Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Research and Analysis Report – B2005/0055

Final

Wire-strike Accidents in General Aviation: Data Analysis 1994 to 2004

Re-released

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Abstract

Wire strikes are a significant safety concern for the aviation industry, in particular, the general aviation sector. Wire strikes may result in fatalities and/or the destruction of an aircraft. This report analyses the characteristics of wire-strike occurrences in the general aviation sector using accident and incident data collected by the Australian Transport Safety Bureau. The analysis found that 119 wire-strike accidents and 98 wire-strike incidents were reported between 1994 and 2004. The rate of wire-strike accidents reported per 100,000 hours flown ranged from around 0.9 in 1997 and 1998 to 0.1 in 2003. The figures suggested a downward trend beginning in 1998, with a return to previous accident rates in 2004. Reported wire-strike accidents were primarily in three of the statistical groups used by the Australian Transport Safety Bureau for investigative purposes – aerial agriculture, other aerial work, and private/business. The majority of wire-strike accidents were associated with aerial agriculture operations (62 per cent) followed by other aerial work (20 per cent), and private/business operations (15 per cent). The findings reinforce the clear danger to pilots flying at low level in the vicinity of powerlines and the need to be proactive in reducing the risks associated with such, including the implementation of risk management plans, thorough pre-flight planning and preparation, ongoing training, the use of powerline markers, and due diligence and care.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations. Accordingly, the ATSB also conducts investigations and studies of the transport system to identify underlying factors and trends that have the potential to adversely affect safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and, where applicable, relevant international agreements. The object of a safety investigation is to determine the circumstances to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and findings. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. While the Bureau issues recommendations to regulatory authorities, industry, or other agencies in order to address safety issues, its preference is for organisations to make safety enhancements during the course of an investigation. The Bureau is pleased to report positive safety action in its final reports rather than make formal recommendations. Recommendations may be issued in conjunction with ATSB reports or independently. A safety issue may lead to a number of similar recommendations, each issued to a different agency.

The ATSB does not have the resources to carry out a full cost-benefit analysis of each safety recommendation. The cost of a recommendation must be balanced against its benefits to safety, and transport safety involves the whole community. Such analysis is a matter for the body to which the recommendation is addressed (for example, the relevant regulatory authority in aviation, marine or rail in consultation with the industry).

EXECUTIVE SUMMARY

The aim of this study was to provide an analysis of wire-strike accidents and incidents. This should increase knowledge and insight in the Australian aviation community and improve safety in low-level flight.

A search of the Australian Transport Safety Bureau's accident and incident database identified 119 wire-strike accidents and 98 wire-strike incidents between 1994 and 2004. The rate of wire-strike accidents per 100,000 hours flown ranged from around 0.9 in 1997 and 1998 to 0.1 in 2003. The figures suggested a downward trend from 1998 to 2003, but in 2004 the rate increased to 0.7.

There were 169 people involved in the 119 wire-strike accidents reported between 1994 and 2004. In almost two-thirds of these accidents the occupant received some degree of injury. There were 45 people fatally injured, 22 seriously injured, and 42 who received minor injuries.

Reported wire-strike accidents and incidents were restricted to general aviation operations, primarily in three of the statistical groups used by the Australian Transport Safety Bureau for investigative purposes – aerial agriculture operations, other aerial work[1], and private/business operations. The majority of wire-strike accidents involved aerial agriculture operations, accounting for 74 accidents or 62 per cent. Other aerial work operations recorded the second highest number of wire-strike accidents with 24 accidents (20 per cent), followed by private/business operations, which accounted for 18 accidents (15 per cent). One accident was recorded in the charter category and two were recorded in the flying training category.

Fixed-wing aircraft were involved in 57 per cent of wire-strike accidents and rotary-wing aircraft were involved in 43 per cent. Given that fixed-wing aircraft out number rotary-wing aircraft by seven to one in the Australian aviation industry, rotary-wing aircraft were over-represented in the data. This imbalance may reflect the different nature of work undertaken by these two types of aircraft, with rotary-wing operations involving a higher level of risk in relation to wire strikes. In the absence of specific data on low-level operations, analysis of risk exposure levels for fixed-wing and rotary-wing operations was not possible.

1 See section 2.3 for definitions of the ATSB statistical groups.

ABBREVIATIONS

AGL	Above ground level
ATSB	Australian Transport Safety Bureau
BASI	Bureau of Air Safety Investigation
BTRE	Bureau of Transport and Regional Economics
CAO	Civil Aviation Orders
CAR	Civil Aviation Regulations
GA	General aviation
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
MTOW	Maximum take-off weight
n	Number
PMA	Prior moving average
RAAF	Royal Australian Air Force
RPT	Regular public transport
SWER	Single wire earth return
TSI Act	Transport Safety Investigation Act
VFR	Visual flight rules
VHF	Very high frequency
WSPS	Wire-strike protection system

1 INTRODUCTION

1.1 Background to the report

The aim of this study was to provide an analysis of wire-strike accidents and incidents to the Australian aviation community to increase knowledge and insight towards improved safety in low-level flight. A search of the Australian Transport Safety Bureau's (ATSB) accident and incident database identified 119 wire-strike accidents and 98 wire-strike incidents between 1994 and 2004. The rate of wire-strike accidents per 100,000 hours flown ranged from around 0.9 in 1997 and 1998 to 0.1 in 2003. The figures suggest a downward trend beginning in 1998, with a return to previous accident rates in 2004.

This research was initiated in response to three wire-strike accidents involving helicopters associated with locust control operations:

- An accident involving a Bell 206B helicopter conducting aerial work near Forbes, New South Wales on 31 October 2004 in support of the Forbes area locust control campaign. The accident resulted in minor injuries to one passenger and extensive damage to the helicopter (ATSB Report: 200404285). The aircraft is pictured in Figure 1.
- An accident involving a Bell 47G-4A helicopter preparing for a locust spraying operation near Mudgee, New South Wales on 1 November 2004. The accident resulted in minor injuries to the pilot and destruction of the aircraft (ATSB Report: 200404286).
- An accident involving a Bell 206B helicopter conducting aerial work near Dunedoo, New South Wales on 22 November 2004 in support of the Dubbo area locust control campaign. The accident resulted in fatal injuries to the pilot and one passenger, serious injuries to another passenger, and extensive damage to the helicopter. (ATSB Report: 200404590). The aircraft is pictured in Figure 2.

Figure 1: Bell 206B helicopter after striking powerlines during a locust control campaign near Forbes on 31 October 2004

Figure 2: Bell 206B helicopter after striking powerlines during a locust control campaign near Dunedoo on 22 November 2004

Wire strikes are associated with low-level flight, including the phases of flight including takeoff and landing. Operating in the low-level environment is inherently dangerous as there are a greater number of obstacles to avoid, there is significantly less time to regain control of an emergency situation, and there is a higher workload as pilots must negotiate the hazardous environment in addition to their normal workload (ATSB, 2005a).

While the hazards of low-level flight are recognised by the aviation industry, some activities require aircraft to be flown at very low levels. For example, most aerial agriculture operations and other aerial tasks such as mustering and powerline inspections are carried out below 500 feet above ground level (AGL).

In some cases the consequences of a wire-strike will be minor; for example, the propeller of a fixed-wing aircraft may cut an unseen wire, or a helicopter pilot may notice the wire in sufficient time to manoeuvre away. In less forgiving circumstances the wire may snare the aircraft, resulting in an accident that could cause the destruction of the aircraft and possible injury or death of the occupants.

Despite research at the flight planning stage, reconnaissance of the proposed ‘low-flying area’ prior to the operation, and a constant lookout during flight, wires are often difficult to detect. The likelihood of a pilot seeing wires is determined by a number of factors including the number of wires, type of support structure, length of wire span, the environment and the background against which the pilot is viewing the wires. Importantly, there is evidence to suggest that many pilots have prior knowledge of the presence of wires before they strike them. This indicates that there are reasons, other than a lack of awareness, causing wire-strike accidents and incidents to occur.

1.2 Objective of the report

The purpose of this report was to examine wire-strike accidents reported to the ATSB involving general aviation operations between 1994 and 2004. A detailed analysis of human factors is beyond the scope of this report.

2 BACKGROUND

2.1 The Australian aviation industry

The Australian civil aviation industry can be divided into four main categories based on *Civil Aviation Regulations 1988*[2]. These are regular public transport (RPT), charter, aerial work and private operations. Civil aviation operations do not include military operations.

Regular public transport operations are those used for the commercial purpose of transporting persons generally, or transporting cargo for persons generally, for hire or reward in accordance with fixed schedules to and from fixed terminals over specific routes with or without intermediate stopping places between terminals[3]. Charter operations are those that carry passengers or cargo for hire or reward and either are not on fixed schedules or are not available for use by persons generally[4].

Aerial work[5] is sub-divided as:

- aerial surveying;
- aerial spotting;
- agricultural operations;
- aerial photography;
- advertising;
- flying training;
- ambulance functions;
- carriage of goods for the purposes of trade other than on fixed schedules; and
- any other purpose that is substantially similar to those specified above.

Private operations[6] include the personal transportation of the aircraft owner, operations for purposes that do not include remuneration and those components for flying training relating to endorsement of an additional type or category of aircraft in a pilot licence.

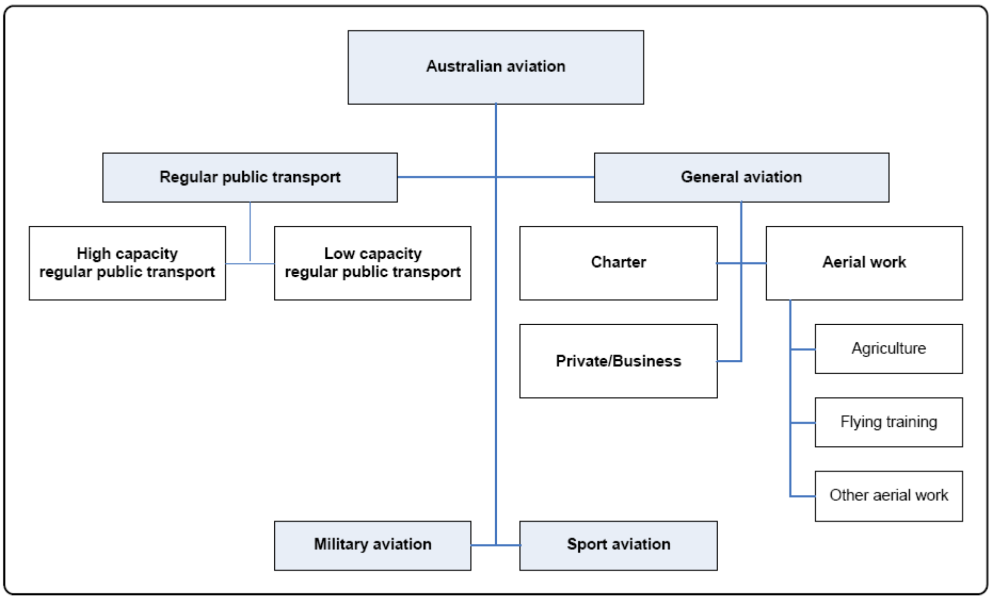
2.2 ATSB accident and incident database

The ATSB is responsible for the independent investigation of accidents and incidents involving civil aircraft in Australia. The ATSB's aviation accident and incident database captures data predominantly from accidents and incidents involving RPT and general aviation (GA) aircraft. Some data on sport and military operations are included in the database.

2 Civil Aviation Regulations 1988 (CAR) 2 (6).
3 CAR 206 (1) (c) and CAR 2 (7) (c).
4 CAR 206 (1) (b) and CAR 2 (7) (b).
5 CAR 206 (1) (a) and CAR 2 (7) (a).
6 CAR 2 (7) (d).

Investigations into accidents involving sport operations (eg ultralights, microlights, gyrocopters, gliders and hang gliders) will only be conducted if it benefits future safety and sufficient resources are available (ICAO, 2003). Military operations are generally overseen by military safety authorities.

Figure 3: ATSB statistical groups for the Australian aviation industry



For statistical purposes, the ATSB divides the Australian aviation industry into several different groups. As shown in Figure 3, the two major groups are RPT and GA, with RPT divided into high capacity and low capacity operations and GA divided into charter, private[7] and business, and aerial work. Aerial work includes operations involving agriculture, flying training and other aerial work. The main statistical groups used in this report include:

Regular public transport

Regular public transport[8] operations refer to air transport operations used for the commercial purpose of transporting persons generally, or transporting cargo for persons generally. These operations are conducted for hire or reward in accordance with fixed schedules to and from fixed terminals over specific routes with or without intermediate stopping places between terminals.

