wind speed individually accounted for some of the variation. The effect of FFDI and other factors on predicted first attack success is shown in Figures 9-11. The FFDI limits between the fire danger classes are illustrated in these figures.

The third factor included in the logistic model was response time for aerial suppression. Aerial suppression response time was found to be more significant than the time between detection and first suppression (regardless of resource type). The effect of aerial suppression response time on probability of first attack success is illustrated in Figure 10, which shows that this effect becomes more critical with increasing FFDI.

The final factor included in the model was overall fuel hazard. This factor is based on the Overall Fuel Hazard Guide (McCarthy *et al.* 1999), which describes the fuel profile in terms of both a hazard rating, and a hazard score. This hazard rating combines the individual influences of surface, near surface, elevated (shrub) and bark fuels. Descriptions and photographs are used for the assessment of each of these fuel components, which are then combined to give an overall hazard rating using a series of tables. The Overall Fuel Hazard Guide uses five classes for fuel hazard rating (low, moderate, high, very high, extreme). These were converted to numerical scores (1-5) for analysis. Vertically arranged fuels (near-surface, elevated and bark fuels) influence the overall hazard rating and score more than surface fuels.



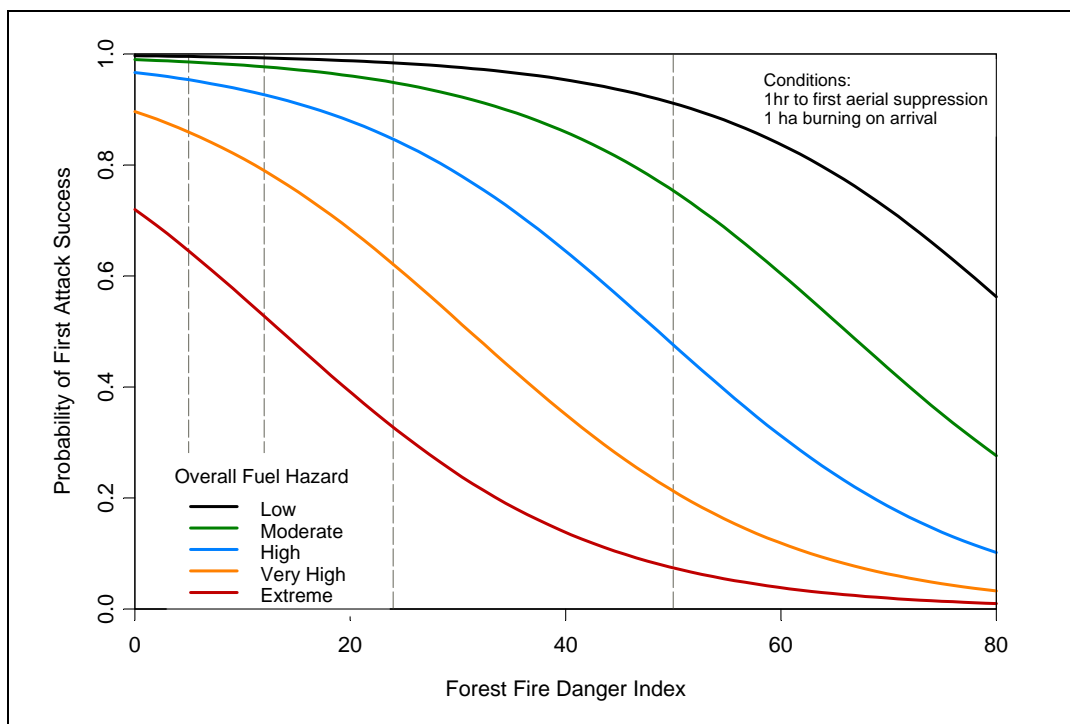
**Figure 10.** The effect of time to first air attack and FFDI on predicted first attack success.

Overall fuel hazard was included in the model, as it accounted for more variation in the data than any of its components individually. This was probably due to the range of vegetation types within the dataset. The effect of overall fuel hazard on probability

of first attack success, as predicted by the model, is shown in Figure 11. This figure shows that fuel hazard has a large influence on first attack success, and supports the contention that fires are easier to suppress in fuels with low to moderate hazard ratings. This is the major reason for undertaking prescribed burning, and has been the subject of many research papers (see review by Fernandes and Botelho 2003).

The first attack success model for FFDI fuel types, presented in Equation 1 has many limitations. Firstly this model can only be considered as a preliminary model because of the limited size of the current dataset. A larger dataset is required for a more rigorous analysis. This would potentially allow an extended dataset to be split on the basis of vegetation type. An expanded range of the factors in the dataset could extend the range of conditions under which the model could be applied.

It must also be emphasised that this dataset only contains data from fires that have used aircraft in first attack roles. Because of the large number of fires that occur during a fire season, it was only feasible to collect data from those that included aerial suppression. The SOR form contained specific questions about the effectiveness of aircraft at each of these fires including what the differences in containment time would have been if aircraft were not available.



**Figure 11.** The effect of FFDI and overall fuel hazard assessment on predicted first attack success.

### 3. First attack success decision tree

The decision tree built from the Forest FDI dataset (Figure 7) was designed to give a probability of first attack suppression success based on two factors, FFDI and time to first attack. FFDI is normally forecast each day during the fire season. Time to first attack can be estimated using the location of the fire, and its distance from the nearest available resource. Other factors, such as overall fuel hazard and fire size on arrival, were not used as they are usually not known until crews arrive at the fire.

The probability of first attack success declined with increasing FFDI and response time, as would be expected. Response time was found to be more critical in the very high range (FFDI 25-49), than the low to high range (FFDI <24), as indicated by the shorter cut off time in the decision tree. There was not enough data in the extreme range (FFDI >50) to detect an effect from response time. However, because the majority of the fires with FFDI > 50 were attacked within half hour of detection it was decided to include the time criteria to emphasise its importance. Differences in probability, with and without aircraft, are most pronounced when response time was <2h (FFDI <24), or <0.5h (FFDI 25-49). The presence of aircraft was critical to first attack success in most of these cases, as aircraft were generally the first resources to reach the fire.

The decision tree can be used to quickly estimate the probability of first attack success when a fire is reported. The resulting probability may act as a prompt for the dispatcher to send more resources than normally dispatched at first attack to improve the chances of early containment. A comparison of the estimated probabilities with aircraft, and without aircraft, could be used to justify the decision to dispatch aircraft to a fire. This decision should be made early, and would be influenced by likely response time of ground resources. Local knowledge of the fuel, terrain, and accessibility of the fire site, may also influence the decision.

It must be stressed that this decision tree is a preliminary model. More data is required to give increased rigour to the estimated probabilities, particularly for situations outside the range of the current dataset. The probability of success due to aircraft is reliant on the expert opinion of those who provided data, and is therefore subject to bias.

The use of only two factors in the decision tree masks the effect of other factors influencing first attack success. Some of the anomalies in the scatter plot (Figure 6) are related to extremes in fuel hazard. This was particularly the case for fires where first attack was not successful, response times were less than two hours and FDI were in the low to moderate fire danger indices. Improvements in prediction may come from refining the vegetation classes in this dataset, which may then allow each fuel type to be considered individually. This would only be possible with a substantially increased dataset.

### 4. Future work

The preliminary results highlight the importance of this data for determining the significant factors for quick containment of fires and for developing decision tools. Future work will refine the existing models, giving them more rigour through larger

datasets and focus them on specific fuel types. The data collection program for this work will continue over subsequent fire seasons, adding to the existing dataset. Current efforts are focused on obtaining information to fill the gaps in the incomplete operational reports, thereby increasing the data available for analysis.

## 4. Other Operational Studies

### 4.1 *Tracking data*

Commercial navigational tracking systems and global positioning system (GPS) units are currently in use throughout Australia on a large number of fixed wing firebombers and a limited number of helicopters. Commercial tracking systems (e.g. Satloc and AgNav) are used in agricultural aircraft to record the flight and spray coverage. They provide a data logging function making it possible to track time and date, GPS position at each logging interval, altitude and heading, and potentially the coverage level setting.

The tracking data from many fixed wing firebombers is proving to be valuable for data analysis. When combined with weather, vegetation, fuel, and fire information the GPS tracking data collected during a wildfire can generate the following information:

- Productivity information such as turnaround time, delivery rates and fuel cycles;
- Flight characteristics including aircraft altitude and speed;
- Location and characteristics of drops; and
- Air attack and containment strategies.

For the purposes of this report several track logs from throughout Australia have been analysed to evaluate the effectiveness and productivity of each aerial suppression activity (See Appendix 3). The most useful data were collected from fixed wing firebombers that were fitted with a commercial tracking system. This was due to both the format of the data provided and also the relative lack of complexity in the flight path when compared to helicopters. The tracking information could be used to assess productivity and hence determine the appropriate aerial resources required for a suppression task.

### 4.2 *Researcher collected suppression effectiveness data*

Data for the analysis of suppression effectiveness, was collected by researchers attending fires that had aircraft deployed to them. Researchers attending fires had the opportunity to collect more detailed information than operational personnel completing the SOR forms.

The collection of data for the analysis of aerial suppression effectiveness requires an extensive and varied methodology. The most useful data compares fire behaviour, when affected and unaffected by suppression drops. Information collected by the researchers includes location and timing of drops; drop coverage characteristics; fuel hazard; fire behaviour; weather; and ground suppression effort. The research team developed a range of procedures for different data collection scenarios including airborne observation of suppression activities and ground observations during and after the fire. Procedures for data collection from active firelines had to balance rapidly changing fire ground conditions with the requirement to collect reliable and detailed data. Categorized visual assessments were the most practical method for rapidly estimating fuel hazards, canopy cover, drop coverage, fire behaviour, fuel consumption, and drop effectiveness. Photographic and video recordings were also made to support this data.

