COMMONWEALTH DEPARTMENT OF
TRANSPORT AND REGIONAL DEVELOPMENT

10

Hazards and Risks

Proposal for a Second Sydney Airport
at Badgerys Creek or Holsworthy Military Area

Technical Paper

PPK
Environment & Infrastructure

Prepared for:

COMMONWEALTH DEPARTMENT OF
TRANSPORT AND REGIONAL DEVELOPMENT

GPO Box 594
Canberra ACT 2601

10

Hazards and Risks

Proposal for a Second Sydney Airport
at Badgerys Creek or Holsworthy Military Area

Technical Paper

Prepared by:

PPK
Environment & Infrastructure

ACN 078 004 798
A NATA Certified Quality Company
PPK House
PO Box 248
Concord West NSW 2138

Four Elements
Level 1, 24 Falcon Street
Crows Nest NSW 2065

Peter M. Davidson
PO Box 107
Norfolk Island NSW 2899

John Travers and Associates
1 Francis Byrnes Road
Jilliby NSW 2459

December 1997
Report No: 58H233B PR2724
ISBN No: 0642280401

Explanatory Statement

This technical paper is not part of the Draft Environmental Impact Statement (EIS) referred to in paragraph 6 of the Administrative Procedures made under the Environment Protection (Impact of Proposals) Act 1974.

The Commonwealth Government is proposing to construct and operate a second major airport for Sydney at Badgerys Creek. This technical paper contains information relating to the Badgerys Creek airport options which was used to assist the preparation of the Draft EIS.

The technical paper also assesses the impacts of developing a major airport at the Holsworthy Military Area. On 3 September 1997, the Government eliminated the Holsworthy Military Area as a potential site for Sydney's second major airport. As a consequence, information in this technical paper relating to the Holsworthy Military Area is presented for information purposes only.

Limitations Statement

This technical paper has been prepared in accordance with the scope of work set out in the contract between Rust PPK Pty Ltd and the Commonwealth Department of Transport and Regional Development (DoTRD) and completed by PPK Environment and Infrastructure Pty Ltd (PPK). In preparing this technical paper, PPK has relied upon data, surveys, analyses, designs, plans and other information provided by DoTRD and other individuals and organisations, most of which are referenced in this technical paper. Except as otherwise stated in this technical paper, PPK has not verified the accuracy or completeness of such data, surveys, analyses, designs, plans and other information.

This technical paper has been prepared for the exclusive use of DoTRD. PPK will not be liable to any party other than DoTRD and assumes no responsibility for any loss or damage suffered by any other party arising from matters dealt with in this technical paper, including, without limitation, matters arising from any negligent act or omission of PPK or for any loss or damage suffered by any other party in reliance upon the matters dealt with and opinions and conclusions expressed in this technical paper.

Acknowledgments

Data used to develop the figures contained in this document have been obtained and reproduced by permission of the Australian Bureau of Statistics, NSW Department of Land and Water Conservation, NSW National Parks and Wildlife Service (issued 14 January 1997), NSW Department of Urban Affairs and Planning and Sydney Water. The document is predominantly based on 1996 and 1997 data.

To ensure clarity on some of the figures, names of some suburbs have been deleted from inner western, eastern, south-eastern and north-eastern areas of Sydney. On other figures, only 'Primary' and 'Secondary' centres identified by the Department of Urban Affairs and Planning's Metropolitan Strategy, in addition to Camden, Fairfield and Sutherland, have been shown.

Copyright

CONTENTS

Page Number

PART A: INTRODUCTION

CHAPTER 1 INTRODUCTION 1 - 1

1.1 A BRIEF HISTORY 1 - 1
1.2 THE PROPOSAL 1 - 3
1.3 AIR TRAFFIC FORECASTS 1 - 5
1.4 OPERATION OF THE AIRPORT OPTIONS 1 - 6