- **High capacity RPT**

A high capacity[9] aircraft used for RPT operations is an aircraft that is certified for a maximum seating capacity exceeding 38 or a maximum payload exceeding 4,200 kg.

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7 Aircraft being operated with the experimental designation are included in the private category for recording and analysis purposes.

8 CAR 206 (1) (c) and CAR 2 (7) (c).

9 Civil Aviation Orders Section 82.0

- **Low capacity RPT**

An aircraft with a maximum seating capacity of 38 or less, or a maximum payload of 4,200 kg or below[10] used for RPT operations is referred to as a low capacity aircraft.

General aviation

'General aviation' is defined as all non-scheduled civil flying activity other than RPT and sport aviation operations. The GA operations can be further divided into commercial and non-commercial operations. Commercial operations in GA include charter and aerial work. Aerial work includes, for example, flying training, agriculture operations, surveying, aerial photography, and aerial ambulance operations. Non-commercial refers to private and business operations.

- **Charter operations**

Charter operations involve the carriage of cargo and/or passengers on non-scheduled operations by the aircraft operator, or the operators' employees, in trade or commerce, excluding regular public transport operations.

- **Aerial work**[11]

Aerial work operations comprise agricultural operations, flying training and other aerial work.

a. **Agricultural operations -** operations involving the carriage and/or spreading of chemicals, seed, fertilizer or other substances for agricultural purposes. It includes operations for the purpose of pest and disease control. Agricultural operations are a component of aerial work, but are usually separated for reporting purposes.

b. **Flying training -** flying under instruction for the issue or renewal of a license, rating, aircraft type endorsement or conversion training, including solo navigation exercises conducted as part of course of applied flying training. Flying training is a component of aerial work, but is usually separated for reporting purposes.

c. **Other aerial work -** includes operations conducted for the purposes of aerial work other than 'flying training' and 'agricultural operations'. Operations classified as other aerial work include aerial operations involving surveying and photography, spotting, ambulance, stock mustering, search and rescue, towing (including glider, target and banner towing), advertising, cloud seeding, fire fighting, and coastal surveillance.

- **Business**

Business flying is associated with a business or profession, but not directly for hire and reward.

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10 Civil Aviation Orders Section 82.0.

11 Due to the large proportion of aerial work operations associated with agricultural operations and flying training, these groups are separated for analysis. The remaining aerial work operations are referred to as 'other aerial work'.

- **Private**

Private flying refers to flying for recreation or personal transport that is not associated with a business or profession. Test and ferry/positioning flying is not grouped under private flying. Such activity is allocated to the principle operation that is generally undertaken by the aircraft.

Sport aviation

Typically, the ATSB does not investigate and report on sport aviation accidents or incidents. For the purposes of this report, however, it was necessary to include data on sport aviation. This included sport aviation activities involving hang gliders, balloons, autogyros, gliders/sailplanes, ultralights and airships.

2.3 Accident and incident indicators

Accident and incident indicators have enabled the ATSB to examine the characteristics and safety trends associated with aviation within Australia. For example, the report *Aviation Safety Indicators – A report on safety indicators relating to Australian aviation* (ATSB, 2005b), used accident rates to examine the number of fatal and non-fatal accidents for the GA sector from 1990 to 2003.

To identify safety and industry trends in aviation it is necessary to use some type of measure or indicator. The International Civil Aviation Organization (ICAO) definitions for an aircraft accident and an aircraft incident have been adopted by Australia and have been incorporated into ATSB investigative and data analysis processes. The definitions provided in Annex 13 to the Convention on International Civil Aviation (ICAO, 2001) are:

> **Accident** - an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:
>
> a) a person is fatally or seriously injured as a result of:
>
> - being in the aircraft, or
> - direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
> - direct exposure to jet blast,
>
> except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or
>
> b) the aircraft sustains damage or structural failure which:
>
> - adversely affects the structural strength, performance or flight characteristics of the aircraft, and
> - would normally require major repair or replacement of the affected component,

except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin; or

c) the aircraft is missing or is completely inaccessible.

Note 1. For statistical uniformity only an injury resulting in death within thirty days of the date of the accident is classified as a fatal injury by ICAO.
Note 2. An aircraft is considered to be missing when the official search has been terminated and the wreckage has not been located.

Incident - an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.

3 GENERAL AVIATION

A search of the ATSB's accident and incident database identified that all of the wire-strike fatal accidents reported to the ATSB during the period 1994 to 2004, involved operations within the GA sector.

GENERAL AVIATION SNAPSHOT

- In 2004, there were 715 active commercial aircraft operators performing GA activities. Approximately 65 per cent of the operators were small businesses operating three or less aircraft (BTRE, 2005).
- In general, the aircraft types associated with GA are single-engine fixed-wing aircraft of around 5,700 kg maximum takeoff weight (MTOW) or less, and rotary-wing aircraft of 2,960 kg MTOW or less.
- Between 1994 and 2004, GA fixed-wing aircraft performed an average of 1.5 million flying hours annually, and rotary-wing aircraft performed 0.27 million flying hours annually.
- In 2002, there were approximately 6,700 single-engine and 1,700 multi-engine fixed-wing aircraft operating in GA. Most of the aircraft were between 21 and 25 years old (BTRE, 2003).
- There were approximately 900 single-engine and 80 multi-engine rotary-wing aircraft in use, mostly between 11 and 15 years old (BTRE, 2003).

An operator's decision to use a fixed-wing or rotary-wing aircraft is often determined by a number of factors, including, but not limited to, aircraft availability, purchase cost, operating and maintenance costs, manoeuvrability, range, nature of the intended task(s) and aircraft capability in relation to the terrain associated with proposed operations.

Of the 119 wire-strike accidents identified during the reporting period, 62 per cent involved aerial agriculture operations (n = 74), 20 per cent involved other aerial work operations (n = 24) and 15 per cent involved private/business operations (n = 18).

3.1 Aerial agriculture operations

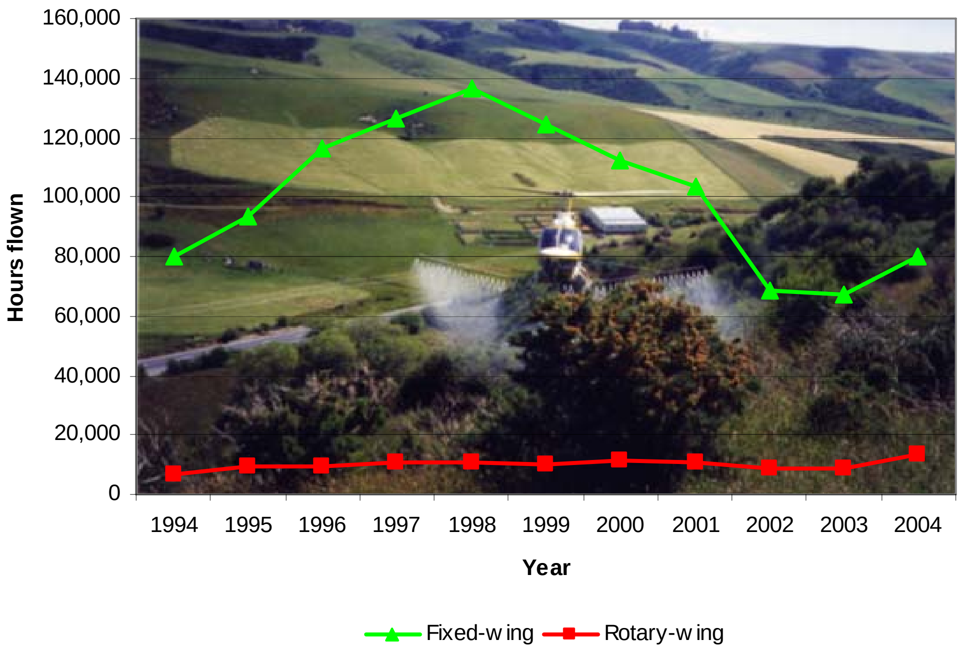
Pilots involved in aerial agriculture operations perform a variety of tasks. These include spraying for diseases and pests, sowing seed, and top dressing various crops such as cotton, rice and sugar cane.

Source: Photo courtesy of Antony Annan

The nature of agricultural flying is determined by environmental factors and the growing cycle. For example, the 2002 to 2003 drought reduced agricultural flying activity in Australia by over 35 per cent (BTRE, 2005).

Figure 4 shows the hours flown in fixed-wing and rotary-wing aircraft for aerial agriculture operations between 1994 and 2004. During this period, 91 per cent of all aerial agriculture operations were performed in fixed-wing aircraft. The remaining nine per cent were performed in rotary-wing aircraft.

Figure 4: Hours flown in aerial agriculture operations, 1994 to 2004



Source: Photo courtesy of Antony Annan

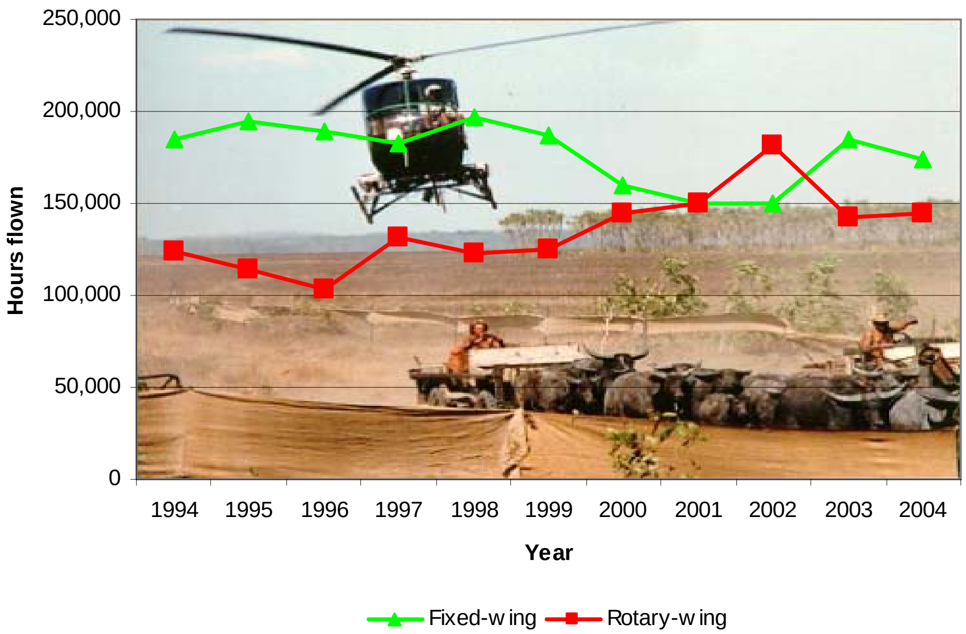
The average yearly flying hours for agricultural operations between 1994 and 2001 was 110,600 hours. This number reduced to around 70,000 hours during the drought of 2002 and 2003. A slight recovery was experienced in hours flown for both fixed-wing and rotary-wing aircraft in 2004, to just over 93,000 hours in total.

3.2 Other aerial work operations

Operations within the other aerial work category comprise a number of activities including aerial stock mustering, aerial surveying, aerial spotting, search and rescue, and fire fighting operations. A combination of both fixed-wing and rotary-wing aircraft are used across all the other aerial work activities.

Figure 5 shows the hours flown in fixed-wing and rotary-wing aircraft for other aerial work operations between 1994 and 2004. Fixed-wing aircraft accounted for an average of 57 per cent of all other aerial work operations during the reporting period, while rotary-wing aircraft accounted for the remaining 43 per cent.

Figure 5: Hours flown involving other aerial work operations, 1994 to 2004



Source: Photo courtesy of Keith Stewart

Fixed-wing activity varied across the reporting period, ranging from around 150,000 hours annually to nearly 200,000 hours annually. Rotary-wing aircraft have become increasingly popular for other aerial operations, and in 2002 exceeded the number of hours flown by fixed-wing aircraft.