Researchers collected data on suppression effectiveness with great difficulty. Access to active fire grounds while aerial suppression was in progress was limited by a number of logistical and safety issues related to the unplanned and emergency nature of these events. For this reason the suppression effectiveness data collected by the research team was very limited. The details of the data collected by the research team are given in Appendix 4.

### 4.3 *Infrared Imagery*

Infrared cameras are able to record imagery through smoke and light vegetation cover and have been used to monitor fire behaviour and hot spots. Forward looking infrared (FLIR) cameras mounted in observing aircraft have been used in suppression evaluation in North America (e.g. George *et al.* 1989; Ogilvie *et al.* 1995). Wet areas from drops can be detected for a period after suppressants are dropped, allowing the location to be defined. Aircraft mounted FLIR allows real-time monitoring of the durability of drop zones and the fire behaviour around them. This activity would not normally be seen because of smoke.

FLIR imagery of suppression operations is costly and difficult to acquire, as it uses specialised equipment and is best captured from aircraft. Arrangements must be made to hire suitable equipment and have it mounted on a helicopter. Research utilising FLIR equipment is best attempted on days when there are likely to be aircraft deployments suitable for assessment. FLIR imagery has been recorded for one fire with aerial suppression for this project. This footage is very limited in its usefulness because of problems related to the operator's equipment and obstruction from a tall forest canopy. Although attempts have been made to collect FLIR imagery from operational fires, the equipment has not been available during extreme fire weather. Attempts to investigate this type of data collection will be made in subsequent fire seasons.

## 5.0 **Experimental Studies**

### 5.1 *Introduction*

Detailed and accurate data can be collected experimentally. The planned nature of experiments allows for comprehensive site assessment and flexibility to target desired weather and burning conditions. The greatest advantage of field experiments over operational studies is the high quality of data that can be collected on the effectiveness of suppression drops on different intensity fires in different fuel types.

Suppression experimental studies can be used to link suppression capacity to fire behaviour. Fire intensity thresholds for different suppression resources can be determined, as can drop holding times. They can be used to compare the effectiveness of different suppression resources, and suppressants, in a range of fuel types and weather conditions. Field experiments can be costly and time consuming to prepare and conduct. Sites suitable for experimental evaluation often require up to 12 months of preparation for a major study.



A small scale experiment investigating the suppression effectiveness of a Type 2 (medium) helicopter on stubble fires was conducted in February 2005 in Tasmania with the assistance of the Tasmania Fire Service. This experiment took advantage of the Tasmania Fire Service's surplus contract aircraft hours, and was executed within a short time of notification of a suitable site. A comprehensive report has been written on this experiment (Plucinski *et al.* 2006).

A similar experiment was planned for February 2006 in a Tasmanian tall eucalypt forest. This experiment was postponed due to unfavourable weather conditions. All pre fire measurements have been made on this site and it is scheduled for experimental burning at a later date. Other small scale experiments could be conducted elsewhere if field sites and aircraft become available, and agency staff are able to assist with site assessment and preparation.

## 5.2 *Experimental design*

The aim of experimental studies into the effectiveness of aerial suppression on different bushfire intensities is to determine the containment thresholds and line construction rates for different suppressants and suppression resources. Different experimental methodologies are required to address these aims.

Experiments to determine fire intensity thresholds require direct attack on moving fire fronts. The critical fire intensity threshold for extinction by different resources can be determined by experiments that collect data on both fires that have and have not been successfully extinguished. Threshold intensity experiments require comprehensive fuel and fire behaviour measurements prior to the fire being suppressed and continued monitoring after drops in order to determine the drop holding times. Experimental drops should target the head fire as head fires produce the most intense fire that can be generated. Drop zones not completely extinguished should be monitored for a period long enough to determine the time required for the fire to burn through them. Data on drop holding times with no associated ground suppression cannot be collected operationally due to safety concerns and logistical issues.

The rate of line construction (productivity) can be determined using experimental fires that are large enough to require multiple drops for containment. Data on the length of fire perimeter and the timing and positioning of drops is essential to determine productivity. Productivity can be determined from operational fires but this data may contain limited information on fuel and fire behaviour. Experiments can be designed to compare productivity rates of different suppression resources under specific fuel and fire behaviour conditions.

Aerial suppression experiments should measure and evaluate drop patterns if they are not known for the aircraft and delivery system combination being used. This can enable the coverage levels of drop footprints to be determined. Such measurement is normally conducted with a grid of cups on a flat and clear area such as a runway. The interception effect of vegetation interception on drop coverage can be determined using the same methodology with drops applied through a representative stand of vegetation.

To be relevant to operational needs, experiments need to be conducted in dry summer conditions under moderate to high forest fire danger classes.

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## Air Attack Supervisor Operational Report

### Explanatory notes on data fields

These notes are to help explain how the Air Attack Supervisor (AAS) should complete the AAS Operational Report (A5 folded on White Card). These AAS Operational Reports are normally filled out at the end of each day's firebombing operations. This form is based directly on the DSE Victoria AAS Operational Report. The information collected on this form will be used as part of the data collection for evaluating the effectiveness of aerial suppression operations by researchers in the Bushfire CRC.

#### Page 1

#### AAS Information

**Date** : date(s) on which the main firebombing effort occurred (1 form/day or fire)  
**AAS** : name of accredited AAS, or Air Observer acting as temporary AAS.  
**AAS Platform Callsign** : aircraft callsign as per national register e.g. FB 262 (NSW)  
**AAS activated** : time (24 hr) at which AAS received despatch call.  
**AAS depart** : time (24 hr) at which AAS departed from normal base, fire airbase, or other going fire, to attend current fire.  
**AAS over fire** : time (24 hr) AAS arrived overhead fire site.  
**AAS return** : time (24 hr) at which AAS returned to normal base or temporary airbase.

#### Fire Information

**Fire No./Name/Location/Sector** : Fire number or name if allocated, general locality of fire, sector name if allocated.  
**Control Agency** : agency responsible for control of fire.  
**Wind direction** : general wind direction during firebombing operations (note significant wind change in comments).  
**Fire aspect** : main topographic aspect of the part of the fire subject to firebombing.  
**Fire on Arrival** : fuel components involved in the *flaming zone of the fire* at arrival.  
**Fire Size - Arrival** : fire size (ha) at time of AAS arrival.  
**Fire Size - Completion** : fire size (ha) at the cessation of firebombing for that day.  
**Flame height - Arrival** : average flame height (m) at commencement of firebombing operations (related to "Fire on Arrival" above).  
**Fire Elevation** : elevation of fire (ft) above sea level.  
**FDI** : average Fire Danger Index during firebombing operations for that day (note significant changes to FDI during the day in Comments). Note Forest or Grassland FDI  
**Slope** : slope class for part of fire subject to firebombing (select 2 classes if applicable)  
**Vegetation Type** : class of vegetation for fire area generally - may need to comment at bottom of page for variations within fire area.  
**Land Tenure** : eg: Private Property/Crown Land/ State Forest/ National Park (or other conservation reserve).

#### Operational Information

**IMT operating** : have Incident Controller/Operations Officer/ Planning Officer/ Logistics Officer roles been individually filled, and IMT operating as per AIMS-ICS,

**Ops Officer Name** : Name of Officer responsible for operational resources suppressing fire.

**Ground Support** : were ground forces actively involved in *containing* the fire together with the aerial forces (i.e. may not be total forces attending).

**Ground Support Type** : What type of ground resources were actively involved in *containing* the fire on the ground.

#### Page 2

#### Drop Information

Drop Times recorded for each drop by firebomber and agent i.e. (W = water / F = foam / R = retardant / G = Gel). Also turnaround times for each firebomber and total amount delivered for the day (may be transferred from the AAS log). May record average drop length (m) on ground if available.

#### Page 3

#### Operational Evaluation

**Bombing Aircraft Use - Strategies/Tactics** : use of direct or indirect attack or combination (by %). Which part(s) of fire were attacked (Head/Flank/Back), or other protection objective (crew, assets etc.).

**Effectiveness** : effectiveness of ground support, effect of discrete firebomber types, effect of all bombing aircraft, and communications - rated from 1 to 5. Assets protected by numbers and (\$) value if available). Restrictions to effectiveness (note in Comments if these were *important/critical to non-containment*). Space for comment on all factors - note relative importance of each factor to effectiveness if possible.

#### Page 4

#### Operational Evaluation cont'd.

**Aircraft filling locations/bases** : where did the firebombing aircraft mostly fill up from - may be one for Fixed Wings and one or more for Helicopters.

**Total loads or litres delivered** : how much did each firebomber actually carry to the fire for that day.

**Ferry distance to fill/load point** : how far (km) to the fill/load point from the fire (should correspond with aircraft av. speed and turnaround time).


**Average % of Aircraft Max Capacity carried** : were the firebombers able to carry close to maximum, or were they restricted by hot/high airstrip length, fuel load etc.

**Overall Aircraft Objective** : did the aircraft achieve the objective(s) set for the air operation for the day (may be different to the overall task of containing the fire).

**Additional Comments / Information / Issues for Follow** : AAS should attempt to tell short story of operation for the day, and record any information requiring follow-up or future action (especially safety concerns).