CHAPTER 2 CONSULTATIONS 2 - 1

2.1 COMMUNITY CONSULTATION 2 - 1
2.2 OTHER CONSULTATION 2 - 2

CHAPTER 3 METHODOLOGY 3 - 1

3.1 BACKGROUND 3 - 1
3.2 ISSUES INVESTIGATED 3 - 2
3.3 SCOPE OF ASSESSMENT 3 - 3

3.3.1 QUANTITATIVE RISK ASSESSMENT OF AIRCRAFT CRASHES 3 - 3
3.3.2 LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE 3 - 4
3.3.3 ADVERSE METEOROLOGY AND SEISMIC ACTIVITY 3 - 5
3.3.4 BIRD AND BAT STRIKE 3 - 5
3.3.5 FUEL SUPPLY AND STORAGE 3 - 6
3.3.6 SECURITY ISSUES 3 - 6
3.3.7 UNEXPLODED ORDNANCE 3 - 6
3.3.8 CONTAMINATED SITES 3 - 7
3.3.9 FIRE RISK 3 - 7
3.3.10 EMERGENCY PLANS 3 - 7
3.3.11 OVERFLYING OF ORCHARD HILLS DEFENCE FACILITIES 3 - 8
3.3.12 CRASHES INTO WATER SUPPLY INFRASTRUCTURE 3 - 8

PART B: EXISTING ENVIRONMENT

CHAPTER 4 EXISTING ENVIRONMENT 4 - 1

4.1 QUANTITATIVE RISK ASSESSMENT OF AIRCRAFT CRASHES 4 - 1
4.2 LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE 4 - 3

4.3 Adverse Meteorology and Seismic Activity 4 - 3
4.4 Bird and Bat Strike 4 - 4
4.5 Fuel Supply and Storage 4 - 5
4.6 Security Issues 4 - 7
4.7 Unexploded Ordnance 4 - 8
4.8 Contaminated Sites 4 - 8
4.9 Fire Risk 4 - 9
4.10 Emergency Plans 4 - 10
4.11 Overflying of Defence Establishment Orchard Hills 4 - 10
4.12 Crashes into Water Supply Infrastructure 4 - 12

Part C: Assessment of Impacts

Chapter 5 Impacts of Badgerys Creek Options 5 - 1

5.1 Quantitative Risk Assessment of Aircraft Crashes 5 - 1
5.2 Adverse Meteorology and Seismic Activity 5 - 3
5.3 Bird and Bat Strike 5 - 3
5.4 Fuel Supply and Storage 5 - 4
5.5 Security Issues 5 - 5
5.6 Contaminated Sites 5 - 5
5.7 Fire Risk 5 - 6
5.8 Emergency Plans 5 - 7
5.9 Overflying of Defence Establishment Orchard Hills 5 - 8
5.10 Crashes into Water Supply Infrastructure 5 - 13

Chapter 6 Impacts of Holsworthy Options 6 - 1

6.1 Quantitative Risk Assessment of Aircraft Crashes 6 - 1
6.2 Lucas Heights Science and Technology Centre 6 - 2
6.3 Adverse Meteorology and Seismic Activity 6 - 4
6.4 Bird and Bat Strike 6 - 5
6.5 Fuel Supply and Storage 6 - 5
6.6 Security Issues 6 - 7
6.7 Unexploded Ordnance 6 - 7
6.8 Contaminated Sites 6 - 8
6.9 Fire Risk 6 - 9
6.10 Emergency Plans 6 - 10
6.11 Crashes into Water Supply Infrastructure 6 - 11

Part D: Environmental Management

Chapter 7 Environmental Management 7 - 1

7.1 Quantitative Risk Assessment of Aircraft Crashes 7 - 1

7.2 LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE 7 - 2
7.3 ADVERSE METEOROLOGY AND SEISMIC ACTIVITY 7 - 4
7.4 BIRD AND BAT STRIKE 7 - 4
7.5 FUEL SUPPLY AND STORAGE 7 - 5
7.6 SECURITY ISSUES 7 - 7
7.7 UNEXPLODED ORDNANCE 7 - 7
7.8 CONTAMINATED SITES 7 - 9
7.9 FIRE RISK 7 - 9
7.10 EMERGENCY PLANS 7 - 10
7.11 OVERFLYING OF ORCHARD HILLS DEFENCE FACILITIES 7 - 11
7.12 CRASHES INTO WATER SUPPLY INFRASTRUCTURE 7 - 11

PART E: SUMMARY OF IMPACTS

CHAPTER 8 SUMMARY OF POTENTIAL IMPACTS OF HAZARDS AND RISKS 8 - 1

REFERENCES 9 - 1

LIST OF FIGURES

		Following Page No.
Figure 1.1	Potential Airport Sites Currently Being Considered in the Draft EIS	1-3
Figure 1.2	Summary of Passenger Movement Forecasts Used for Environmental Assessment	1-3
Figure 1.3	Predominant Directions of Movement of Aircraft for Airport Operation 1	1-7
Figure 1.4	Predominant Directions of Movement of Aircraft for Airport Operation 2	1-7