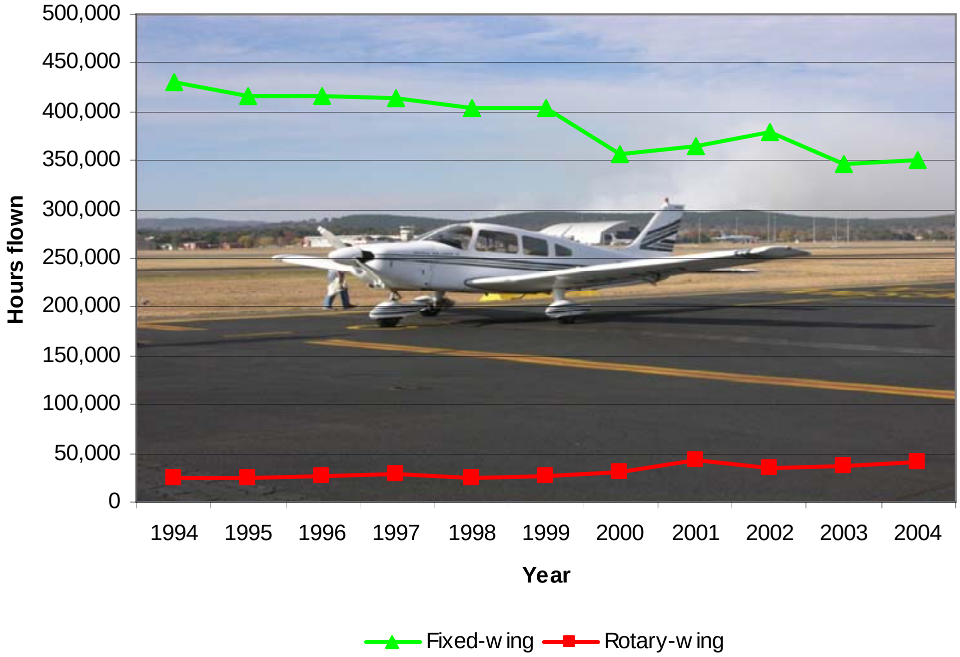
3.3 Private/business operations

Pilots involved in private operations fly for recreational or personal transportation purposes while those involved in business operations are associated with a business or profession, but not directly for hire and reward.

The majority of private/business operations are conducted in Australian civil registered small single-engine aircraft. Business flying is generally characterised by point to point flight, where the flight is conducted to get from point A to point B. Private flying on the other hand, often involves a takeoff and landing at the same aerodrome (BTRE, 2005).

Figure 6 shows the hours flown in fixed-wing and rotary-wing aircraft for private/business operations between 1994 and 2004. During this period, 93 per cent of private/business operations were performed in fixed-wing aircraft while the remaining seven per cent were performed in rotary-wing aircraft.

Figure 6: Hours flown for private/business operations, 1994 to 2004



The use of helicopters for private/business operations has steadily increased over the years from 25,377 hours in 1994 to 40,009 hours in 2004. While rotary-wing aircraft represent only seven per cent of all private/business operations, this represents a 58 per cent increase over the reporting period.

4 OPERATIONAL REQUIREMENTS

4.1 Low level legislation

The Civil Aviation Regulations 1988 contains a number of regulations in relation to low-level flying. Regulation 141 states that 'CASA may authorise low flying … over a specified part of a flying training area for the purpose of flying training.' Regulation 157 details the basic low-level restriction of 1,000 feet over '… any city, town or populous area' or 500 feet over '… any other area …' Subregulation (4) of regulation 157 lists a number of exemptions to the 1,000 and 500 feet rule – most notably for aerial work. Regulation 172 deals with low-level flying associated with Visual Flight Rules (VFR) flights and regulation 178 deals with low-level flying associated with Instrument Flight Rules (IFR) flights.

In recognition of the risks associated with low-level flying, special training and endorsements are required before a pilot can legally conduct low-level flying operations. Civil Aviation Orders (CAO) Parts 20, 29, 40, 82 and 95 contain details of permissions, exemptions and conditions in relation to low-level flying in Australia.

In addition to those requirements prescribed by the Civil Aviation Safety Authority (CASA), flying schools around the country also offer specialised training courses in areas such as low level flying and aerial stock mustering.

4.2 Aerial agricultural operations

To conduct aerial agriculture operations in fixed-wing or rotary-wing aircraft, a pilot must undertake extensive training to obtain an agricultural pilot rating issued by CASA as defined in CAO 40.6.

AGRICULTURAL PILOT (AEROPLANE) RATING

A pilot must hold the following minimum requirements:

- Pass a written examination on matters specified in the syllabus.
- Hold a commercial pilot (aeroplane) licence.
- Complete a course of flying training, which is conducted in two stages:
    - a. Initial agricultural flying training - which involves a minimum flight time of 10 hours dual instruction and covers subjects such as low level familiarisation, take-off and landing, low flying near power lines, and spraying technique.
    - b. Operational agricultural flying training – which involves a minimum flight time of 30 hours and covers subjects such as, airstrip identification, effect of surface conditions, operational planning, flying near high ground and valleys, flying adjacent to wires, and application techniques.

AGRICULTURAL PILOT (HELICOPTER) RATING

A pilot must hold the following minimum requirements:

- Pass a written examination on matters specified in the syllabus.
- Hold a commercial pilot (helicopter) licence and have at least 200 hours of flight time in helicopters.
- Conversion training on the helicopter type in which the training is to be conducted.
- Complete a course of flying training, which is conducted in two stages:
  a. Initial agricultural flying training - which involves a minimum flight time of three hours dual instruction and covers subjects such as hover and slow flight, low level, steep turns, tracking cross wind, and take-offs and landings.
  b. Operational agricultural flying training - involves a minimum of seven hours dual instruction and covers subjects such as treatment area inspection, route selection, height and speed to fly, identification of treatment area, manoeuvring turns, use of markers, and the treatment of a difficult area.

Following the initial issue of an agricultural pilot rating, pilots are closely monitored by an approved agricultural pilot for a given number of flight hours; a minimum of 110 hours for the holder of an agricultural pilot (aeroplane) rating and 20 hours for the holder of an agricultural pilot (helicopter) rating.

Furthermore, CAO 40.6 states that an agricultural pilot may not engage in aerial agricultural operations unless employed by the holder of an aerial work agricultural operator licence. In addition, all States require pilots to hold an agricultural chemical licence or rating (Aerial Agricultural Association of Australia, 2006).

Operations within the aerial agricultural environment are inherently risky given that pilots operate at a height of 100 feet or less above ground level. However, in addition to the requirements as discussed above, the aerial agriculture industry has been proactive in providing its members with the necessary tools to perform their duties to the highest standard. The Aerial Agricultural Association of Australia (AAAA), in conjunction with CASA, has developed the '*Aerial Application Pilots Manual*' to assist pilots who intend to study for an aerial agricultural pilots rating and to provide a useful reference book for all those involved in the aerial agriculture industry. The manual covers subjects such as safety, regulatory requirements, risk control, operational planning, powerlines and hazards, security, airworthiness, meteorology and human factors. Furthermore, the AAAA has responded to industry needs by providing a comprehensive program of conference and convention activities, and training courses to ensure its members are kept up-to-date with legislation, practices and other developments (Aerial Agricultural Association of Australia, 2006).

4.3 Other aerial work operations

Aerial stock mustering

Aerial stock mustering, as defined by CAO 29.10, refers to the use of an aircraft to locate, direct and concentrate livestock whilst flying below 500 feet above the ground.

AERIAL STOCK MUSTERING OPERATIONS

For a pilot to conduct aerial stock mustering activities, he or she must have the following qualifications:

- If conducting private operations, a private pilot's licence.
- If conducting commercial aerial work operations, a commercial pilot's licence.
- A minimum of 100 hours as pilot in command, including at least 50 hours of command in the aircraft type for which the approval is sought.
- A minimum of five hours dual instruction, covering aircraft handling and low flying.
- A minimum 10 hours operational training in aerial stock mustering operations in the preceding 90 days.
- Five hours experience in the type of aircraft to be used for aerial mustering operations.

In response to the increasing use of fixed-wing aircraft in aerial stock mustering within Australia, the Pastoralists and Graziers Association of Western Australia, with the assistance of key industry members, have released a publication titled '*Aerial Mustering Code of Practice*'. Their guide states that the overall goal is 'to reduce the risks that pilots and crews are exposed to when operating in the aerial mustering environment, and ultimately eliminate fatalities.' The code aims to raise the awareness of the industry by examining subjects such as occupational health and safety, aviation regulations, duties of the employee/pilot, provisions for aerial stock mustering and aerial stock mustering techniques (Pastoralists & Graziers Association of WA, 2003).

Fire fighting operations

Over the years, the use of both fixed-wing and rotary-wing aircraft for aerial fire fighting operations within Australia has proliferated, with aerial agricultural aircraft the most common type of aircraft used. The rules and regulations governing aerial fire fighting operations have been recently identified by CASA as over prescriptive, too procedural, and difficult to understand. As a result, in June 2006, CASA released Regulatory Policy – CEO–PN008-2006 'Fire Fighting Operations'. The aim of the policy is to provide regulatory consistency and ensure that aerial fire fighting operations are conducted in a safe manner. As outlined below, the policy covers fixed-wing and rotary-wing aircraft in areas such as operation manuals, working under a State authority, and flight crew qualifications (Civil Aviation Safety Authority, 2006).

REGULATORY POLICY – CEO-PN008-2006

Operations manual

To engage in aerial fire fighting operations, the operator must be authorised by CASA to conduct aerial work operations.

The company operations manual must provide procedures for the conduct of aerial fire fighting operations.

Working under a State authority

Aerial fire fighting operations must be authorised by and conducted under the administration of a nominated responsible authority such as fire control, police etc.

Flight crew qualifications

Pilots conducting aerial fire fighting must hold:

- A commercial pilots licence or higher; and
- An unrestricted agricultural pilot rating; OR
- Completed a low-flying training course accepted by CASA; and
- Flown at least 10 hours as pilot in command carrying out aerial work, practice aerial fire fighting, aerial agricultural operations or other low-flying operations as accepted by CASA within 6 months prior to the proposed aerial fire fighting operations; OR
- Completed a proficiency check relevant to the area of operation or by the fire fighting operator's approved check and training organisation.

Other aerial work activities

With the exception of times such as take-off and landing, low-level flying is normally prohibited. However, when there is a need to conduct low-level flying, operators may apply to CASA for an exception from the regulations. The Civil Aviation Safety Authority will normally issue an approval subject to the operator implementing certain controls intended to reduce the risks specifically associated with low level operations. These controls may include the requirement for pilots to have undertaken formal training in low level flying techniques, or alternatively, hold an aerial agricultural rating (ATSB, 2005a).

4.4 Private/business operations

Generally, pilots within the private/business category have little reason to be flying at low levels unless operating within the vicinity of an aerodrome or flight strip (for takeoff and landing), or in extreme circumstances, conducting a forced landing[12], a precautionary landing[13], or in adverse weather conditions. Given that private/business flights are not normally conducted at low level, there is little training on low flying techniques provided to pilots as part of either the private or commercial pilot's licence syllabus. The training prescribed in the CASA Day (VFR) Syllabus is limited to some navigation exercises and low level circuit training to a minimum height of 500 feet AGL (CASA, 2004a; 2004b).

12 A forced landing is an unscheduled landing caused by an aircraft malfunction, or by improper flight planning or aircraft operation (Kumar, 2005).

13 A precautionary landing is a landing made as a precaution when, in the judgement of responsible person, a hazard exists in continuing the flight (Kumar, 2005).

5 AERIAL CAMPAIGN MANAGEMENT

In June 2005, the ATSB released an aviation research investigation report titled *'Risks associated with aerial campaign management: Lesson from a case study of aerial locust control'* (ATSB, 2005a). The report was also initiated in response to the three wire-strike helicopter accidents in New South Wales in 2004, which involved locust control operations. Aircraft in two of the three accidents were involved in survey operations (other aerial work), and the third was preparing for locust spraying operations.

The purpose of the report was to research the practices used by government organisations to contract aerial operators for locust control in order to identify issues that may enhance future aviation safety. Though predominately focused on locust control operations, the concepts provided in the report are also applicable to other aerial operations such as aerial fire control, other pest management operations, and emergency service operations.

Aerial campaigns are conducted in relatively hazardous environments, often involving low level operations. Hence, there is an increased risk of a wire-strike accident or incident occurring. A clear appreciation of the challenges posed by an aerial campaign is needed by all industry participants.

The following are typical characteristics of an aerial campaign, all of which have the potential to increase the risk to aerial operations.

Community needs

Government agencies are often pressured by communities to initiate and manage aerial campaigns for activities such as locust control and fire control. This may have the potential to increase risk as organisations focus their energy and resources on completing the operation without appropriate planning or resources allocated to controlling the hazards.

The coordination of resources and organisations

The organisational and regulatory complexities associated with the coordination of an aerial campaign may lead to a diffusion of responsibility among the parties involved. For example, in a large locust control operation, the spraying of an area may involve the locust control organisation, a rotary-wing aerial operator, a fixed-wing aerial operator, the property owner, and other government organisations. Generally, the process is cooperative and effective, however, the responsibility for safety may become diffused and elements of safety management lost as no single organisation are aware of the complete operation.

This may be further compounded by the fact that the aviation regulator (CASA) is responsible for setting and maintaining the minimum standards for commercial aviation operations, however, an organisation's duty of care responsibilities come under State, Territory and Federal Occupational Health and Safety legislation.