(For queries contact CRC Researchers: Matt Pilsinski 02 6281 8404 or Greg McCarthy 03 51541208)

## Appendix 2. Suppression Operation Report form

| <b>SUPPRESSION OPERATION REPORT</b>   |  |   |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
|---|--|--|---|---|---|--|---|--|---|---|--|---|--|---|--|---|--|--|--|---|--|----------------------------|--|-------------------------------|--|--|--|--|---|----------------------------|---|--|--|--|---|--|
| To be completed by operations officer/ sector boss/ crew leader on a per incident basis.  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px;"><b>Fire Name:</b></td> </tr> <tr> <td style="padding: 2px;">Date(s) of observations:</td> </tr> </table>  | <b>Fire Name:</b>  | Date(s) of observations:   | <table style="width: 100%;"> <tr> <td style="width: 33%;">Send to: Greg McCarthy<br/>SFES<br/>P.O Box 260,<br/>Orbost, Vic, 3888<br/>Ph: 03 51541208<br/>Fax: 03 51541062<br/>greg.mccarthy@dse.vic.gov.au</td> <td style="width: 33%; text-align: center; vertical-align: top;">OR</td> <td style="width: 33%;">Matt Plucinski<br/>CSIRO<br/>P.O. Box E4008<br/>Kingston, ACT, 2604<br/>Ph: 02 62818404<br/>Fax: 02 62818348<br/>matt.plucinski@enssjv.com</td> </tr> </table> |   |   | Send to: Greg McCarthy<br>SFES<br>P.O Box 260,<br>Orbost, Vic, 3888<br>Ph: 03 51541208<br>Fax: 03 51541062<br>greg.mccarthy@dse.vic.gov.au   | OR  | Matt Plucinski<br>CSIRO<br>P.O. Box E4008<br>Kingston, ACT, 2604<br>Ph: 02 62818404<br>Fax: 02 62818348<br>matt.plucinski@enssjv.com   |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| <b>Fire Name:</b>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Date(s) of observations:  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Send to: Greg McCarthy<br>SFES<br>P.O Box 260,<br>Orbost, Vic, 3888<br>Ph: 03 51541208<br>Fax: 03 51541062<br>greg.mccarthy@dse.vic.gov.au  | OR   | Matt Plucinski<br>CSIRO<br>P.O. Box E4008<br>Kingston, ACT, 2604<br>Ph: 02 62818404<br>Fax: 02 62818348<br>matt.plucinski@enssjv.com |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| <p><b>Operations Officer</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="padding: 2px;">Name:</td></tr> <tr><td style="padding: 2px;">Agency:</td></tr> <tr><td style="padding: 2px;">Normal fire district:</td></tr> <tr><td style="padding: 2px;">Operational fire district:</td></tr> <tr><td style="padding: 2px;">IMT operating: <span style="float: right;">Y/N</span></td></tr> </table>   | Name:  | Agency:  | Normal fire district:   | Operational fire district:  | IMT operating: <span style="float: right;">Y/N</span>   | <p><b>Other Aircraft Usage</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="padding: 2px;">Other aircraft uses: recce/ ground force direction (command &amp; control)/ mapping/ crew transport / FLIR/ Linescan/ aerial ignition</td></tr> <tr><td style="padding: 2px;">Rappell/ RAFT crews deployed:.....rappellers/ RAFTers</td></tr> <tr><td style="padding: 2px;">Handtrail built by rappellers/ RAFTers: (m) helipads built...(no)</td></tr> <tr><td style="padding: 2px;">Did aircraft provide command and control services which improved ground crew deployment around the fire? <span style="float: right;">Y/N</span></td></tr> <tr><td style="padding: 2px;">Was this command and control service critical to normal/ extended first attack containment of the fire? <span style="float: right;">Y/N</span></td></tr> <tr><td style="padding: 2px;">Did aircraft provide recce services which allowed a ground crew to reach the fire? <span style="float: right;">Y/N</span></td></tr> <tr><td style="padding: 2px;">Was this critical to normal/ extended first attack containment of the fire? <span style="float: right;">Y/N</span></td></tr> <tr><td style="padding: 2px;">Did aircraft ferry crews to the fire: <span style="float: right;">Y/N</span></td></tr> <tr><td style="padding: 2px;">Was this ferry service critical to normal/ extended first attack containment of the fire? <span style="float: right;">Y/N</span></td></tr> </table> |   |  | Other aircraft uses: recce/ ground force direction (command & control)/ mapping/ crew transport / FLIR/ Linescan/ aerial ignition | Rappell/ RAFT crews deployed:.....rappellers/ RAFTers | Handtrail built by rappellers/ RAFTers: (m) helipads built...(no)  | Did aircraft provide command and control services which improved ground crew deployment around the fire? <span style="float: right;">Y/N</span> | Was this command and control service critical to normal/ extended first attack containment of the fire? <span style="float: right;">Y/N</span> | Did aircraft provide recce services which allowed a ground crew to reach the fire? <span style="float: right;">Y/N</span> | Was this critical to normal/ extended first attack containment of the fire? <span style="float: right;">Y/N</span> | Did aircraft ferry crews to the fire: <span style="float: right;">Y/N</span>                        | Was this ferry service critical to normal/ extended first attack containment of the fire? <span style="float: right;">Y/N</span> |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Name:   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Agency:   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Normal fire district:   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Operational fire district:  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| IMT operating: <span style="float: right;">Y/N</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Other aircraft uses: recce/ ground force direction (command & control)/ mapping/ crew transport / FLIR/ Linescan/ aerial ignition   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Rappell/ RAFT crews deployed:.....rappellers/ RAFTers   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Handtrail built by rappellers/ RAFTers: (m) helipads built...(no)   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Did aircraft provide command and control services which improved ground crew deployment around the fire? <span style="float: right;">Y/N</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Was this command and control service critical to normal/ extended first attack containment of the fire? <span style="float: right;">Y/N</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Did aircraft provide recce services which allowed a ground crew to reach the fire? <span style="float: right;">Y/N</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Was this critical to normal/ extended first attack containment of the fire? <span style="float: right;">Y/N</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Did aircraft ferry crews to the fire: <span style="float: right;">Y/N</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
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| <p><b>Fire Information</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="padding: 2px;">Fire No./ name/ location/ sector:</td></tr> <tr><td style="padding: 2px;">Control agency:</td></tr> <tr><td style="padding: 2px;">FDI (max during operations) <span style="float: right;">(L/ M/ H/ VH/ E)<br/>(forest/ grassland)</span></td></tr> <tr><td style="padding: 2px;">Max wind speed: <span style="float: right;">km/h</span></td></tr> <tr><td style="padding: 2px;">Wind direction: <span style="float: right;">(N/NE/E/SE/S/SW/W/NW)</span></td></tr> <tr><td style="padding: 2px;">Max temperature: <span style="float: right;">°C</span></td></tr> <tr><td style="padding: 2px;">Minimum relative humidity: <span style="float: right;">%</span></td></tr> <tr><td style="padding: 2px;">Drought index: KBDI/ SDI <span style="float: right;">0-24/ 25-62/ 63-100/ 100+</span></td></tr> <tr><td style="padding: 2px;">Fire aspect: <span style="float: right;">(N/NE/E/SE/S/SW/W/NW)</span></td></tr> <tr><td style="padding: 2px;">Fire slope (average): Nil/ Low/ Mod/ Steep</td></tr> <tr><td style="padding: 2px;">Fire elevation (m ASL):</td></tr> <tr><td style="padding: 2px;">Vegetation type(s): Grass[Natural/ Grazed/ Eaten]/ Crop/ Scrub/ Forest /Heath/ Mallee/ Alpine/ Plantation</td></tr> <tr><td style="padding: 2px;">Curing: <span style="float: right;">% (grass fuels only)</span></td></tr> <tr><td style="padding: 2px;">Surface fine fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span></td></tr> <tr><td style="padding: 2px;">Near-surface fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span></td></tr> <tr><td style="padding: 2px;">Elevated fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span></td></tr> <tr><td style="padding: 2px;">Bark fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span></td></tr> <tr><td style="padding: 2px;">Overall fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span></td></tr> <tr><td style="padding: 2px;">Fuel involved on arrival: Surf/ NSF/ Elev/ Bark/ Crown</td></tr> <tr><td style="padding: 2px;">Average flame height during operations (m):</td></tr> <tr><td style="padding: 2px;">Maximum flame height (m): <span style="float: right;">Time/ date:</span></td></tr> <tr><td style="padding: 2px;">Fire size on arrival (ha):</td></tr> <tr><td style="padding: 2px;">Final fire size (ha):</td></tr> <tr><td style="padding: 2px;">Total fire perimeter (final):</td></tr> </table> | Fire No./ name/ location/ sector:  | Control agency:  | FDI (max during operations) <span style="float: right;">(L/ M/ H/ VH/ E)<br/>(forest/ grassland)</span>   | Max wind speed: <span style="float: right;">km/h</span>   | Wind direction: <span style="float: right;">(N/NE/E/SE/S/SW/W/NW)</span>  | Max temperature: <span style="float: right;">°C</span>   | Minimum relative humidity: <span style="float: right;">%</span>   | Drought index: KBDI/ SDI <span style="float: right;">0-24/ 25-62/ 63-100/ 100+</span>  | Fire aspect: <span style="float: right;">(N/NE/E/SE/S/SW/W/NW)</span>   | Fire slope (average): Nil/ Low/ Mod/ Steep            | Fire elevation (m ASL):  | Vegetation type(s): Grass[Natural/ Grazed/ Eaten]/ Crop/ Scrub/ Forest /Heath/ Mallee/ Alpine/ Plantation                                       | Curing: <span style="float: right;">% (grass fuels only)</span>  | Surface fine fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span>   | Near-surface fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span>  | Elevated fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span>                             | Bark fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span>  | Overall fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span> | Fuel involved on arrival: Surf/ NSF/ Elev/ Bark/ Crown | Average flame height during operations (m): | Maximum flame height (m): <span style="float: right;">Time/ date:</span> | Fire size on arrival (ha): | Final fire size (ha):  | Total fire perimeter (final): | <p><b>Overall Aircraft Effectiveness</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="padding: 2px;">Combined aircraft contribution to overall suppression task (in comparison with total suppression forces)</td> <td style="padding: 2px; text-align: center;">0-25%<br/>25-50%<br/>50-75%<br/>75-100%</td> <td style="padding: 2px; text-align: center;">Low<br/>Mod<br/>High<br/>Most</td> </tr> </table> |  |  | Combined aircraft contribution to overall suppression task (in comparison with total suppression forces) | 0-25%<br>25-50%<br>50-75%<br>75-100%                | Low<br>Mod<br>High<br>Most |   |  |  |  |   |  |