APPENDICES

Appendix A Aircraft Crash Risk Assessment Report
Appendix B Bird and Bat Strike Hazards Report
Appendix C Fuel Supply and Storage Risk Report
Appendix D Preliminary Site Contamination Investigation Report
Appendix E Bush Fire Report
Appendix F Hazard and Risk Assessment for Defence Establishment Orchard Hills

Part A
Introduction

CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

This technical paper addresses the potential hazard and risk impacts identified as part of the previously proposed development of the Second Sydney Airport at either Badgerys Creek or Holsworthy Military Area. It contains information used to prepare the Draft Environmental Impact Statement (EIS) which addresses the overall environmental impacts of the Badgerys Creek airport options.

1.2 A BRIEF HISTORY

The question of where, when and how a second major airport may be developed for Sydney has been the subject of investigation for more than 50 years. The investigations and the associated decisions are closely related to the history of the development of Sydney's existing major airport, located at Mascot.

The site of Sydney Airport was first used for aviation in 1919. It was acquired by the Commonwealth Government in 1921, and was declared an International Aerodrome in 1935. In 1940 the first terminal building and control tower were opened.

In 1945 the airport had three relatively short runways. A major expansion began in 1947, and by 1954 the current east-west runway was opened. The north-south runway was first opened in 1954 and was extended to its current length in 1972. The present international terminal was opened in 1970.

Planning and investigations for a site for a second Sydney airport first started in 1946. A large number of possible sites both within and outside the Sydney Basin have been investigated.

The *Second Sydney Airport Site Selection Program Draft Environmental Impact Statement* (Kinhill Stearns, 1985) re-examined all possible locations for the second airport and chose 10 for preliminary evaluation. Two sites, Badgerys Creek and Wilton, were examined in detail and an EIS was prepared. In February 1986 the then Commonwealth Government announced that Badgerys Creek had been selected as the site for Sydney's second major airport.

The Badgerys Creek site, which is about 46 kilometres west of Sydney's Central Business District and is 1,700 hectares in area, was acquired by the

Commonwealth between 1986 and 1991. A total of $155 million has been spent on property acquisition and preparatory works.

Since 1986, planning for Sydney's second airport has been closely linked to the development of the third runway at Sydney Airport. In 1989 the Government announced its intention to construct a third runway. An EIS was undertaken and the decision to construct the runway was made in December 1991.

At the same time as investigations were being carried out on the third runway, detailed planning proceeded for the staged development of the second airport at Badgerys Creek. In 1991 it was announced that initial development at Badgerys Creek would be as a general aviation airport with an 1,800 metre runway.

The third runway at Sydney Airport was opened in November 1994. In March 1995, in response to public concern over the high levels of aircraft noise, the Commonwealth Senate established a committee in March 1995 to examine the problems of noise generated by aircraft using Sydney Airport and explore possible solutions. The committee's report, *Falling on Deaf Ears?*, containing several recommendations, was tabled in parliament in November 1995 (Senate Select Committee on Aircraft Noise, 1995).

During 1994 and 1995 the Government announced details of its proposed development of Badgerys Creek, and of funding commitments designed to ensure the new airport would be operational in time for the 2000 Olympics. This development included a 2,900 metre runway for use by major aircraft.

The decision to accelerate the development of the new airport triggered the environmental assessment procedures in the *Environment Protection (Impact of Proposals) Act 1974*. In January 1996 it was announced that an EIS would be prepared for the construction and operation of the new airport.

In May 1996, the present Commonwealth Government decided to broaden the environmental assessment process. It put forward a new proposal involving the consideration of 'the construction and operation of a second major international/domestic airport for Sydney at either Badgerys Creek or Holsworthy on a site large enough for future expansion of the airport if required' (Department of Transport and Regional Development, 1996). A major airport was defined as one 'capable of handling up to about 360,000 aircraft movements and 30 million passengers per year' (Department of Transport and Regional Development, 1996).

The Government also indicated that 'Badgerys Creek at this time remains the preferred site for Sydney's second major airport, subject to the favourable outcome of the EIS, while Holsworthy is an option to be considered as an alternative' (Minister for Transport and Regional Development, 1996). The two sites considered in this technical paper are shown in *Figure 1.1*.