Operational irregularity

The need for an aerial campaign such as locust control operations or fire fighting operations is largely dependent on the environmental conditions. Those organisations primarily responsible for the management of such campaigns are able to predict, to some extent, if such operations will be required. However, the exact time, frequency, and size of the operation required is difficult to forecast. The sporadic nature of an aerial campaign has a number of potential influences on the risks associated with the operation such as reducing the time available for organisations to plan and coordinate control activities. Furthermore, for large scale campaigns, pilots and aerial operators from all over Australia may be called on to participate. This requires pilots to operate outside their immediate area of familiarity, which has the potential to increase workload, as pilots need to pay more attention to navigation, the terrain and infrastructure.

High hazard level

Aerial campaigns are conducted in relatively dangerous environments, often involving low-level flying. Low-level operations are inherently more risky than operating at higher levels as:

- there are a greater number of obstacles to avoid, such as vegetation, terrain, powerlines, and other man made structures;
- in the event of an emergency situation, the pilot has significantly less time to control the situation; and
- a pilot's workload is considerably increased at low levels, as they must negotiate the dangerous environment in addition to their normal workload.

Changing environment

Aerial campaigns are conducted in a rapidly changing environment where each flight is likely to be unique as the problem changes in magnitude or position. Furthermore, it is likely that the campaign environment will be constantly changing, with activities being conducted in a number of environments with varying terrain and human population. This irregularity has the potential to reduce the time available for pre-flight planning and in-flight hazard assessment, and reduce the effectiveness of generic risk management systems.

Given the characteristics described above, there have been a number of safety management concepts that have been developed to assist those involved in aerial campaigns:

- Integrated and flexible risk management practices that actively seek and manage risks throughout the design, management and implementation processes.
- As discussed previously, an aerial campaign may involve a number of organisations and aerial operators responsible for differing aspects of the operation. As a result, the potential exists for the requirements of one aspect of the operation to adversely affect another aspect of the operation. Responsibilities for safety need to be clearly defined through an effective management system, seeking external expertise, by monitoring and modifying procedures where needed, and by encouraging information sharing among all those involved in the campaign.

- Organisations involved in aerial campaigns may benefit from developing some of the characteristics identified in high reliability organisations[14]. These organisations have been identified as having an 'organisational mindfulness' which is defined by an attitude that recognises failures, encourages diverse views and approaches to identify risks and solutions, ensures people within the organisation have a clear understanding of the 'big picture', the organisation can cope with unexpected dangers, and a deference to expertise at times of increased risk.

Aerial campaigns by nature are sporadic, somewhat unpredictable, and involve a range of people from differing organisations. This often results in insufficient time to effectively prepare and coordinate the operation, thereby increasing risk of a wire-strike occurring. However, with the appropriate tools, the risks associated with an aerial campaign can be managed to be a low-risk environment.

14 High reliability organisations have a low number of accident and incidents, even though they work in high-hazard complex environments (ATSB, 2005a).

6 WIRE-STRIKE HAZARDS

Wire strikes generally occur when an aircraft is operating in close proximity to the ground, including the landing and take-off phases of flight. However, on occasion, wire strikes have occurred over water where a wire is strung between two high points. On 7 February 2004, a Piper PA-28R-200 aircraft struck powerlines while conducting a private sightseeing flight over Lake Eildon in Victoria. The aircraft struck the powerlines at about the lowest point of the span, which was approximately 133 feet above the water level of the lake (ATSB Report: 200400437).

Low flying is hazardous because of the aircraft's close proximity to obstructions such as trees, powerlines, buildings and radio towers. Colliding with obstructions such as these can cause significant damage to an aircraft, resulting in loss of control and subsequent impact with the ground or water. Impact forces will likely involve further aircraft damage and possibly injury or death to aircraft occupants.

In addition to obstructions, there are several other factors that may elevate the risk of low-level flying. Of significance is the relatively short distance between the aircraft and the ground or water, which according to Freeman (1995) reduces and in some cases removes the options for a pilot to manoeuvre to avoid a collision or recover from a loss of control.

Other factors that may elevate the level of risk include wind velocity (direction and speed), the effect of terrain on the wind and any consequent turbulence, maintaining lift if speed is reduced, maintaining height (particularly over hilly terrain), aircraft inertia, manoeuvring space (especially for turning), avoiding other air traffic and hazards such as birds.

Figure 7 shows the devastating consequences of an accident involving a Bell 47G-3B-1 Soloy[15] helicopter near Wodonga in Victoria that occurred on 19 June 2004. The pilot was the sole occupant and was fatally injured. The operator of the aircraft was contracted to spray herbicide on a property in Victoria, where it collided with powerlines 12 km west of Wodonga. The powerlines '… consisted of two parallel three-strand lightweight high-tensile steel cables, each of 2.75 mm diameter.' A photo of the damaged wires is presented in Figure 8. The powerlines were located on the north-eastern side of a ridgeline, strung across a direct track from the spray area to the replenishment truck (Figure 9). The full investigation report is available on the ATSB website (ATSB Report: 200402669).

15 The designation 'Soloy' indicates that the helicopter had been modified and fitted with a turboshaft engine.

Figure 7: Bell 47G-3B-1 Soloy helicopter after striking powerlines near Wodonga on 19 June 2004

Figure 8: Damaged powerlines after being struck by the Bell 47G-3B-1 Soloy helicopter

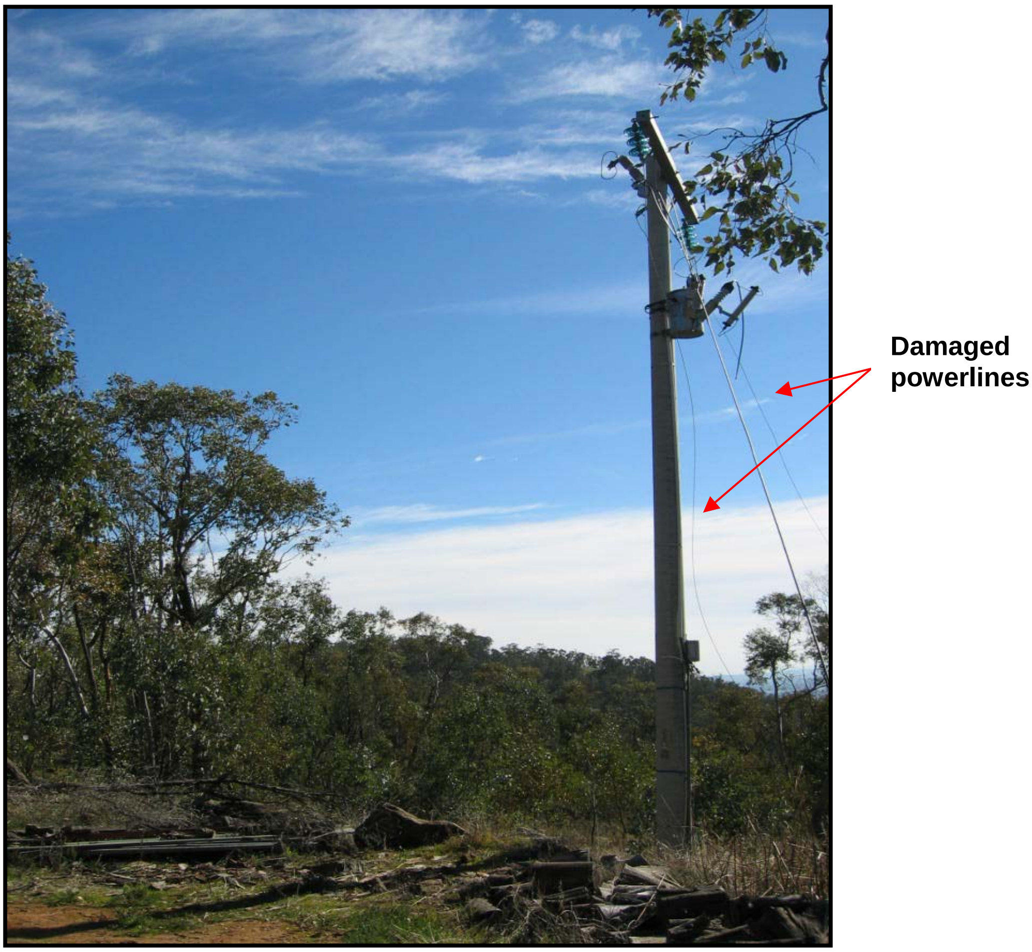
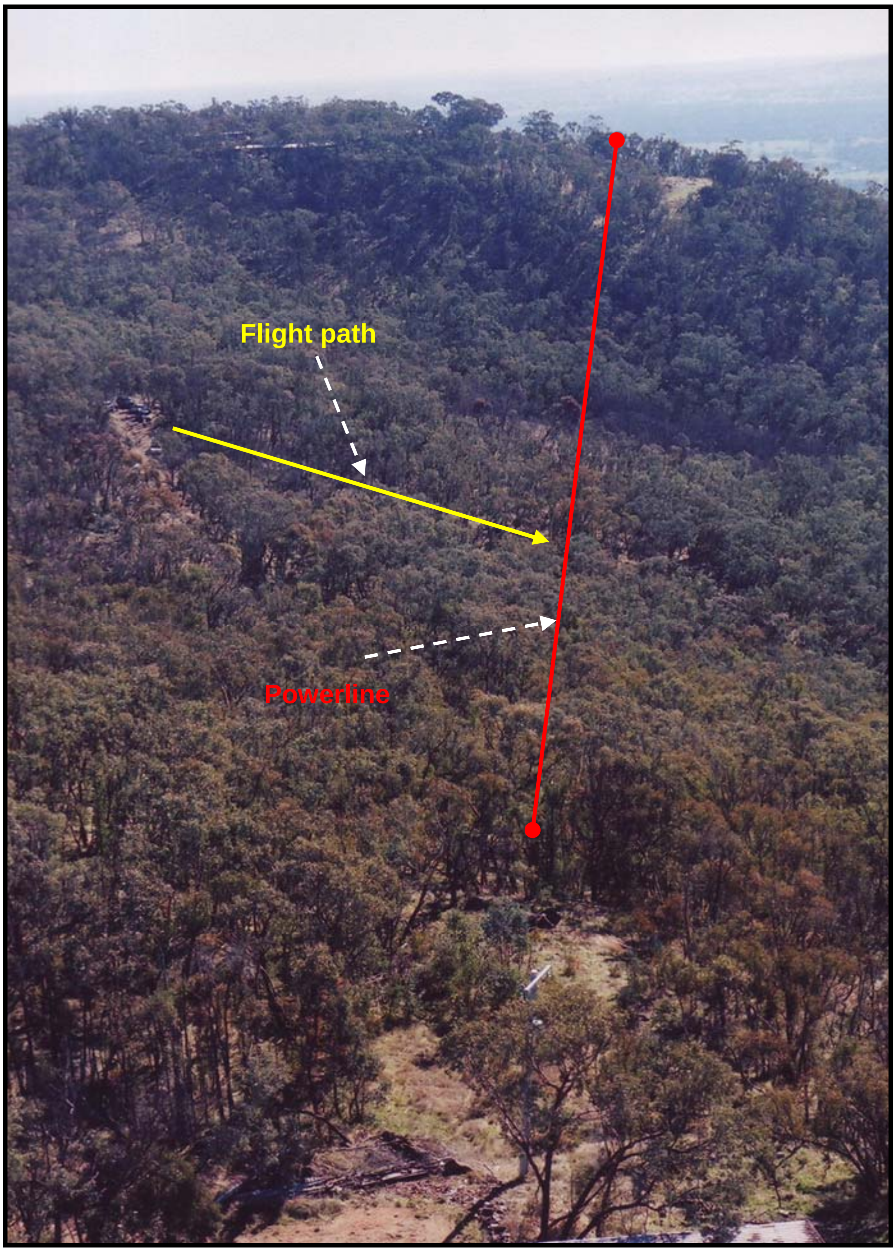


Figure 9: Aerial view of the powerline and the approximate track of the Bell 47G-3B-1 Soloy helicopter



7 POWERLINES

7.1 Characteristics of powerlines

Powerlines have various configurations that range from multiple clusters of high voltage wires carried on large lattice type towers, to a single wire earth return (SWER) system. The former are high tensile heavy gauge wires that may be found at heights in excess of 100 feet AGL. Figures 10 shows examples of various powerline arrangements in New South Wales.

Figure 10: Examples of powerline arrangements in New South Wales

The SWER system is characterised by only one wire. It can be strung in spans of up to 400 metres. The system is particularly hazardous to pilots, as both the wire and the supporting poles may be difficult to distinguish from the background environment. Furthermore, these wires are often found across the approach path to a country paddock or airstrip (Freeman, 1995).