| Fire No./ name/ location/ sector:   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Control agency:   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| FDI (max during operations) <span style="float: right;">(L/ M/ H/ VH/ E)<br/>(forest/ grassland)</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Max wind speed: <span style="float: right;">km/h</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Wind direction: <span style="float: right;">(N/NE/E/SE/S/SW/W/NW)</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Max temperature: <span style="float: right;">°C</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Minimum relative humidity: <span style="float: right;">%</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Drought index: KBDI/ SDI <span style="float: right;">0-24/ 25-62/ 63-100/ 100+</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Fire aspect: <span style="float: right;">(N/NE/E/SE/S/SW/W/NW)</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Fire slope (average): Nil/ Low/ Mod/ Steep  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Fire elevation (m ASL):   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Vegetation type(s): Grass[Natural/ Grazed/ Eaten]/ Crop/ Scrub/ Forest /Heath/ Mallee/ Alpine/ Plantation   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Curing: <span style="float: right;">% (grass fuels only)</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Surface fine fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Near-surface fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Elevated fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Bark fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Overall fuel hazard: <span style="float: right;">L/ M/ H/ VH/ E</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Fuel involved on arrival: Surf/ NSF/ Elev/ Bark/ Crown  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Average flame height during operations (m):   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Maximum flame height (m): <span style="float: right;">Time/ date:</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Fire size on arrival (ha):  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Final fire size (ha):   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Total fire perimeter (final):   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Combined aircraft contribution to overall suppression task (in comparison with total suppression forces)  | 0-25%<br>25-50%<br>50-75%<br>75-100%   | Low<br>Mod<br>High<br>Most   |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| <p><b>Timing</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="padding: 2px;">Detection time (24hrs):</td></tr> <tr><td style="padding: 2px;">Detection to first suppression work – Aircraft (hrs):</td></tr> <tr><td style="padding: 2px;">Detection to first suppression work – Ground (hrs):</td></tr> <tr><td style="padding: 2px;">First suppression work to checking (hrs):</td></tr> <tr><td style="padding: 2px;">Could containment have been achieved by ground forces only in the first 8 hours: <span style="float: right;">Y/N</span></td></tr> <tr><td style="padding: 2px;">24 hours: <span style="float: right;">Y/N</span></td></tr> </table>   | Detection time (24hrs):  | Detection to first suppression work – Aircraft (hrs):  | Detection to first suppression work – Ground (hrs):   | First suppression work to checking (hrs):   | Could containment have been achieved by ground forces only in the first 8 hours: <span style="float: right;">Y/N</span> | 24 hours: <span style="float: right;">Y/N</span>   | <p><b>Ground Forces</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="padding: 2px;">Ground forces present: Y/N</td></tr> <tr><td style="padding: 2px;">Type and number: .....fire fighters with hand tools<br/>.....light tanker / slip on<br/>.....Heavy tanker<br/>.....Small dozer (=D5)<br/>.....Large dozer (&gt;D6)<br/>.....Graders/ other plant</td></tr> <tr><td style="padding: 2px;">Amount of handtrail built ground forces:.....(m) <span style="float: right;">*.....<br/>(m/person/hr)</span></td></tr> <tr><td style="padding: 2px;">Amount of dozer/ grader trail built: .....(m) <span style="float: right;">*.....<br/>(m/hr)</span></td></tr> <tr><td style="padding: 2px;">Amount of edge knocked down by tankers: .....(m) <span style="float: right;">*.....<br/>(m/hr)</span></td></tr> <tr><td style="padding: 2px;">Amount of edge knocked down by hose lays.....(m) <span style="float: right;">*.....<br/>(m/hr)</span></td></tr> <tr><td style="padding: 2px;">Amount of backburn lit and controlled:.....(m) <span style="float: right;">*.....<br/>(m/hr)</span></td></tr> </table> <p>(*Optional: Average production rates if they can be easily calculated)</p> |  |   | Ground forces present: Y/N                            | Type and number: .....fire fighters with hand tools<br>.....light tanker / slip on<br>.....Heavy tanker<br>.....Small dozer (=D5)<br>.....Large dozer (>D6)<br>.....Graders/ other plant | Amount of handtrail built ground forces:.....(m) <span style="float: right;">*.....<br/>(m/person/hr)</span>                                    | Amount of dozer/ grader trail built: .....(m) <span style="float: right;">*.....<br/>(m/hr)</span>   | Amount of edge knocked down by tankers: .....(m) <span style="float: right;">*.....<br/>(m/hr)</span>                     | Amount of edge knocked down by hose lays.....(m) <span style="float: right;">*.....<br/>(m/hr)</span>              | Amount of backburn lit and controlled:.....(m) <span style="float: right;">*.....<br/>(m/hr)</span> |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Detection time (24hrs):   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Detection to first suppression work – Aircraft (hrs):   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Detection to first suppression work – Ground (hrs):   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| First suppression work to checking (hrs):   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Could containment have been achieved by ground forces only in the first 8 hours: <span style="float: right;">Y/N</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| 24 hours: <span style="float: right;">Y/N</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Ground forces present: Y/N  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Type and number: .....fire fighters with hand tools<br>.....light tanker / slip on<br>.....Heavy tanker<br>.....Small dozer (=D5)<br>.....Large dozer (>D6)<br>.....Graders/ other plant  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Amount of handtrail built ground forces:.....(m) <span style="float: right;">*.....<br/>(m/person/hr)</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Amount of dozer/ grader trail built: .....(m) <span style="float: right;">*.....<br/>(m/hr)</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Amount of edge knocked down by tankers: .....(m) <span style="float: right;">*.....<br/>(m/hr)</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Amount of edge knocked down by hose lays.....(m) <span style="float: right;">*.....<br/>(m/hr)</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Amount of backburn lit and controlled:.....(m) <span style="float: right;">*.....<br/>(m/hr)</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| <p><b>Firebombing</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="padding: 2px;">AAS operating: <span style="float: right;">Y/N</span> fixed wing/ helicopter/ ground</td></tr> <tr><td style="padding: 2px;">Number of bombing aircraft and type: ..... Fixed wing<br/>Helicopter ..... Heavy (1) ..... Medium (2) ..... Light (3)</td></tr> <tr><td style="padding: 2px;">Loads used and type:<br/>..... Water .....Foam ..... Retardant .....Gel</td></tr> <tr><td style="padding: 2px;">Fire perimeter affected by firebombing operation:.....(%)<br/>Of this (%), how much head%....flank%....back%....spot</td></tr> <tr><td style="padding: 2px;">Fire bombing contribution to perimeter containment task (in comparison with total containment forces)</td> <td style="padding: 2px; text-align: center;">0-25%<br/>25-50%<br/>50-75%<br/>75-100%</td> <td style="padding: 2px; text-align: center;">Low<br/>Mod<br/>High<br/>Most</td> </tr> </table>  | AAS operating: <span style="float: right;">Y/N</span> fixed wing/ helicopter/ ground | Number of bombing aircraft and type: ..... Fixed wing<br>Helicopter ..... Heavy (1) ..... Medium (2) ..... Light (3)                 | Loads used and type:<br>..... Water .....Foam ..... Retardant .....Gel  | Fire perimeter affected by firebombing operation:.....(%)<br>Of this (%), how much head%....flank%....back%....spot | Fire bombing contribution to perimeter containment task (in comparison with total containment forces)                   | 0-25%<br>25-50%<br>50-75%<br>75-100%   | Low<br>Mod<br>High<br>Most  | <p><b>Aircraft Restrictions and Resourcing</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td style="padding: 2px;">Were aircraft restricted by:</td> <td style="padding: 2px;">Was this critical to checking?</td> </tr> <tr><td style="padding: 2px;">Terrain/ Turbulence <span style="float: right;">Y/N</span></td> <td style="padding: 2px; text-align: center;">Y/N</td> </tr> <tr><td style="padding: 2px;">Smoke <span style="float: right;">Y/N</span></td> <td style="padding: 2px; text-align: center;">Y/N</td> </tr> <tr><td style="padding: 2px;">Daylight <span style="float: right;">Y/N</span></td> <td style="padding: 2px; text-align: center;">Y/N</td> </tr> <tr><td style="padding: 2px;">Vegetation <span style="float: right;">Y/N</span></td> <td style="padding: 2px; text-align: center;">Y/N</td> </tr> <tr><td style="padding: 2px;">Other restrictions?:</td> <td></td> </tr> <tr><td style="padding: 2px;">Were there enough aircraft for first attack?: <span style="float: right;">Y/N</span></td> <td></td> </tr> <tr><td style="padding: 2px;">the larger event?: <span style="float: right;">Y/N</span></td> <td></td> </tr> <tr><td style="padding: 2px;">If not, how many more and what type were required?</td> <td></td> </tr> <tr><td style="padding: 2px;">Fixed wing <span style="float: right;">.....</span></td> <td style="padding: 2px; text-align: center;">Larger event</td> </tr> <tr><td style="padding: 2px;">Light helicopter <span style="float: right;">.....</span></td> <td></td> </tr> <tr><td style="padding: 2px;">Medium helicopter <span style="float: right;">.....</span></td> <td></td> </tr> <tr><td style="padding: 2px;">Heavy helicopter <span style="float: right;">.....</span></td> <td></td> </tr> </table> |   |   | Were aircraft restricted by:   | Was this critical to checking?  | Terrain/ Turbulence <span style="float: right;">Y/N</span>   | Y/N   | Smoke <span style="float: right;">Y/N</span>   | Y/N   | Daylight <span style="float: right;">Y/N</span>  | Y/N  | Vegetation <span style="float: right;">Y/N</span>      | Y/N   | Other restrictions?:   |                            | Were there enough aircraft for first attack?: <span style="float: right;">Y/N</span> |                               | the larger event?: <span style="float: right;">Y/N</span>  |  | If not, how many more and what type were required? |  | Fixed wing <span style="float: right;">.....</span> | Larger event               | Light helicopter <span style="float: right;">.....</span> |  | Medium helicopter <span style="float: right;">.....</span> |  | Heavy helicopter <span style="float: right;">.....</span> |  |
| AAS operating: <span style="float: right;">Y/N</span> fixed wing/ helicopter/ ground  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Number of bombing aircraft and type: ..... Fixed wing<br>Helicopter ..... Heavy (1) ..... Medium (2) ..... Light (3)  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Loads used and type:<br>..... Water .....Foam ..... Retardant .....Gel  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Fire perimeter affected by firebombing operation:.....(%)<br>Of this (%), how much head%....flank%....back%....spot   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Fire bombing contribution to perimeter containment task (in comparison with total containment forces)   | 0-25%<br>25-50%<br>50-75%<br>75-100%   | Low<br>Mod<br>High<br>Most   |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Were aircraft restricted by:  | Was this critical to checking?   |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Terrain/ Turbulence <span style="float: right;">Y/N</span>  | Y/N  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Smoke <span style="float: right;">Y/N</span>  | Y/N  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Daylight <span style="float: right;">Y/N</span>   | Y/N  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Vegetation <span style="float: right;">Y/N</span>   | Y/N  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Other restrictions?:  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Were there enough aircraft for first attack?: <span style="float: right;">Y/N</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| the larger event?: <span style="float: right;">Y/N</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| If not, how many more and what type were required?  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Fixed wing <span style="float: right;">.....</span>   | Larger event   |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Light helicopter <span style="float: right;">.....</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Medium helicopter <span style="float: right;">.....</span>  |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| Heavy helicopter <span style="float: right;">.....</span>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |
| <p><b>Comments and Attachments</b></p> <p>Please attach any additional comments or information, such as incident reports, maps/ sketch plans, photos (with captions) etc.</p>   |  |  |   |   |   |  |   |  |   |   |  |   |  |   |  |   |  |  |  |   |  |                            |  |                               |  |  |  |  |   |                            |   |  |  |  |   |  |