Following the substantial completion of a Draft EIS on the Badgerys Creek and Holsworthy airport options, the Government eliminated the Holsworthy Military Area as a potential site for Sydney's second major airport. The environmental assessment showed that the Badgerys Creek site was significantly superior to the Holsworthy Military Area. As a result a Draft EIS was prepared which examines only the Badgerys Creek site. While this technical paper examines both the Badgerys Creek and Holsworthy airport options, only the parts of the assessment relating to the Badgerys Creek airport options were used to assist the preparation of the Draft EIS.

1.3 THE PROPOSAL

The Commonwealth Government proposes the development of a second major airport for Sydney capable of handling up to 30 million domestic and international passengers a year. By comparison, Sydney Airport will handle about 20 million passengers in 1997. The *Second Sydney Airport Site Selection Program Draft Environmental Impact Statement* anticipated the airport would accommodate about 13 million passengers each year (Kinhill Stearns, 1985).

A stated objective of the Government is the building of a second major airport in the Sydney region to a full international standard, subject to the results of an EIS. In the Government's view, Sydney needs a second major airport to handle the growing demand for air travel and to control the level of noise experienced by Sydney residents (Coalition of Liberal and National Parties, 1996).

Government policy (Coalition of Liberal and National Parties, 1996) indicates:

- that Sydney's second airport will be more than just an overflow airport and will, in time, play a major role in serving Sydney's air transport needs; and
- a goal of reducing the noise and pollution generated by Sydney Airport as much as possible and that the Government would take steps to ensure that the noise burden around Sydney Airport is shared in a safe and equitable way.

The assumptions made on how the Second Sydney Airport would operate and the master plans which set out the broad framework for future physical development of the airport are based on an operational limit of 30 million passengers a year. The main features include parallel runways, a cross wind runway and the provision of the majority of facilities between the parallel runways.

Consideration has also been given to how the airport may be expanded in the future and the subsequent environmental implications. Such an expansion could not proceed, however, unless a further detailed environmental assessment and decision making process were undertaken by the Government.

Five airport options are considered, as well as the implications of not proceeding with the proposal. Three of the airport options are located at Badgerys Creek and two are located within the Holsworthy Military Area. Generally, the airport options are:

- Badgerys Creek Option A which has been developed to be generally consistent with the planning for this site undertaken since 1986. The airport would be developed within land presently owned by the Commonwealth with two parallel runways constructed on an approximate north-east to south-west alignment;

- Badgerys Creek Option B would adopt an identical runway alignment to Option A, but provides an expanded land area and also a cross wind runway;

- Badgerys Creek Option C would provide two main parallel runways on an approximate north to south alignment in addition to a cross wind runway. Again the land area required would be significantly expanded from that which is presently owned by the Commonwealth;

- Holsworthy Option A would be located centrally within the Holsworthy Military Area and would have two main parallel runways on an approximate north to south alignment and a cross wind runway; and

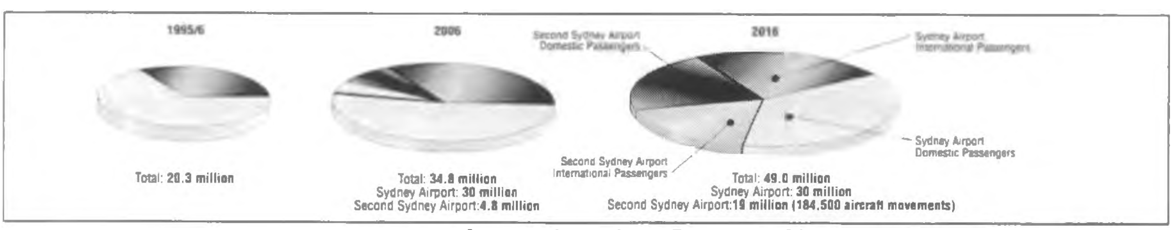
- Holsworthy Option B would be located in the south of the Holsworthy Military Area and would have two main parallel runways on an approximate south-east to north-west alignment and a cross wind runway.

To ensure that the likely range of possible impacts of the airport options are identified a number of different assumptions about how the airport options would be developed and operate have been adopted. These different assumptions relate to the number and types of aircraft that may operate from the airport, the flight paths used and the direction of take offs and landings.