Guy wires[16] can also be difficult for pilots to see, even when the location of the wire is known. As shown in Figure 11, guy wires are generally located at either the end of a wire run or on a bend in the run to counterbalance the pull of the wires.

Figure 11: Example of a guy wire

7.2 Identifying powerlines

A number of factors associated with powerlines, such as the number of wires, the height of the wires, and the direction of the wire run, can determine whether or not a pilot sees a wire. Additionally, the material used to manufacture the wire can impact visibility, for example, copper wire oxidises to blue/grey – a difficult colour to distinguish against Australian eucalypts. Aluminium might offer a better contrast as it oxidises to silver. Single powerlines are possibly the greatest hazard, as they can be extremely difficult to detect from the air and can be encountered in the most unexpected places in rural areas (RAAF, 1997). Other factors restricting visibility include the position of the sun, changing light conditions, background camouflage, the obscuring effects of terrain, and poor weather. A more obvious factor is a dirty windscreen.

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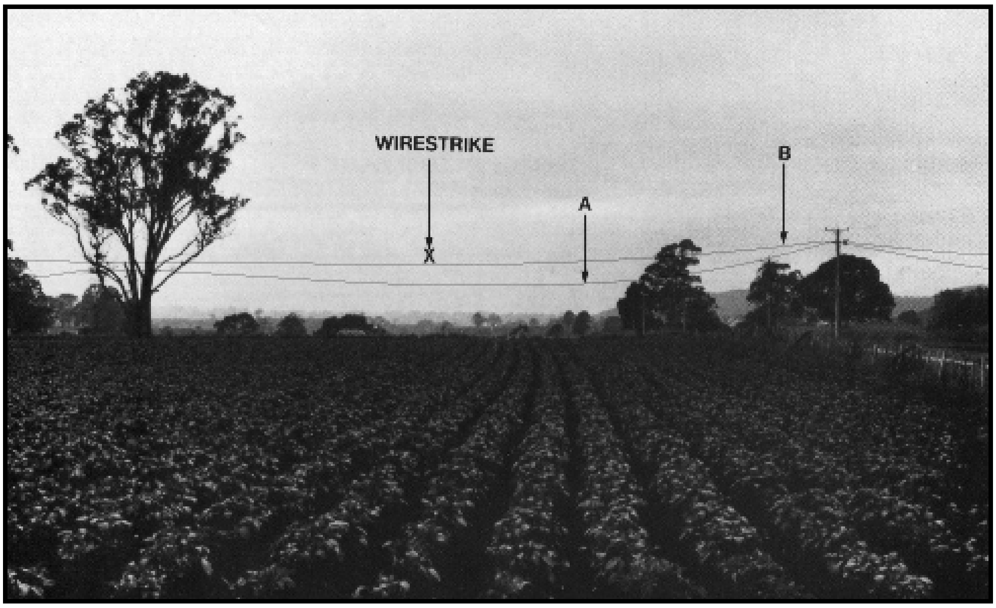
16 A wire used to secure a power pole in position against the pull of the wire run.

Even if a wire can be seen, a pilot's ability to judge its position accurately may be reduced by a number of factors. For example, ambient temperature can change the location of the wire by causing the wire to sag or tighten, and windy conditions may cause sagging wires to be blown about (Harris, 2003). In addition, the ability to judge distance correctly can be distorted by optical illusions. As illustrated in Figure 12, higher wires appear to be further away when viewed in combination with lower wires. This effect only resolves at distances less than 100 metres, thereby leaving the pilot little time to react (Freeman, 1995).

Figure 12: Focussing on high and low wires together can create the illusion that the higher wire (B) is further away than the lower wire (A)



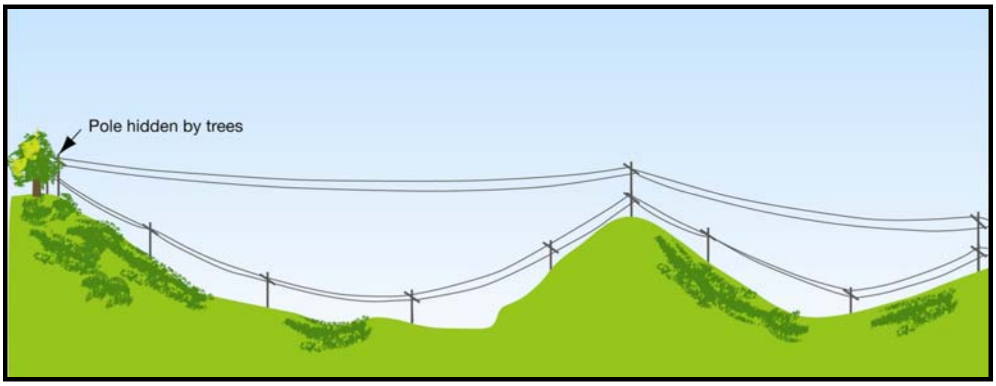
Source: BASI (1985)

The ability to identify the presence of powerlines can be facilitated by objects and landmarks on the ground. Buildings such as houses and sheds are likely to have power connected through above-ground wires. Roads may also provide a convenient path for powerlines. Furthermore, power poles may offer clues as to wire direction and height. By identifying at least two poles, a pilot may be able to gauge the path of the wire. Insulators attached to the poles run in the same direction as the wire and may also assist in identifying the number of wires and their direction. The orientation of the insulators could indicate whether the wire continues in the same direction or turns a corner. The presence of bucked arms[17] could provide evidence of additional wires or a new wire run.

Although poles provide pilots with one of the most reliable indicators of the presence of wires, the poles themselves are not always easy to see. Wooden poles, in particular, can be easily camouflaged by the landscape or hidden by foliage and trees (Figure 13). Since poles are typically used by pilots to alert them to the presence of a wire run, concealed poles may increase the risk of a wire-strike.

17 Bucked arms are the cross members on a powerline structure that support additional wire runs.

Figure 13: Wire hazard caused by the pole being hidden by trees



Source: Aerial Agricultural Association of Australia (2004)

Another factor hindering a pilot's ability to detect poles is the physiological limitations of the eye. When looking straight ahead, each eye has a normal field of vision of about 120 degrees vertically and about 200 degrees horizontally (Miller & Tredici, 1991). However, the field of vision that enables clear and detailed perception of objects is far narrower. According to Freeman (1995), for poles to be visible to the pilot, they must be positioned within a 70 degree angle. Problems arise when the wire span is long and requires poles to be placed several hundred metres apart. When this occurs, the pilot's ability to focus on the pole and recognise a potential wire hazard is decreased.

In addition to the issues described above, there are a number of other human factor limitations that may contribute to a wire-strike accident or incident, such as information processing, stress, fatigue, and fitness to fly. However, one of the major human factors associated with low-level aerial tasks is pilot distraction. According to the *Aerial Application Pilots Manual*, without some positive reminder of the presence of the wire, it is easy for a pilot to forget about it. This is especially true if a distraction occurs at the critical moment when the pilot should be thinking about initiating the pull-up (Aerial Agricultural Association of Australia, 2004).

PILOT DISTRACTION

There are a number of factors that cause pilot distraction. These include deteriorating weather conditions, personal stress, objects on the ground, radio calls, equipment malfunctions and passengers. A recent aviation research investigation report published by the ATSB suggests that pilot distractions can be broadly classified into four different groups (ATSB, 2006c) including:

- Visual distraction – looking at the spraying area, or particularly eye-catching scenery
- Auditory distraction – radio or mobile phone
- Biomechanical (physical) distraction – manipulating a control
- Cognitive distraction – being 'lost in thought' or engrossed in the task

Each of these types of distraction, either singularly or in combination, can take a pilot's attention away from the task of flying.

7.3 Wire-strike prevention

7.3.1 Situational awareness

Risk mitigation strategies associated with low-level flying rely heavily on the level of situational awareness maintained by the pilot. Strategies used to establish and maintain adequate situational awareness include reading the physical structure indicators (ie orientation of insulators, presence of bucked arms and sighting two or more poles), self discipline, pre-flight briefing, pre-flight reconnaissance and observation, memory and awareness, appropriate flying techniques, maintenance of a good visual scan and consideration of weather factors (BASI, 1991). Additionally, pilots need to guard against deviating from low-flying routes and areas previously checked for wires.

To assist pilots in the detection of wires, a number of non-human strategies have been developed. These include wire markers and wire detection systems. Additionally, wire-strike protection systems could, if fitted, provide a defence against the consequences of a wire-strike.

7.3.2 Wire markers

The requirements for the mapping and marking of power cables and their supporting structures are published in the following Australian Standards:

> **AS 3891.1 - 1991 Air Navigation -** cables and their supporting structures - mapping and marking. Part 1: Permanent marking of overhead cables and their supporting structures. This standard, approved on 18 February 1991 and published on 15 April 1991, '...specifies the requirements for aircraft warning markers for use on overhead cables and their supporting structures' (Standards Australia, 1991).
>
> **AS 3891.2 - 1992 Air Navigation -** cables and their supporting structures - mapping and marking. Part 2: Marking of overhead cables for low-level flying. This standard, approved on 1 September 1992 and published on 14 December 1992, '...specifies requirements for permanent and temporary marking of overhead cables and their supporting structures for visual warnings to pilots of aircraft involved in low-level flying operations'. Pilots are required to '...be satisfied as to the need for and effectiveness of markers prior to commencing low-level operations' (Standards Australia, 1992)

Since the introduction of the current standards, the aviation industry has experienced many changes including the increasing demand for aerial fire-fighting services and the use of global positioning systems to assist aircraft engaged in aerial agricultural operations. As a result, Standards Australia is in the process of revising the standards for the marking of overhead cables for the safety of aircraft. The review is expected to take into consideration the use of cost effective and temporary markers, and the size of cables requiring marking (Energy Networks Association, 2006).

In general, there is no requirement for the marking of cables with a height above terrain or obstacles of less than 90 metres. The standards assume pilot familiarity with the hazards in the low-level operating area, and that a visual reminder is only required of the exact location of the cables. Additionally, approval by the cable owner is required for the installation of above-ground wire markers.

Wire markers can be white, yellow, red or orange, and may be spheres, warning lights, marker panels or over-crossing markers in accordance with Standards Australia. The markers shown in Figure 14 and Figure 15 are red spheres.

Figure 14: Example of a marker mounted on a powerline

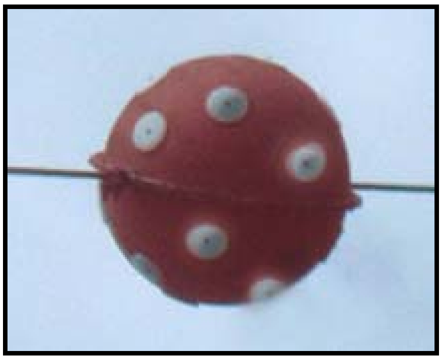


Figure 15: Example of wire markers mounted on a multi-strand powerline

More recently, Country Energy (New South Wales) has developed a cost effective powerline 'flag marker' to be used in areas such as crop spraying and harvesting, temporary or non-licensed aircraft landing areas, temporary air bases for fire fighting operations and external construction sites. As shown in Figure 16 and Figure 17, the marker is a mud flap shaped marker with a green retro reflector. The marker is designed to clip onto a range of conductors to increase visibility (A. Burman, personal communication, June 5, 2006).

Figure 16: Example of a 'flag marker' used for aerial operations

Source: Country Energy

Figure 17: Example of a 'flag marker' used on overhead powerlines

Source: Country Energy

The supporting structures of powerlines may also be illuminated, but this only provides pilots with a visual cue at night. One system currently installed in Norway and under trial in North America is a low-powered radar system mounted on or near powerline support structures that detects aircraft within a specified distance of powerlines and the support structure. Once detected, the system activates strobe lights and, if the aircraft continues on its original track, the system transmits a warning on locally-used very high frequency (VHF) radios.

7.3.3 On-board detection systems

A number of on-board detection systems have been developed to warn pilots of their proximity to wires. These include:

- A system that detects the electromagnetic field generated by powerlines. However, this system does not identify the location of the wire and will only activate if the wire is live.
- A system that utilises lasers to scan the environment ahead of the aircraft for wires and other flight obstacles.
- A system that uses a database of terrain and wire location information to warn pilots of rising terrain and obstacles that are more than 100 feet above the ground.

Alerts for on-board detection systems can be in the form of an aural alert, which may also give an indication of the proximity of the wire, and/or a visual alert, which may be an illuminated warning light or an indication on a map display.