## Suppression Operational Report - Explanatory notes on data fields

### Operations Officer

**Name, Agency** (self explanatory),  
**Normal Fire District:** home district of operations officer  
**Operational Fire District:** where suppression operation occurred.  
**IMT operating :** was an IMT established to manage the suppression operation on the first day Y/N.

### Fire Information

**Fire No./Name/Location/Sector :** Fire number or name if allocated, general locality of fire, sector name if allocated.  
**Control Agency:** agency responsible for suppression of fire.  
**FDI Maximum Fire Danger Index** during suppression operations for that day (note significant changes to FDI during the day in Comments). State weather the forest or grassland meter has been used  
**Wind speed & direction:** maximum wind speed (km/h) & direction during suppression (esp. firebombing) operations (note significant wind change in Comments)  
**Temp & RH:** include if on-site or AWS data available  
**Drought Index/Soil Dryness:** note if observed – circle KBDI or SDI and range: 0-25 (Wet Soil), 26-62 (Damp Soil), 63-100 (Dry Soil), 100+ (Very Dry Soil).  
**Fire aspect** main topographic aspect of the fire – indicate if split between 2 or 3 aspects  
**Fire Elevation:** elevation of fire (m) above sea level.  
**Slope :** slope class for the fire generally: Nil=flat, Low<5°, Mod <15°, Steep >15°  
**Vegetation Type(s):** class(es) of vegetation for fire area generally. For grass fuels indicate whether they are natural, grazed (including cut) or eaten out.  
**Curing (%) :** estimated percent dead grass (grass fuels only)  
**Component and Overall Fuel Hazard:** Surface Fine Fuel Hazard, Bark Hazard, Near-surface Fuel Hazard, Elevated Fuel Hazard & Overall Fuel Hazard as per Overall Fuel Hazard Guide (1999)  
**Fuel involved on arrival:** fuel components involved in the *flaming zone of the fire* at arrival.  
**Flame height – Average/Maximum:** average flame height (m) during operations, maximum flame height. State time/date of maximum flame height observation.  
**Fire Size - Arrival:** fire size (ha) at time of 1<sup>st</sup> suppression forces arrival.  
**Final Fire Size:** fire size (ha) at the cessation of suppression.  
**Total fire perimeter (final):** length of perimeter around the fire.

### Timing

**Detection time:** time of first detection of fire;  
**Detection to first suppression work, aircraft and ground:** time passed between detection and first direct suppression/containment work;  
**First Suppression work to checking:** time for all suppression forces to halt further spread of fire.  
**Containment without aircraft** - estimate if ground suppression forces could have achieved containment in 8 hrs, or 24 hrs, without the aircraft effort.

### Firebombing

**AAS operating :** note Y/N Fixed wing, helicopter or ground  
**No. of firebombing aircraft and type** (self explanatory),  
**Loads used and type:** Number of loads of water, foam, retardant, and gel delivered by bombing aircraft

**Fire perimeter affected by aircraft operation:** estimated percentage of total perimeter affected by firebombing. Of this piece of perimeter affected by firebombing, what types of fire were mostly affected i.e. head/ flank/ back/ spot - split into % again  
**Firebombing contribution to perimeter containment:** estimate the contribution of firebombing to the perimeter containment task i.e. as a part of the total containment line construction.

### Other Aircraft Use

**Other aircraft uses:** note if aircraft also used for: recon/mapping, crew transport, command and control, FLIR/Linescan, aerial ignition.  
**Rappel/RAFT crew deployed:** no. in crew (no.), handtrail built (m), helipads built (no.)  
**Aircraft command and control** – note if aircraft helped improve deployment of ground forces, and was this critical to containment Y/N.  
**Aircraft recon** – note if aircraft helped locate fire for ground forces, and was this critical to containment Y/N.  
**Aircraft ferry** – note if aircraft transported crew (includes Rappel/RAFT) to fire and was this critical to containment Y/N.

### Overall Aircraft Effectiveness

**Aircraft contribution to overall suppression task** – give an estimate of the aircraft contribution to the overall suppression task, in comparison with total suppression forces.  
*(i.e. if Air Suppn + Ground Suppn = Total Suppn Effort, Air Suppn% = ?)*

### Ground forces (i.e. accessed fire from ground)

**Present:** note if any ground forces were working Y/N.  
**Type and number:** note the number of for each type – active suppression only, [not support or back-up]  
**Amount of .....**: distance of **handtrail built by ground forces** (built by crews who accessed the fire by vehicles, not Rappel/ RAFT crews), **dozer/ grader trail built** (dozer trail, along fire line only), **edge knocked down by tankers, edge knocked down by hose lays** (more than 2 lengths of hose from a tanker, or using a portable pump), or **backburn lit and controlled** (total length of backburn). \* **Optional:** please give any **average production rates** (handtrail in m/person/hr, other containment lines in m/hr), if they can be readily calculated.

### Aircraft Restrictions & Resourcing

**Note the important restrictions** to aircraft use, including both the ones listed, and any others which may have been important e.g. communications. Note particularly if these restrictions were critical to the overall forces not checking the fire at first attack (or extended first attack).  
**Note whether there were enough aircraft for the task at hand**, both for first attack, and also for the larger event (if fire went to Extended First Attack or Campaign status)  
**Note types and numbers of aircraft required** which potentially could have improved the outcome status of the fire. Outcome status definitions:  
**Normal First Attack:** within 8 hrs, mostly <10 ha;  
**Extended First Attack:** within 48 hrs, mostly <400 ha;  
**Campaign Fire:** more than 48 hrs, mostly > 400 ha

### Comments & Attachments

Please note any further information about the fire suppression operation which was particularly important and may not be obvious from the above data. Please include a sketch plan, any maps, and particularly any photos (with captions) which could help appreciation of what occurred during suppression.

### Appendix 3. Research Application of Aircraft Tracking Data

This appendix presents examples of aircraft tracking data collected from operational fires. Examples of some basic productivity data collected from fixed wing firebombers and helicopters are presented in Sections A3.1 and A3.2 respectively. A case study comparing two simultaneous fires containing productivity information derived from tracking systems is given in Section A3.3.

#### A3.1 Examples of productivity data – Fixed wing firebombers

Aircraft tracking data were collected from fixed wing firebombers with satellite tracking systems installed (e.g. Satloc, AgNav).

These dedicated tracking systems yielded valuable data and were configured to record:

- Latitude and longitude
- Aircraft speed
- Aircraft height
- Aircraft direction
- Time

Synthesis of the tracking data can be used to reconstruct firebombers' flight paths to estimate the location and timing of aerial drops. Examples of productivity data taken from fixed wing firebombers working on operational fires are given in Table A3.1. This table shows turnaround time data collected direct from the tracking systems log file along with some drop length data measured on the ground by researchers. Average productivity can be calculated when both turnaround times and average drop lengths are known.