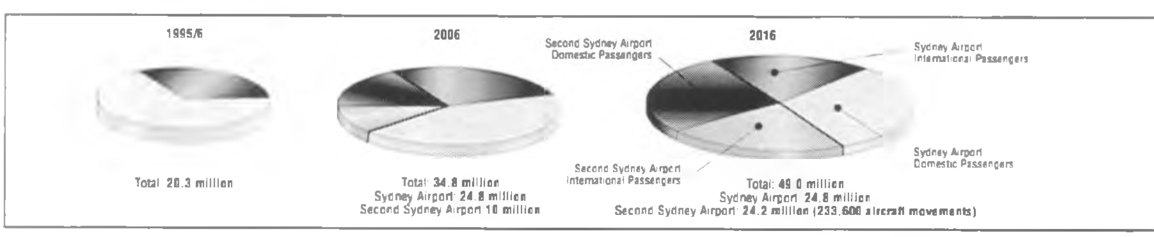
The number of flights into and out of the proposed Second Sydney Airport would depend on a number of factors including the types of aircraft that would use the airport and the associated numbers of passengers in each aircraft. The

Figure 1.1

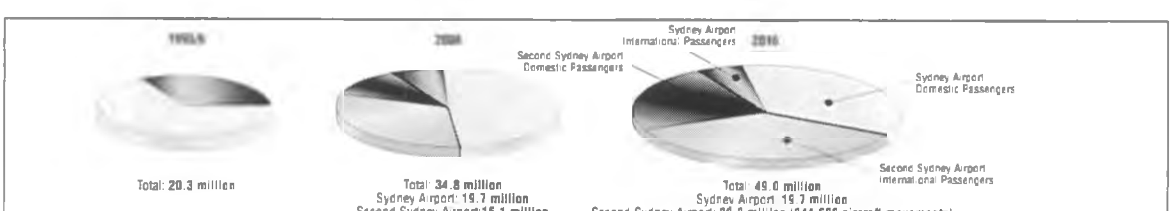
Potential Airport Sites Considered in the Draft EIS



Assumptions about Passenger Movements for Air Traffic Forecast 1



Assumptions about Passenger Movements for Air Traffic Forecast 2



Assumptions about Passenger Movements for Air Traffic Forecast 3

Figure 1.2

Summary of Passenger Movement Forecasts Used for Environmental Assessment

proposal put forward by the Government anticipates a major airport handling 30 million passengers and up to 360,000 aircraft movements per year.

Air traffic forecasts have been developed based on an examination of the number and type of aircrafts that would use the airport as it approaches an operating level of 30 million passengers per year. This examination has shown that if the airport accommodated about 245,000 aircraft movements each year, the number of air passengers would approach 30 million. This assumes a relatively high percentage of international flights being directed to the Second Sydney Airport. Therefore it is appropriate for this Draft EIS to assess the airport operating at a level of 245,000 aircraft movements per year, rather than the 360,000 originally anticipated by the Government. It has been assumed that this level of operation could be reached by about 2016.

1.4 AIR TRAFFIC FORECASTS

Cities around the world which have developed second major airports have responded to their particular needs in different ways. For example, the original airport in Dallas, United States, is now used for short range traffic that does not connect with other flights. Second airports in New York and Washington serve as hubs for particular airlines. In Taipei, Taiwan, smaller domestic aircraft use the downtown airport and larger international flights use a newer airport 40 kilometres from the city.

It is clear that each metropolitan area around the world has unique characteristics and the development of multi-airport systems respond to particular local circumstances. The precise role and consequential staging of development of the Second Sydney Airport would be the subject of future Government decisions. To assist in developing a realistic assessment of the potential impacts of the Second Sydney Airport, three sets of air traffic forecasts for the airport were developed. Each forecast assumes a major airport would be developed, however, this may be achieved at different rates of growth.

The three potential air traffic scenarios considered for the Second Sydney Airport are shown in *Figure 1.2*. They are:

- *Air Traffic Forecast 1* where the Second Sydney Airport would provide only for demand which cannot be met by Sydney Airport. This is an overflow forecast, but would nevertheless result in a significant amount of air traffic at the Second Sydney Airport. The proportion of international and domestic air traffic is assumed to be similar at both airports;

- *Air Traffic Forecast 2* where the Second Sydney Airport would be developed to cater for 10 million passengers a year by 2006, with all further growth after this being directed to the second airport rather than Sydney Airport. The proportion of international and domestic traffic is also assumed to be similar at both airports; and

- *Air Traffic Forecast 3* which is similar to Forecast 2 but with more international flights being directed to the Second Sydney Airport. This would result in the larger and comparatively noisier aircraft being directed to the second airport. It would accommodate about 29.3 million passengers by 2016.