7.3.4 Wire-strike protection systems

As a final defence, when pilot situational awareness and on-board systems fail to detect a wire in sufficient time to avoid contact, a passive wire-strike protection system (WSPS) may protect the aircraft from the most severe consequences of a wire-strike. These are designed to cut or deflect wires away from an aircraft. The types of WSPS vary depending on whether the aircraft is fixed-wing or rotary-wing. They have proven to be an effective safeguard by extensive testing and over two decades of use by both military and non-military operators' worldwide (Jackson, Boitnott, Fasanella, Jones & Lyle, 2004; RAAF, 1997). However, to enable the WSPS to operate effectively, the wire must contact the cutter at an appropriate angle and the aircraft must also have adequate forward speed. This combination of circumstances may not always be present during low-level aerial operations.

Wire-strike protection systems for fixed-wing aircraft are designed to cut wires that could pass under the aircraft, in order to prevent the wires from coming into contact with the landing gear, or pass over the aircraft, possibly contacting the tail section. Serrated deflection wires may also be fitted from the cabin to the tail section, with the purpose of cutting the wire or lifting it over the tail section.

Fixed-wing aircraft used in aerial agriculture operations have had WSPS fitted as standard equipment for several years. Fixed-wing aircraft used for other purposes rarely carry WSPS as fitment often requires reinforcing parts of the aircraft and may cost several thousand dollars. In general, they are not fitted unless it is expected that the aircraft will spend many hours in low-level flight.

On rotary-wing aircraft, WSPS are generally fitted to larger, heavier and faster models. Smaller aircraft, including Robinson series helicopters, generally have no structural hard points to fit a WSPS and are generally too light and, in many instances, travel too slowly for WSPS to be effective.

For larger helicopters, WSPS typically consists of an upper cutter/deflector, a windshield deflector and a lower cutter/deflector. The cutters are equipped with high tensile steel cutting blades to sever the wire, reducing the possibility of wires entering the cockpit area and damaging flight controls and/or becoming entangled in the landing gear or rotor assemblies. There are also explosive WSPS that cut the wire when activated, although these are typically only found on military rotary-wing aircraft.

8 METHOD

8.1 Data sources

Information for this report was provided by the Bureau of Transport and Regional Economics (BTRE), ATSB transport safety investigators, aerial agriculture operation specialists and other aviation experts. The data analysed was extracted from the ATSB's aviation accident and incident database.

8.2 Aviation accident and incident database

In accordance with the *Transport Safety Investigation Act 2003*, all accidents and incidents related to flight safety in Australia or by Australian operators overseas must be reported to the ATSB. All reported occurrences that meet defined criteria are then entered into the ATSB database. The reliability of the database is therefore dependent on individual compliance with the compulsory reporting requirements. Despite these requirements, anecdotal evidence suggests under-reporting of accidents and incidents persists, especially where aircraft and/or property damage is minor. The degree of under-reporting is difficult to estimate. The data in this report is likely to under-represent the actual numbers of wire strikes, and will tend to capture the more serious occurrences over the larger number of minor accident that might occur each year, but not be reported to the ATSB.

8.3 Data analysis

The ATSB accident and incident database was searched to identify occurrences that involved an aircraft striking a wire between 1994 and 2004. Of these occurrences, 11 were identified where another critical event such as engine failure or simulated engine failure, fuel starvation, and in one case main rotor failure, occurred prior to the wire-strike event. These occurrences were removed from the dataset in order to focus on accidents and incidents where a wire strike was the primary event.

The remaining accidents and incidents were then categorised by the type of operation being conducted at the time of the wire-strike. During the reporting period, 217 reported wire-strike accidents and incidents occurred during GA operations and 21 occurred during sport aviation operations. There were no wire-strike accidents or incidents recorded during RPT operations. The 21 sport aviation occurrences were removed from the dataset, thereby restricting the dataset to GA.

Of the 217 GA accidents and incidents, 98 were classified as incidents. As anecdotal evidence from aviation industry bodies suggests that incidents involving a wire-strike are significantly under-reported to the ATSB, all wire-strike *incidents* were excluded from the analyses. The remaining 119 occurrences were accidents involving a wire-strike as a primary event, and are hereafter referred to as 'wire-strike accidents'.

Tests of statistical significance were not undertaken due to the low number of observations, the low volume of occurrences in some categories and marked seasonal effects, particularly in aerial agriculture operations. In cases where numbers were sufficient for interpretation, trends were not apparent and analysis was not warranted.

9 RESULTS

9.1 Trends in wire-strike accidents and incidents

Accidents and incidents

In total, there were 217 GA accidents and incidents reported to the ATSB between 1994 and 2004 where the primary event was a wire strike. Of the number of accidents reported, 34 involved fatalities.

Table 1 shows the number of accidents and incidents annually ranged from 33 in 1998 to eight in 2002, with an average of 19.7 per year. The number of wire-strike accidents ranged from 16 in 1997 and 1998 to two in 2003, with an average of 11 accidents per year.

Table 1: Accidents and incidents involving a wire-strike, 1994 to 2004

Year	Accidents	*Fatal accidents*	Incidents	Total accidents and incidents
1994	14	*4*	5	19
1995	14	*5*	7	21
1996	13	*4*	7	20
1997	16	*4*	7	23
1998	16	*5*	17	33
1999	11	*3*	10	21
2000	9	*2*	12	21
2001	10	*3*	10	20
2002	3	*1*	5	8
2003	2	*0*	10	12
2004	11	*3*	8	19
Total	***119***	***34***	***98***	***217***

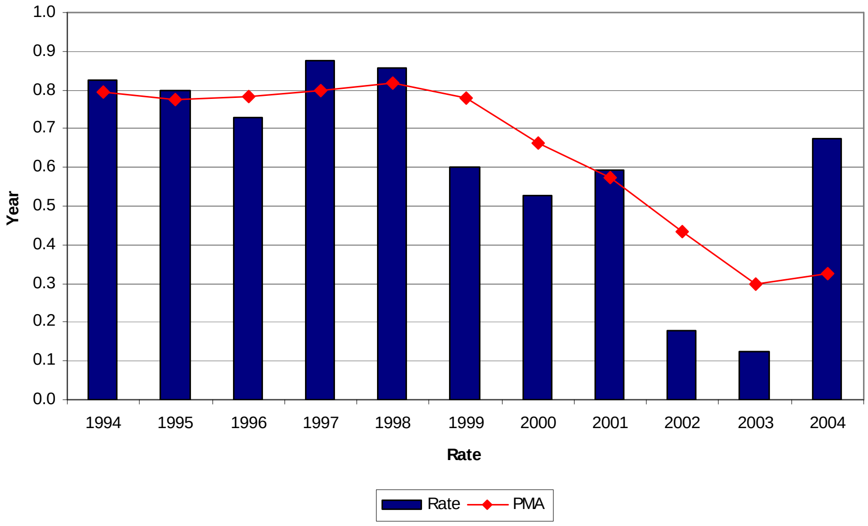
Accident rate for GA

A 3-year prior moving average (PMA)[18] was calculated by combining the data for a particular year with the previous 2 years and calculating the average. This calculation evened out random variation in the data, making trends more apparent. Figure 18 shows that the PMA for the rate of wire-strike accidents per 100,000 hours flown declined from 1998, indicating a downward trend. From 2003 to 2004, the PMA increased slightly.

18 PMA – used to smooth the graphical presentation of data from a small number of occurrences when the time period spans several years.

Figure 18 also shows that the rate of wire-strike accidents per 100,000 GA hours flown ranged from around 0.9 in 1997 and 1998, to 0.1 in 2003. There were 0.7 wire-strike accidents per 100,000 hours flown in 2004, indicating an increase in accidents compared with the previous year.

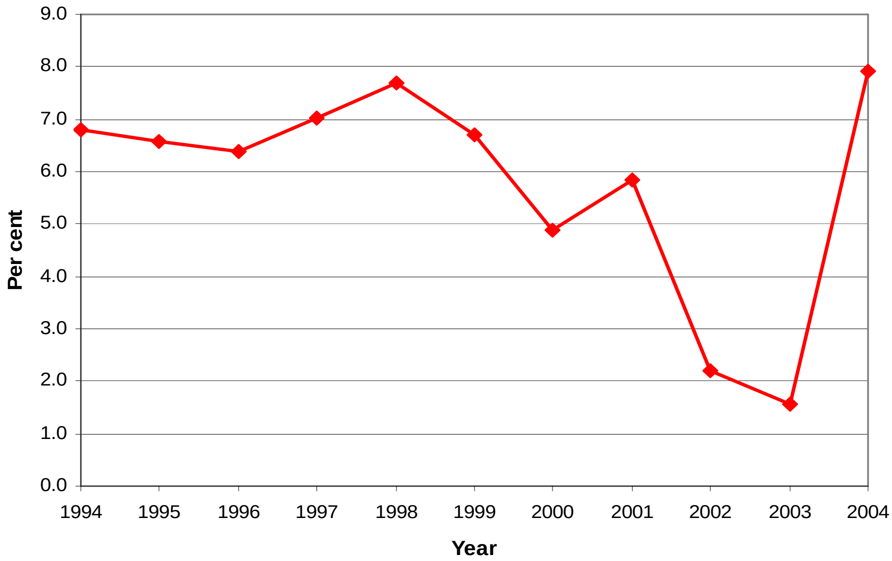
Figure 18: Wire-strike accidents for GA operations per 100,000 hours flown, 1994 to 2004



Wire-strike accidents compared with all GA accidents

Figure 19 shows that between 1994 and 2004 wire-strike accidents ranged between 1.6 per cent in 2003 to 7.9 per cent in 2004 of all GA accidents, with an average of 5.8 per cent each year over the period. There was a significant reduction in the proportion of GA wire-strike accidents in 2002 and 2003, to 2.2 per cent and 1.6 per cent respectively.

Figure 19: Wire-strike accidents as a proportion of all GA accidents, 1994 to 2004



Occupant injuries

Table 2 shows there were 169 people involved in the 119 wire-strike accidents between 1994 and 2004, of which 109 received some degree of injury. This included 45 people (27 per cent) with fatal injuries, 22 (13 per cent) with serious injuries, and 42 (25 per cent) with minor injuries. There were 60 (35 per cent) people who were not injured. This excludes two ground injuries that occurred in 1999 and 2001.

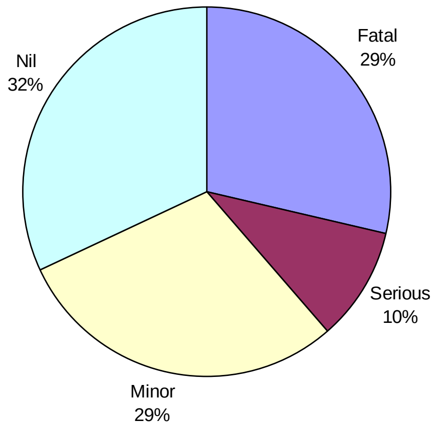
The numbers were too low to assess any emerging trends in levels of injury over time. Notably, no one was seriously injured or killed in 2003. In contrast, during 2004 seven people were fatally injured, the highest since 1998, and two people were seriously injured.

Table 2: People involved in wire-strike accidents by level of injury, 1994 to 2004

Year	Fatal	Serious	Minor	Nil	Total
1994	4	2	5	7	18
1995	7	2	6	3	18
1996	4	3	2	9	18
1997	5	1	2	14	22
1998	7	3	5	5	20
1999	4	3	3	5	15
2000	2	2	1	10	15
2001	4	3	7	0	14
2002	1	1	2	0	4
2003	0	0	1	2	3
2004	7	2	8	5	22
Total	***45***	***22***	***42***	***60***	***169***

Figure 20 shows the proportion of wire-strike accidents by the maximum level of injury received in relation to the accident. Nearly one third (29 per cent) of wire-strike accidents resulted in at least one fatal injury, 10 per cent resulted in at least one serious injury, and 29 per cent resulted in at least one minor injury. There were no injuries for 32 per cent of wire-strike accidents.

Figure 20: Percentage of wire-strike accidents by maximum level of injury, 1994 to 2004



9.2 Pilot awareness of the wire

Of the 119 accidents involving a wire-strike between 1994 and 2004, information about whether or not the pilot had prior knowledge of the wire was established in 82 cases. Table 3 shows that 63 per cent of these pilots were aware of the wire before it was struck.

Table 3: Wire-strike accidents and pilot's awareness of the wire before the accident, 1994 to 2004

	Number	Per cent
Aware	52	63
Unaware	30	37
Total	***82***	***100***

9.3 Phase of flight

Table 4 shows that 81 per cent of wire-strike accidents occurred during the manoeuvring phase of flight. This phase includes that part of the flight directly involved in conducting the purpose of the flight (eg during agricultural spraying and during the survey component of other aerial work activities).