**Table A3.1.** Examples of productivity data derived from tracking systems installed in fixed wing firebombers.

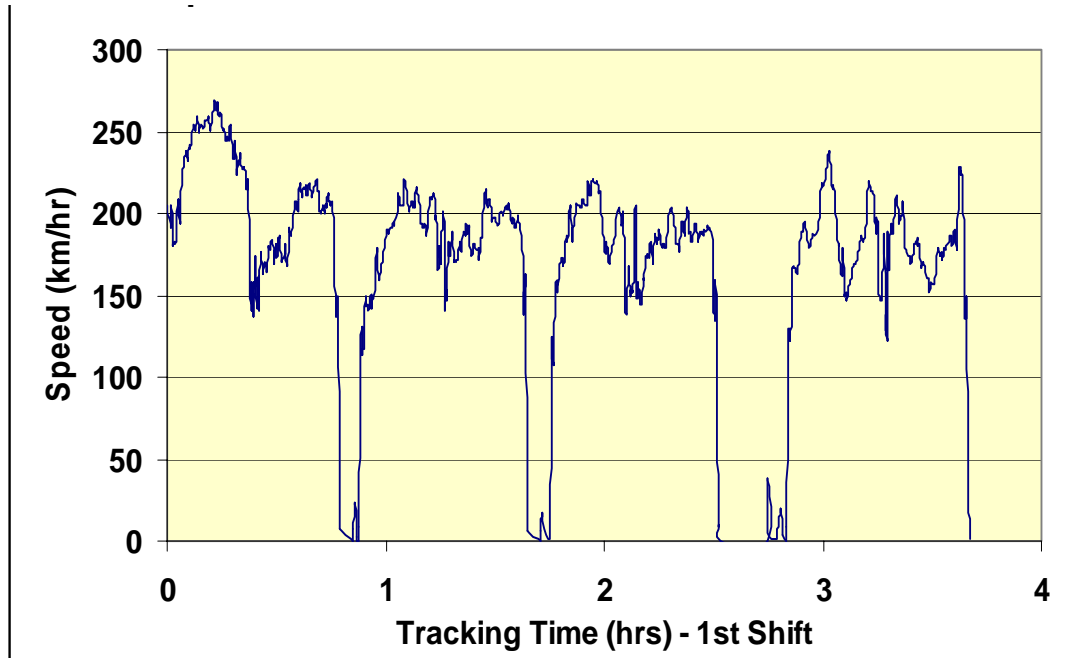
| <b>Fire name</b>                             | <b>Aircraft type used for data collection</b> | <b>Average turnaround time (minutes)</b> | <b>Average drop length measured (m)</b> | <b>Average productivity (m h<sup>-1</sup>)</b> |
|--|---|--|---|--|
| Griffin Track<br>(21/12/05 Horsham Fire #17) | AT 802  | 47                                       | 68                                      | 87   |
| Billywing<br>(20/1/06 Horsham Fire #30)      | 2 x<br>AT 802                                 | -  | 60*                                     | -  |
| Neerabup<br>(19/2/06 Swan Coastal Fire #94)  | AT 802<br>AT 602                              | 34<br>49**                               | -                                       | -  |
| Mt King<br>(1/3/06 Cann River Fire #36)      | Dromader                                      | -  | 62                                      | -  |
| Granite Creek<br>(12/3/06 Orbost Fire #16)   | Dromader                                      | 46                                       | -                                       | -  |

\* Average of two drops with unknown overlap

\*\* AT 602 started at a base 80km further from fire than AT 802, so had a much slower turnaround time for its first drop.



Turnaround times can be determined from aircraft speed recorded in the log file. An example of speed data from a firebombing mission is given in Figure A3.1. The zero speed points correspond with the refilling times. The most prominent dips in speed during each travel period correspond with the times that drops were made. A list of turnaround times from Figure A3.1 is given in Table A3.2.



**Figure A3.1.** Aircraft speed versus tracking time (hours) of a PZL Dromader firebomber at the Granite Creek Fire from aircraft GPS, first 4 hours (first shift).

**Table A3.2** Turnaround times (take-off, deliver load, return to reload) of a PZL Dromader firebomber at the Granite Creek Fire.

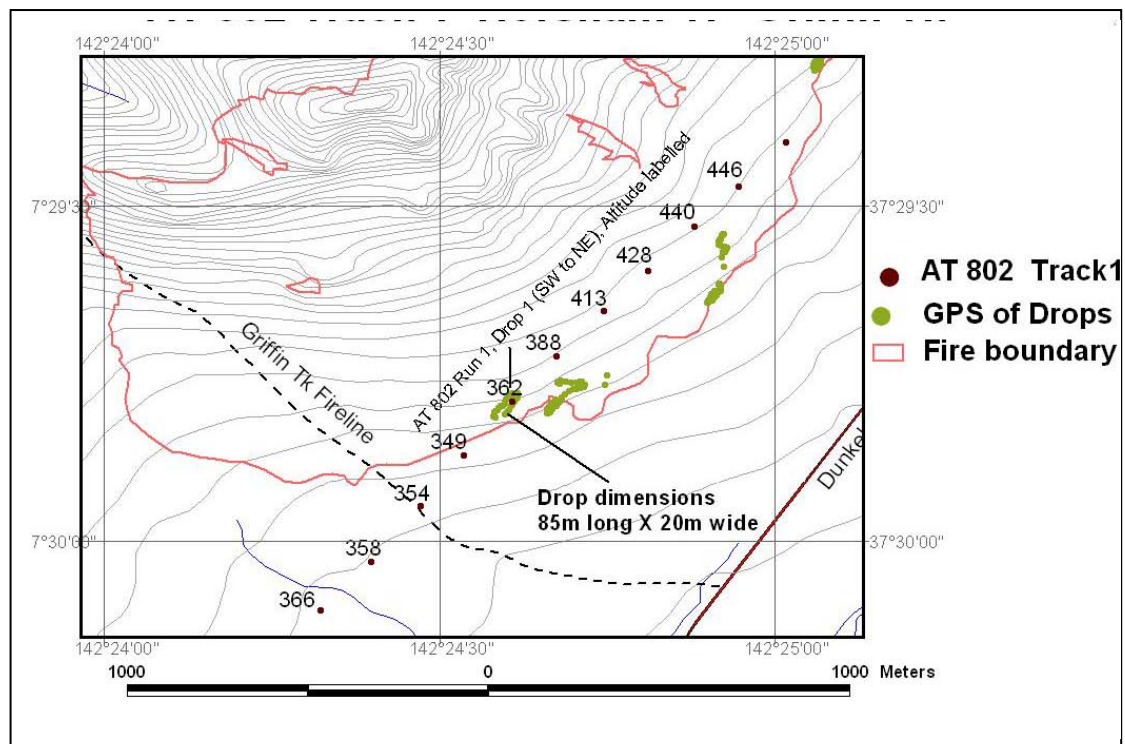
| <b>Bomb run no.</b> | <b>Turnaround (minutes)</b> | <b>Depart - Reload Base(s)</b> | <b>Turnaround distance (km)</b> |
|---------------------|-----------------------------|--------------------------------|---------------------------------|
| 1                   | 60                          | Benambra - Delegate            | 165                             |
| 2                   | 52                          | Delegate - Delegate            | 130                             |
| 3                   | 47                          | Delegate - Delegate            | 130                             |
| 4                   | 50                          | Delegate - Delegate            | 130                             |
| 5                   | 54                          | Delegate - Marlo               | 96                              |
| 6                   | 32                          | Marlo - Marlo                  | 62                              |
| 7                   | 32                          | Marlo - Marlo                  | 62                              |
| <b>Average</b>      | <b>46</b>                   |                                | <b>111</b>                      |

The perimeters of the drop patterns were located using a handheld GPS. The GPS units were accurate to within 2-3m. This was sufficient to record drop dimensions for placement into a geographic information system (GIS). Long term retardant remained visible on the site until washed away by rain and thus could be located some days after the suppression operation. Foam and water drops were very difficult to find and could not be located more than an hour after dropping. Examples of retardant drop pattern dimensions measured during ground verification are given in Table A3.3.

**Table A3.3.** Drop dimensions from 10 retardant drops located by GPS plot on the fireground at the Griffin Track Fire.

| Drop position  |            | Drop length | Drop width | Drop area         |
|----------------|------------|-------------|------------|-------------------|
| Latitude       | Longitude  | (m)         | (m)        | (m <sup>2</sup> ) |
| S 37.4967      | E 142.4099 | 85          | 20         | 1900              |
| S 37.4965      | E 142.4113 | 75          | 13         | 2000              |
| S 37.4960      | E 142.4116 | 58          | 17         | 1500              |
| S 37.4939      | E 142.4152 | 60          | 10         | 900               |
| S 37.4925      | E 142.4153 | 61          | 8          | 900               |
| S 37.4881      | E 142.4177 | 73          | 15         | 1400              |
| S 37.4863      | E 142.4193 | 82          | 9          | 1400              |
| S 37.4852      | E 142.4193 | 75          | 12         | 1400              |
| S 37.4797      | E 142.4220 | 70          | 12         | 1500              |
| S 37.4784      | E 142.4218 | 40          | 20         | 1100              |
| <b>Average</b> |            | <b>68</b>   | <b>14</b>  | <b>1400</b>       |

Tracking data and associated ground verification data can be overlaid on GIS base maps. An example of this is given in Figure A3. The height and direction of the firebomber are displayed from the aircraft GPS data. The ground GPS data show the dimensions of the drop pattern (long-term retardant) from the inputs of load volume, aircraft speed, height and heading.



**Figure A3.3.** Altitude labelled track (brown dots) of an Air Tractor 802 at the Griffin Track Fire also showing ground GPS plot of retardant drop area (green areas).

The firebomber track in Figure A3.3 shows the following information:

1. The firebomber can be seen descending into the drop target from the southwest and ascending away from the drop to the northeast.

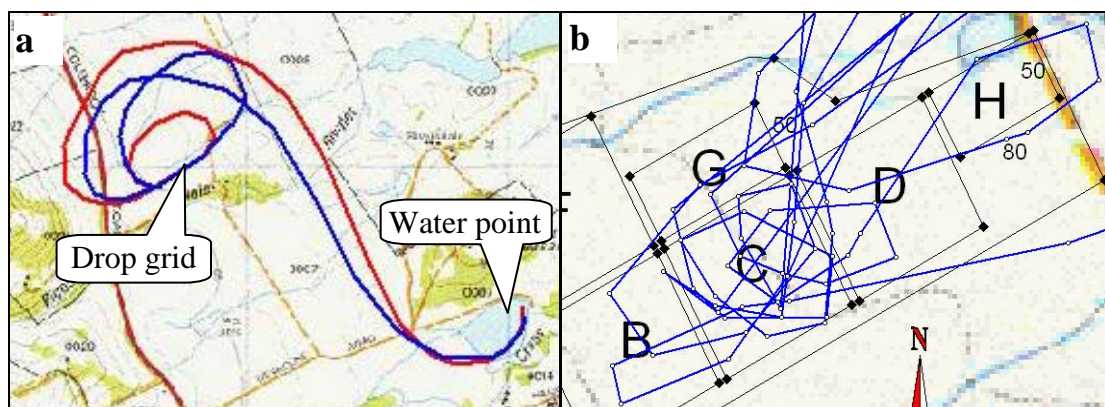
2. The tracks lowest point is just before the drop. The drop dimensions measured on the ground were 85m long by 20m wide.
3. The aircraft speed stabilises at  $220\text{km h}^{-1}$  prior to the drop (Note: this is not shown on the map, but is contained in the data file of the track).
4. The drop height is about 17m above the canopy (digital terrain elevation 320m, canopy height 12m, aircraft GPS altitude about 349m).

### A3.2 Examples of productivity data – Helicopters

A major problem in analysing GPS track data from helicopters arises from the complexity of their flight paths during aerial suppression activities. Helicopters are able to make quick changes in direction, making it difficult to determine drop location and calculate turnaround times.

Tracking systems are less common in helicopters than infixed wing aircraft that are used for agricultural spraying. Most aircraft have at least one standard GPS unit installed, which can be used to provide a limited track log of a mission. The logging rate of these non-specialised units may be less frequent than specialised tracking systems. The tracking record from a standard GPS mounted in a helicopter is of a coarser resolution and does not have a record of timing and location of suppressant drops.

Examples of helicopter track logs plotted from a standard GPS during suppression experiments (Plucinski *et al.* 2006) are given in Figure A3.4a and b. Figure A3.4a shows the tracks of a helicopter dropping water on a container grid to determine drop pattern characteristics. The track file could be used to determine the speed and height of the helicopter when dropping, but only because the exact time and location of the drop was known. Figure A3.4b illustrates problems associated with complex helicopter flight paths and infrequent and irregular logging times for plotting tracks from a fire with multiple split load drops.



**Figure A3.4:** **a)** GPS track of helicopter flight path during drop pattern testing (different colour lines represents two different drop flights). **b)** Complex helicopter flight path associated with multiple split load drops on an experimental fire.

A log was obtained from a specialised tracking system installed in a high volume Type 1 helicopter. This was the only known helicopter to have a tracking system

installed during the 2005/06 fire season in Australia. The format of the track log generated from this particular system was cumbersome and the information required for track plotting was difficult to retrieve. The tracking system was able to collect information on position, speed, direction, and the load weight. The load weight could be used to calculate the volume of each drop. Information collected during the suppression of a 5 hectare fire by this tracking system is presented in Table A3.4. The timing data in this table was verified by notes taken during the operation.

The resolution of the location information captured by this system was coarse, and did not allow the exact location of drops to be determined. Drop times and the volume of each drop can be determined by the weights recorded in the track log. The event log presented in Table A3.4 shows that the load volume of the loads picked up by the helicopter increased with time until the helicopter was refuelled. Only the two drops made immediately before refuelling were within 1000L of the maximum capacity able to be carried by this aircraft (9000L).

Productivity could not be determined for this fire as most of the drops were not used for line holding. Many of the drops targeted burning material away from the fire edge, as access for ground crews was difficult.

**Table A3.4.** Event log of a Type 1 helicopter working on a 5 hectare fire.

| Load | Drop | Time     | Latitude  | Longitude  | Speed<br>(km h <sup>-1</sup> ) | Load<br>capacity<br>(litres) | Turnaround<br>time<br>(min:sec) | Water<br>source |
|------|------|----------|-----------|------------|--------------------------------|------------------------------|---------------------------------|-----------------|
| 1    | 1    | 15:04:58 | S 33 24.9 | E 150 44.2 | 102                            | 5900                         |                                 | far dam         |
| 2    | 2    | 15:14:33 | S 33 25.0 | E 150 44.2 | 98                             | 5800                         | 09:35                           | far dam         |
| 3    | 3    | 15:20:31 | S 33 25.0 | E 150 44.2 | 115                            | 6000                         | 05:58                           | horse dam       |
| 4    | 4    | 15:31:04 | S 33 24.9 | E 150 44.2 | 111                            | 5500                         | 10:33                           | far dam         |
| 5    | 5    | 15:35:28 | S 33 25.0 | E 150 44.2 | 131                            | 6900                         | 04:24                           | near dam        |
| 6    | 6    | 15:39:54 | S 33 25.0 | E 150 44.2 | 109                            | 6800                         | 04:26                           | near dam        |
| 7    | 7    | 15:44:16 | S 33 24.9 | E 150 44.2 | 119                            | 6900                         | 04:22                           | near dam        |
| 8    | 8    | 15:49:26 | S 33 24.9 | E 150 44.2 | 122                            | 8100                         | 05:10                           | near dam        |
| 8    | 9    | 15:50:20 | S 33 25.0 | E 150 44.1 | 107                            |                              |                                 |                 |
| 9    | 10   | 15:54:46 | S 33 24.9 | E 150 44.2 | 104                            | 7900                         | 05:20                           | near dam        |
| 9    | 11   | 15:55:50 | S 33 25.0 | E 150 44.1 | 109                            |                              |                                 |                 |
| 10   | 12   | 16:00:26 | S 33 24.9 | E 150 44.2 | 128                            | 8100                         | 05:40                           | near dam        |
| 10   | 13   | 16:01:35 | S 33 25.0 | E 150 44.2 | 107                            |                              |                                 |                 |
| 11   | 14   | 16:07:00 | S 33 25.0 | E 150 44.1 | 113                            | 8000                         | 06:34                           | near dam        |
| 11   | 15   | 16:08:00 | S 33 24.9 | E 150 44.2 | 124                            |                              |                                 |                 |
| 12   | 16   | 16:22:18 | S 33 24.9 | E 150 44.2 | 91                             | 6000                         | 15:18 <sup>1</sup>              | near dam        |
| 13   | 17   | 16:26:17 | S 33 24.8 | E 150 44.2 | 113                            | 5600                         | 03:59                           | near dam        |

<sup>1</sup> This turnaround time includes refuelling of the aircraft.

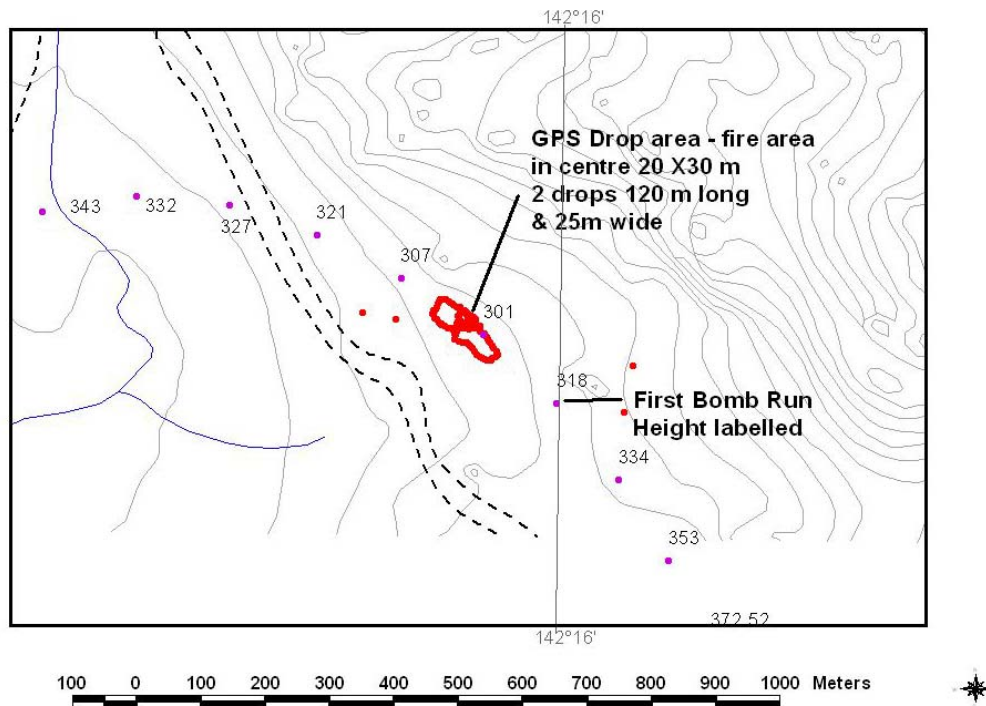
### A3.3 Operational first attack comparison using productivity data

Firebomber logs were obtained for two fire events which occurred in the Horsham Fire District (western Victoria) on Friday 20 January 2006 (FFDI 26). The first fire (Mt Lubra fire), could not be contained at first attack, and eventually burnt out 130,000ha of the Grampians National Park. The second fire (Billywing fire) was effectively contained at first attack using two drops of fire retardant. The Billywing fire had the potential to spread rapidly in difficult terrain and fuels, and could have potentially burnt out many thousands of additional hectares in the western Grampians if not contained at first attack.