Table 4: Wire-strike accidents by phase of flight, 1994 to 2004

	Number	Per cent
Manoeuvring	96	81
Approach	8	7
En-route	6	5
Landing	2	2
Take-off	5	4
Taxiing	2	2
Total	***119***	***100***

Note: Components may not sum to totals due to rounding.

9.4 Type of operation

Table 5 shows that 62 per cent of the 119 wire-strike accidents between 1994 and 2004 occurred within the aerial agriculture operations category (74 accidents). The other aerial work category recorded 24 accidents (20 per cent) and the private/business flying category recorded 18 accidents (15 per cent). The charter category recorded one accident, while the flying training category recorded two.

Table 5: Wire-strike accidents by ATSB statistical categories, 1994 to 2004

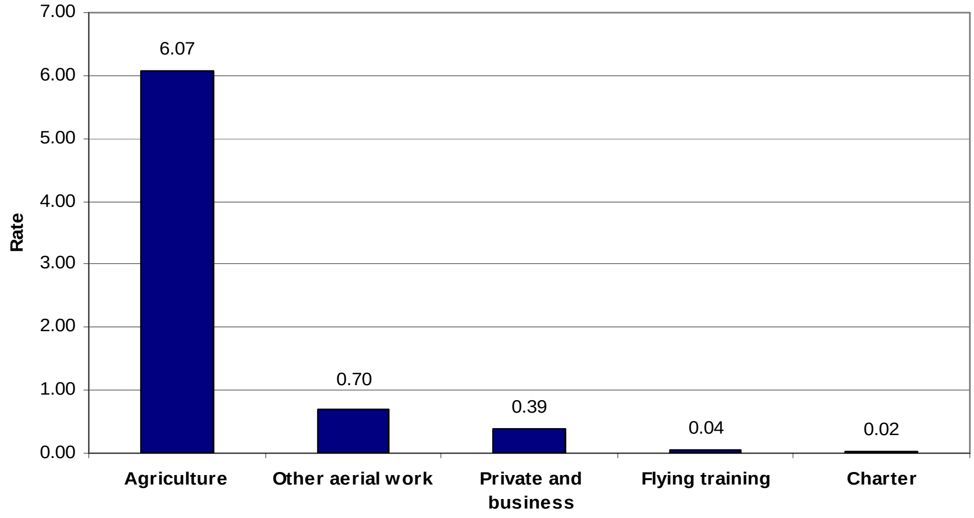
Year	Charter	Agriculture	Flying training	Other aerial work	Private/ business	Total
1994	0	9	1	3	1	14
1995	0	8	0	3	3	14
1996	0	8	0	5	0	13
1997	1	8	0	3	4	16
1998	0	12	1	1	2	16
1999	0	8	0	0	3	11
2000	0	6	0	2	1	9
2001	0	6	0	2	2	10
2002	0	2	0	1	0	3
2003	0	1	0	0	1	2
2004	0	6	0	4	1	11
Total	***1***	***74***	***2***	***24***	***18***	***119***

It is worth noting that there was a significant reduction in the number of hours flown by aircraft involved in aerial agriculture operations during 2002 and 2003. This is likely to be associated with drought conditions during these years. It may also explain the significant decline in wire-strike accidents during 2002 and 2003, and the subsequent increase in accidents in 2004 as drought conditions eased.

In addition, there was a relatively low number of wire-strike accidents involving other aerial work category aircraft (eg low-level agricultural pest survey, feral animal control and mustering) in 2002 and 2003. Again, this may be related to drought conditions.

Figure 21 presents the rate of wire-strikes by flying category per 100,000 hours flown. Aerial agriculture operations experienced a rate of 6.07 wire-strike accidents per 100,000 hours flown. This was almost nine times the rate of accidents for the other aerial work category (0.7) and almost 16 times the rate for private and business flying (0.39). Furthermore, aircraft operating within the flying training category recorded 0.04 wire-strike accidents per 100,000 hours flown and the charter category recorded 0.02.

Figure 21: Wire-strike accidents for GA operations per 100,000 hours flown, 1994 to 2004



The large discrepancy between aerial agriculture operations and other flying categories is likely to be a reflection of the considerable amount of low-level flying conducted during aerial agriculture operations compared with other flying categories. Legitimate low-level flying also makes up a component of tasks completed by the other aerial work category operators and may explain the higher rate compared with the other categories. There was no data available to compare low-level flying risk exposure within each statistical category.

9.4.1 Aerial agriculture operations

Figure 22 shows the rate of wire-strike accidents per 100,000 hours flown for aerial agriculture operations. The yearly accident rate ranged from 10.4 in 1994 to 1.3 in 2003. Rates for 2002 and 2003 showed notable declines, but figures appeared to return to the previous level in 2004 with a rate of 6.4. It is not possible to ascertain from the data available the reasons for the decreased accident rate in 2002 and 2003, however, the reduction in rates coincided with drought conditions and a decrease in agricultural flying[19].

Of the 74 wire-strike accidents recorded in the ATSB database, 15 involved fatal injuries to the pilot.

19 Caution should be exercised when interpreting these results, since the number of accidents per year was relatively small and a single accident could influence the rate considerably.

Figure 22: Wire-strike accidents for aerial agriculture operations per 100,000 hours flown, 1994 to 2004

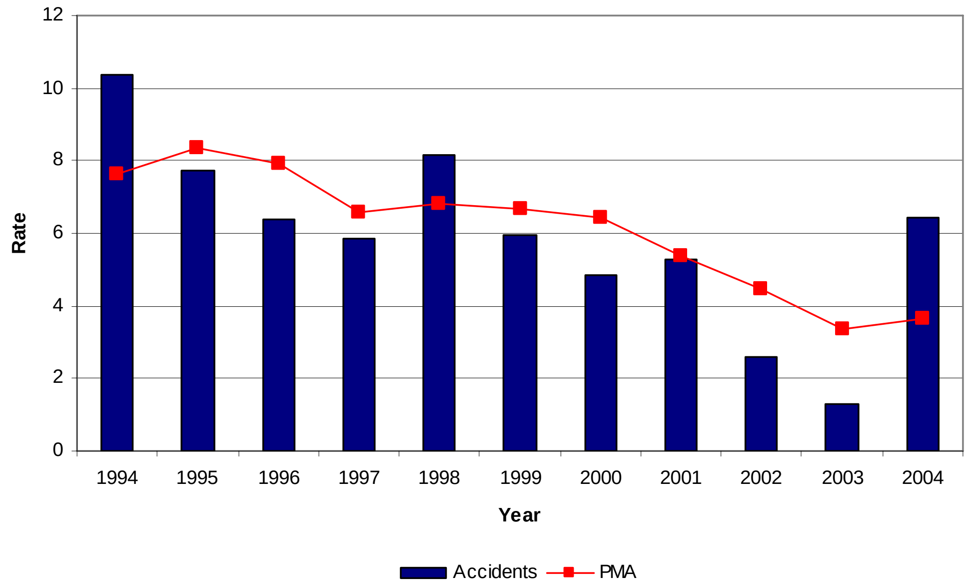
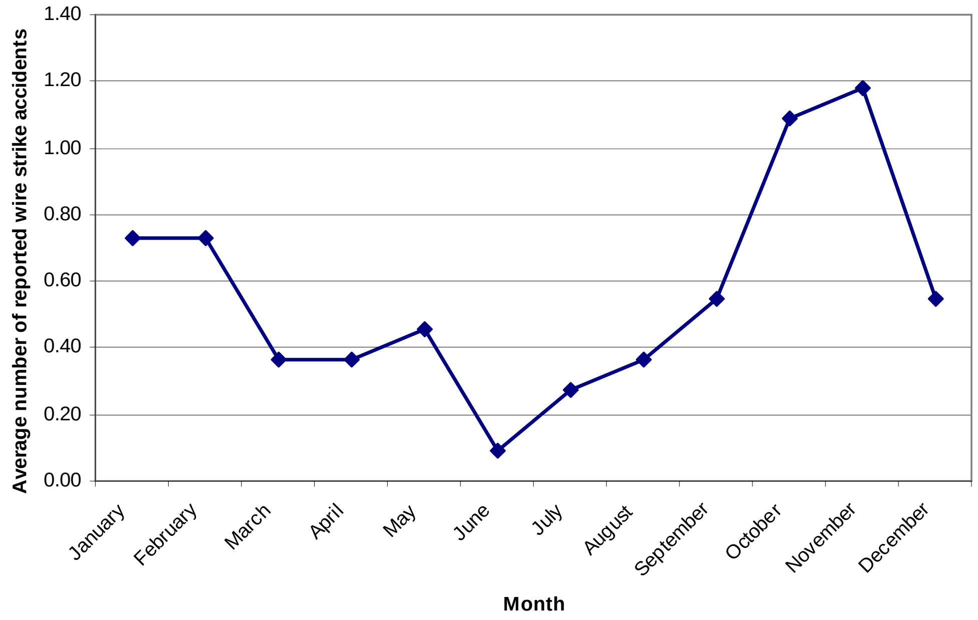


Figure 23 shows the average number of wire-strike accidents reported to the ATSB per month over the period 1994 to 2004. It also depicts a seasonal increase from September through to February, most likely corresponding to an increase of agricultural activity over the period.

Figure 23: Average number of wire-strike accidents reported per month for aerial agriculture operations, 1994 to 2004



Of the 74 wire-strike accidents between 1994 and 2004 involving aerial agriculture aircraft, the pilot's prior knowledge, or lack of knowledge, of the wire was established in 55 cases. Table 6 shows that 71 per cent of pilots were aware of the wire before they struck it.

Table 6: Wire-strike accidents involving aerial agriculture aircraft and pilots' awareness of the wire before the accident, 1994 to 2004

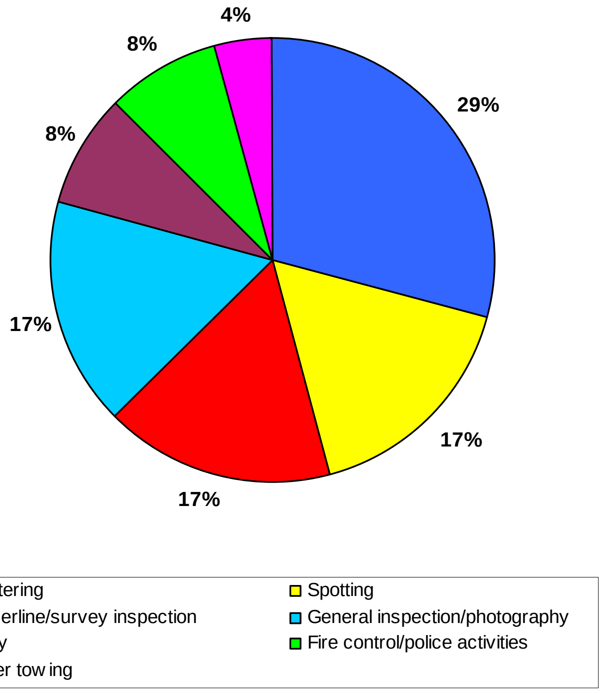
	Number	Per cent
Aware	39	71
Unaware	16	29
Total	***55***	***100***

9.4.2 Other aerial work operations

Of the 119 wire-strike accidents between 1994 and 2004, other aerial work operations accounted for 20 per cent (n = 24), the second highest after aerial agricultural operations (62 per cent, n = 74). Nine of the 24 wire-strike accidents in other aerial work operations resulted in fatalities.

Figure 24 shows the distribution of the 24 accidents among the varying subgroups within the other aerial work category. Like aerial agriculture, it is unsurprising that aerial mustering accounts for the greatest proportion of accidents within this category (29 per cent) given this activity is normally conducted very close to the ground. Powerline/survey inspection, aerial inspection/photography and aerial spotting each accounted for 17 per cent of wire-strike accidents within this statistical grouping over the reporting period.

Figure 24: Distribution of wire-strike accidents for other aerial work operations, 1994 to 2004



9.4.3 Private/business operations

Of the 18 wire-strike accidents involving private/business operations, 61 per cent involved operations within the vicinity of a landing area. This involved take-off, approach, landing, and conducting an aerial inspection of the landing area. The remaining 39 per cent involved low level flying activities.

Table 7: Wire-strike accidents involving private/business operations by activity, 1994 to 2004

	Number	Per cent
Operations within the vicinity of a landing area	11	61
Low level flying	7	39
Total	***18***	***100***

Of particular concern, are the accidents involving low level flying. One such example is the wire-strike accident of a Piper Aircraft Corporation PA-28R-200 Arrow, VH-TRZ over Lake Eildon, Victoria on 7 February 2004 (ATSB Report: 200400437). The pilot was conducting a private sightseeing flight over Lake Eildon with three passengers onboard when the aircraft struck a power cable. The power line was not fitted with marker devices, and nor was it required to be. The aircraft struck the power cable at about 133 feet above the water level of Lake Eildon. The aircraft was substantially destroyed and the four occupants were fatally injured. Even though the investigation could not determine why the pilot descended the aircraft to an unsafe height, it does highlight the dangers associated with flying at low level, especially for those pilots who have not received specialised training in low level operations.

Ten of the 18 wires-strike accidents involving private/business operations category resulted in fatal injuries. This was higher than the fatality rate for either aerial agriculture or other aerial work categories.

Furthermore, those pilots intending to operate into an unfamiliar landing area should ensure that they take all the necessary precautions to reduce the likelihood of a wire-strike incident or accident form occurring. This may involve identifying the hazards within that area prior to the operation by contacting the owner or operator of the landing area, reviewing the relevant maps and publications, and conducting an aerial inspection of the landing area at a suitable height prior to landing.

9.5 Fixed-wing and rotary-wing accidents

Table 8 shows that, between 1994 and 2004, 57 per cent of reported wire-strike accidents involved fixed-wing aircraft and 43 per cent involved rotary-wing aircraft. Given that there were seven times more fixed-wing aircraft than rotary-wing aircraft in use[20], rotary-wing aircraft appear to be considerably over-represented in the data.

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20 As at February 2005, there were 8,812 fixed-wing aircraft compared with 1,196 rotary-wing aircraft on the Australian civil aircraft register (ATSB, 2005b).

Table 8: Wire-strike accidents, 1994 to 2004

Year	Fixed-wing	Rotary-wing	Total
1994	6	8	14
1995	8	6	14
1996	6	7	13
1997	12	4	16
1998	10	6	16
1999	8	3	11
2000	5	4	9
2001	7	3	10
2002	2	1	3
2003	0	2	2
2004	4	7	11
Total	***68***	***51***	***119***

Table 9 shows that of the three main statistical categories, 68 per cent of wire-strike accidents involving agricultural aircraft occurred in fixed-wing aircraft and 32 per cent occurred in rotary-wing aircraft. For other aerial work operations, only eight per cent involved fixed-wing aircraft while the remaining 92 per cent involved rotary-wing aircraft. Fixed-wing aircraft were involved in 72 per cent of wire-strike strikes within the private and business category, with the remaining 28 per cent involving rotary-wing aircraft.

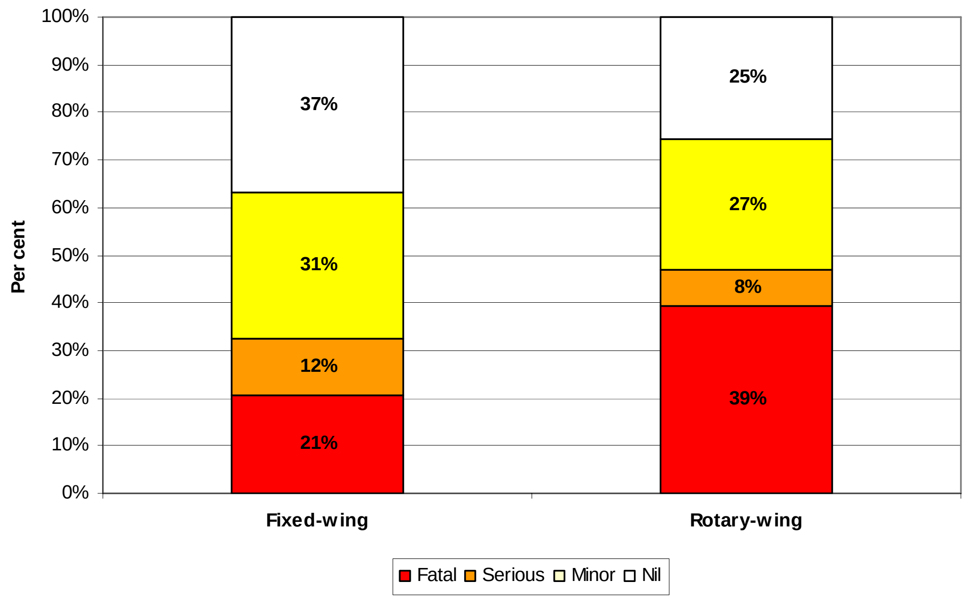
Table 9: Fixed-wing and rotary-wing wire-strike accidents by ATSB statistical categories, 1994 to 2004

Statistical category	Fixed-wing	Rotary-wing	Total
Agriculture	50	24	74
Other aerial work	2	22	24
Private/business	13	5	18
Flying training	2	0	2
Charter	1	0	1
Total	***68***	***51***	***119***

Though the BTRE does collect data on hours flown for different categories of operations, detailed aggregation is not available for hours flown at low-level as opposed to hours flown not at low-level. In the absence of specific data on low-level operations, analysis of risk exposure levels for fixed-wing and rotary-wing operations is not possible.

Figure 25 shows that 21 per cent of fixed-wing wire-strike accidents resulted in fatalities compared with 39 per cent for rotary-wing accidents. Furthermore, 37 per cent of fixed-wing wire-strike accidents involved no injury compared with 25 per cent for rotary-wing accidents. In relation to both aircraft types, only a small percentage of occurrences involving serious injuries were reported.

Figure 25: Wire-strike accidents by injury level and aircraft type, 1994 to 2004



9.5.1 Location of wire-strike

Table 10 shows that of the 68 fixed-wing wire-strike accidents reported, the location of the wire strike on the aircraft could be identified in 52 cases. The most common location was the aircraft landing gear (25.0 per cent), the leading edge of the wing (23.1 per cent) and the engine/propeller (21.2 per cent).

Table 10: Fixed-wing wire-strike accidents by location of wire strike, 1994 to 2004

	Number	Per cent
Landing gear	13	25.0
Wing leading edge	12	23.1
Engine/propeller	11	21.2
Deflector - top of fin to cabin	5	9.6
Fin	5	9.6
Other	3	5.8
Windscreen	3	5.8
Total	***52***	***100.0***

Note: Components may not sum to totals due to rounding.

Table 11 shows that, of the 51 rotary-wing accidents involving a wire strike, the location of the wire-strike on the helicopter could be identified in 35 cases. The most common location was the helicopter main rotor or rotor mast (37.1 per cent) followed by the landing gear (22.9 per cent).

Table 11: Rotary-wing wire-strike accidents by location of first wire strike, 1994 to 2004

	Number	Per cent
Main rotor/mast	13	37.1
Landing gear	8	22.9
Bubble	4	11.4
Tail rotor	4	11.4
Other	3	8.6
Windscreen	2	5.7
Spray boom	1	2.9
Total	***35***	***100.0***

Table 12 shows that of the 119 wire-strikes accidents involving a fixed-wing or rotary-wing aircraft, 50 per cent of the aircraft received substantial damage and 49 per cent were destroyed. A greater proportion of rotary-wing aircraft were destroyed (59 per cent) compared with fixed-wing aircraft (41 per cent).

Table 12: Wire-strike accidents by aircraft damage level and aircraft type, 1994 to 2004

	Fixed-wing		Rotary-wing		Total	
	Number	Per cent	Number	Per cent	Number	Per cent
Destroyed	28	41	30	59	58	49
Substantial	39	57	21	41	60	50
Minor	1	1	0	0	1	1
Total	***68***	***100***	***51***	***100***	***119***	***100***

10 DISCUSSION

Between 1994 and 2004, the rate of wire-strike accidents for GA operations showed signs of decline, particularly in 2002 and 2003. It is possible that drought conditions may have influenced low-level flying activity for these years, and in turn, influenced the corresponding accident rate. The rate for 2004 showed a return to previous accident levels. However, the overall numbers are too small to draw definitive conclusions about trends or the reasons for the recent increase in the rate of wire-strike accidents.

During the period studied, aerial agriculture operations had an accident rate that was considerably higher than other general aviation categories. This was may have been influenced by the amount of flying conducted at low-level. The other aerial work category recorded the second highest accident rate, possibly reflecting the higher level of exposure to low-level flying relative to the other GA categories.

The percentage of wire-strike accidents involving fixed-wing aircraft (57 per cent) was slightly higher compared with rotary-wing aircraft (43 per cent). Given that there were seven times more fixed-wing aircraft than rotary-wing aircraft registered in Australia, rotary-wing aircraft appear to be over-represented in the data. However, the vast majority of fixed-wing aircraft would not conduct low level flights routinely, and so a direct comparison based on aircraft registrations is unlikely to provide a true picture of the relative exposure rates to the hazards of low level flight.

Twenty-nine per cent of wire-strike accidents resulted in fatalities. Of the 169 people involved in wire-strike accidents, 45 (27 per cent) were fatally injured and a further 13 per cent sustained serious injuries. Occupants of rotary-wing aircraft suffered the higher fatality rate with 39 percent receiving fatal injuries, nearly twice the fatality rate for occupants of fixed-wing aircraft in wire-strike accidents (21 per cent). Although the numbers were too low to assess whether this difference was statistically significant, the finding suggests that occupants of rotary-wing aircraft are more likely to be fatally injured in the event of a wire-strike accident compared with those in a fixed-wing aircraft.

Over the period 1994 to 2004 there were 18 wire-strike accidents involving aircraft in private/business operations. This is only six fewer accidents than reported by operators conducting other aerial work operations. Importantly, more than 50 per cent of the wire-strike accidents in private/business operations resulted in fatal injuries, and in one case where passengers were carried, multiple fatalities. By comparison, the fatality rate for aerial agriculture operations, which had the highest number of wire-strike accidents, was considerably lower at 20 per cent.

It was found that a large proportion of pilots had prior knowledge of the wire (63 per cent) before coming into contact with it. Although this report did not investigate the human factors that may have been involved in the events leading up to a wire-strike accident, it is possible that one factor may have been pilot distraction. Evidence that many pilots already knew of the existence and location of powerlines supports claims that distraction is one of the major causes of wire-strikes during aerial agriculture and other aerial work. Other human factors that may be involved might include stress, fatigue, workload and visibility.

The findings of this report suggest that the aviation industry would benefit from further research into wire-strike accidents. Evidence of the relatively high number of occurrences where the pilot was aware of the powerline before it was struck suggests that this issue warrants particular attention. Further research should also include an examination of the human factors that may be associated with the situational awareness of low-flying pilots. The Australian aviation industry would also benefit from research on measures that may assist pilots to become more attentive and alert to wires during low-level flight.

11 CONCLUSIONS

The information presented in this report provides an overview of wire-strike accidents in GA operations and their associated characteristics for the period 1994 to 2004. The key findings indicate that 119 GA wire-strike accidents were reported to the ATSB during this period, with an average of 11 accidents per year. Of the 169 people involved in a wire-strike accident, 45 were fatally injured. The findings also pointed to the relatively high number of occurrences associated with aerial agriculture operations, involving both fixed-wing and rotary-wing aircraft. Another interesting finding was the high percentage (63 per cent) of pilots who were aware of the wire hazard before they struck it.

In line with Australia's declining fatal accident rate (ATSB, 2006a), the findings showed that the number of wire-strike accidents had decreased between 1998 and 2003. The highest number of wire-strike accidents in Australia occurred in 1997 and 1998, and the lowest number was recorded in 2003. An increase in accidents was observed between 2003 and 2004, with 11 accidents occurring in 2004. This marked a rise from the previous two years, making the number of wire-strike accidents for 2004 equal to the annual average for the period.

Subsequent to the analyses presented in this report, 2005 saw a slight decline in the number of wire-strike accidents. In total, four accidents were reported to the ATSB during 2005. None of the accidents resulted in a fatal injury; however one resulted in serious injury and the other two in minor injuries.

During the first quarter of 2006 three additional wire-strike accidents were reported to the ATSB, two of which were fatal. While the final ATSB investigation reports for these fatal accidents are yet to be released, the circumstances suggest that low-level flying continues to take a toll on aircraft and occupants.

Moreover, the accidents continue to highlight the need for the aviation industry to be proactive in ensuring that appropriate measures are developed and implemented for reducing the occurrence of wire-strike accidents. This includes the development of specialised and adequate training for pilots who operate extensively in the low-level environment. Various sectors of the GA industry, and particularly the aerial agriculture industry, have spent considerable time and resources in combating the problem of wire-strike occurrences through the implementation of training courses and the publication of guidance material. Other sectors within GA can benefit from the experiences of these sectors when flying in the low-level environment.

Furthermore, pilot's who intend to operate into an unfamiliar landing area should remain vigilant and ensure that all the necessary precautions are taken to reduce the risks associated with operating within the low level environment.

It is crucial that pilot's must be aware of the inherent dangers associated with operating at low levels. This is especially true of other aerial work and private/business operations where an additional responsibility for passengers might exist.

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