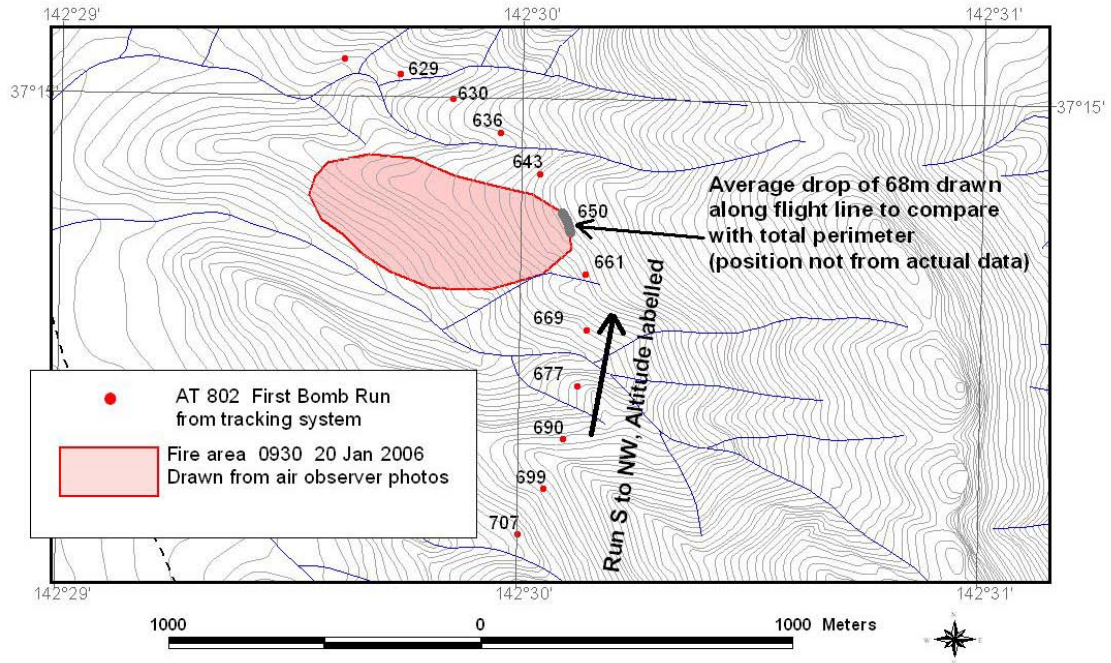
The important difference between these two fire events was the initial fire size when aerial first attack was started. The Billywing fire, was only 0.04 hectares with a 90 metre perimeter when effectively contained by two drops of retardant (Figures A3.5). The Mt Lubra fire was estimated to be 25 hectares with a 2000 metre perimeter when first aerial attack started (Figure A3.6).

With an average turnaround of 30 minutes for the Mt Lubra Fire (from the track log), and allowing for at least 10m overlap on sequential drops, theoretically a productivity of  $100\text{m h}^{-1}$  (line holding) could have been obtained for a single Air Tractor 802. As the fire was expanding in perimeter at a rate of  $650\text{m h}^{-1}$  (2000m at 0830h to 7500m at 1700h), a fleet of seven to eight aircraft with a similar productivity would have been required to cope with the hourly perimeter increase. A further four to five aircraft would also have been needed to deal with the original 2000m of perimeter. This number of aircraft (if available) would have exceeded the loading capacity of local airstrips during the crucial first attack period.

These two fires illustrate the importance of early detection and rapid first attack to minimise fire size and suppression time. The data collected from these fires provided good quality information for verification of the findings presented in Section 3.



**Figure A3.5.** First drop track, AT 802, at the Billywing Fire at 0915h on 20 January 2006. Fire area 0.04ha (20m x 30m) and 90m perimeter - effectively contained by 2 drops of retardant producing a drop pattern of 120m long and 25m wide.



**Figure A3.6.** First drop track, AT 802, at the Mt Lubra Fire at 0836h on 20 January 2006. Fire area 25ha and 2000m perimeter (estimated from aerial photographs). Assumed drop length of 68m (Table A3.2) drawn along flight path for comparison with fire perimeter (not located from actual tracking data).

## **Appendix 4. Post fire field assessment of suppression drops**

### *Introduction*

This appendix details information collected by researchers at fires. The information presented here was collected using two data collection forms. These forms were designed to be completed on the site of suppression, with the first designed to be filled when the fire is active and suppression operations are in progress. The second form was designed to be completed on the fireground after active suppression had ceased. These forms were designed to capture information on fuel, weather, topography, fire behaviour, and suppression effort (particularly direct firebombing) as well as the suppression effect of firebombing and associated ground suppression at the firebombing location.

The assessment of the effect drops had on fire behaviour was conducted at three different locations around the drop zone:

1. Area where the fire is approaching the drop zone;
2. Within the drop zone; and
3. Area burnt if fire breached, burnt around or spotted over the drop zone.

Researchers sought permission to enter the fire ground from ground crew supervisors and remained in contact with them while on site. Information was collected on fuel, weather, topography, fire behaviour, and suppression effort. The suppression effect of firebombing and associated ground suppression at the firebombing location was recorded. The location and type of ground resources (i.e. hand crew, tankers, dozers, etc) were also recorded. The suppression effects of drops were rated as: no effect, little effect, slowed fire substantially, or stopped fire. The post fire assessments were made using fire severity indicators, such as the heights of leaf scorch, leaf consumption, and bark burnt. Drops that were breached by fire were investigated thoroughly so that the reasons could be determined.

### *Discussion of preliminary results*

Despite the efforts of researchers to get to as many fires as possible data have only been obtained from 16 events (3 events assessed during suppression activities). This was mainly due to the logistic issues related to accessing fire grounds outlined in Section 4.2.

Another major problem in the collection of this data was the temporary nature of the suppressants used. Only two observations were made where the suppressant was foam and only one observation was made where the suppressant was water. Measurements of the effectiveness of water and foam were made immediately after the drop, as the drops were very difficult to locate afterwards (i.e. more than one hour after the drop). The other observations all came from fire grounds where long term retardant was used. Retardant remains visible until washed away by rain and can therefore be identified and assessed by researchers in post fire surveys.



Fire severity indicators from seven drops that were breached are listed in Table A4.1. In these cases the drops were breached due to the absence of ground suppression within the vicinity of the drop before the fire was able to burn through or around it.

**Table A4.1.** Comparative fire severity indicators for seven observations where fire breached the aerial drop zone.

|   | <b>Average leaf consumption height (m)</b> | <b>Average leaf scorch height (m)</b> | <b>Average bark burn height (m)</b> |
|---|--|---------------------------------------|-------------------------------------|
| Area burnt as fire approached drop zone                                 | 1.5  | 12.3                                  | 8.4                                 |
| Area burnt after fire breach drop zone                                  | 0.5  | 8.7                                   | 3.7                                 |
| Average height reduction in fire severity indicators due to drop effect | 1.0  | 3.6                                   | 4.7                                 |

The main differences between the observations of drops that halted fire spread and those of drops that were breached are detailed in Table A4.2. The table highlights the importance of follow up ground suppression and the type of fire impacting the drop zone. All of the drops that stopped fires were supported by ground crews constructing mineral earth breaks in place. The type of fire impacting the drop zone is indicative of fire intensity, with head fires exhibiting higher intensities than flank and backing fires.

**Table A4.2.** Differences in fire outcomes with ground suppression and head fire impact.

| <b>Outcome type</b>                                  | <b>Percent with ground suppression present (within 2 hours)</b> | <b>Average percent of drop length impacted by head fire</b> |
|--|---|---|
| Fire crossed aerial drop zone (7 observations)       | 14  | 36  |
| Fire did not cross aerial drop zone (9 observations) | 67  | 6   |

There were insufficient data to draw strong conclusions or recommendations but the data indicates some general trends:

1. Observations of drops that did not stop fire spread found evidence of reduced fire intensity (reduction in leaf consumption height, leaf scorch height and bark burn height) but no evidence of ground suppression follow up after the drop (i.e. <2 hours).
2. Aerial suppression is more likely to halt fire spread when backed up with ground support, such as construction of a mineral earth trail as soon as possible after the drop has occurred.
3. Drop zones are more likely to be burnt through (or spotted over) when impacted by high intensity fire.

### *Successful aerial suppression without associated ground suppression*

There were only four documented examples of aerial suppression being effective in the absence of ground suppression in the current researcher and operational datasets (300 observations).

Post fire assessment by the research team of a small spot fire (20m x 27m) associated with the Fulham fire (Dept of Sustainability and Environment Horsham Fire 18, 13 January 2005) found it to be contained by seven loads of retardant. Although a mineral earth trail was eventually placed around this fire three days later, the retardant had effectively stopped any fire spread and the fire had burnt out.

Three reports of aerial suppression containing fires using Class A foam were made by operations personnel completing Suppression Operations Reports. These fires were also very small (<0.05ha), had flame heights less than 0.5m, burnt under relatively mild weather conditions, and had minimal canopy impact on drop penetration. Two of these fires were also in light and patchy fuels.

The low frequency (<2%) of these observations demonstrates that fire containment from aerial suppression alone is rare and requires favourable weather and fuel conditions. Successful aerial suppression in the absence of ground support was also only where the fires were small (i.e. <0.5ha). The current data indicate that aerial suppression with associated ground suppression is more likely to produce effective fire containment.

### *Future work*

More data is required to verify the trends in the operational fireground data collected by researchers. Experimental work, where fire behaviour and drop characteristics can be closely monitored, is required to obtain this data. Opportunities to collect sound fireground data operationally are limited and are unlikely to yield enough data to draw statistically valid conclusions. Operational fireground observations from researchers are useful for indicating trends and could assist operational verification of experimental results.