1.5 OPERATION OF THE AIRPORT OPTIONS

At any airport, aircraft operations are allocated to runways (which implies both the physical runway and the direction in which it is used) according to a combination of wind conditions and airport operating policy. The allocation is normally performed by Air Traffic Control personnel.

Standard airport operating procedures indicate that a runway may not be selected for either approach or departure if the wind has a downwind component greater than five knots, or a cross wind component greater than 25 knots. If the runway is wet, it would not normally be selected if there is any downwind component. This applies to all aircraft types, although larger aircraft would be capable of tolerating relatively higher wind speeds. Wind conditions at the airport site therefore limit the times when particular runways may be selected. However, there would be a substantial proportion of the time, under low wind conditions, when the choice of runways would be determined by airport operating policy.

For the environmental assessment, the maximum and minimum likely usage for each runway and runway direction was estimated and the noise impact of each case calculated. The actual impact would then lie between these values and would depend on the operating policy which is applicable at the time.

The three airport operation scenarios were adopted for the environmental assessment, namely:

- *Airport Operation 1* shown in *Figure 1.3*. Aircraft movements would occur on the parallel runways in one specified direction (arbitrarily chosen to be the direction closest to north), unless this is not possible due to meteorological conditions. That is, take offs would occur to the north from the parallel runways and aircraft landing would approach from the south, travelling in a northerly direction. Second priority is given to operations in the other direction on the parallel runways, with operations on the cross wind runway occurring only when required because of meteorological conditions;

- *Airport Operation 2* shown in *Figure 1.4.* As for Operation 1, but with the preferred direction of movements on the parallel runways reversed, that is to the south; and

- *Airport Operation 3.* Deliberate implementation of a *noise sharing* policy under which seven percent of movements are directed to occur on the cross wind runway (equal numbers in each direction) with the remainder distributed equally between the two parallel runway directions.

Since a cross wind runway is not proposed at Badgerys Creek Option A, only Operations 1 and 2 were considered for that option.

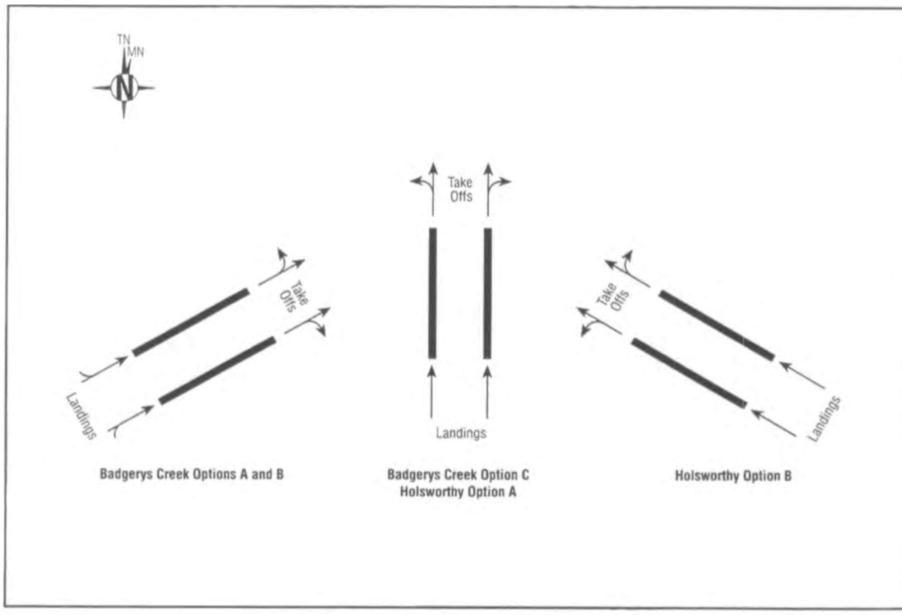


Figure 1.3
Predominant Directions of Movement of Aircraft for Airport Operation 1
Note: Cross wind runway used only when required because of meteorological conditions

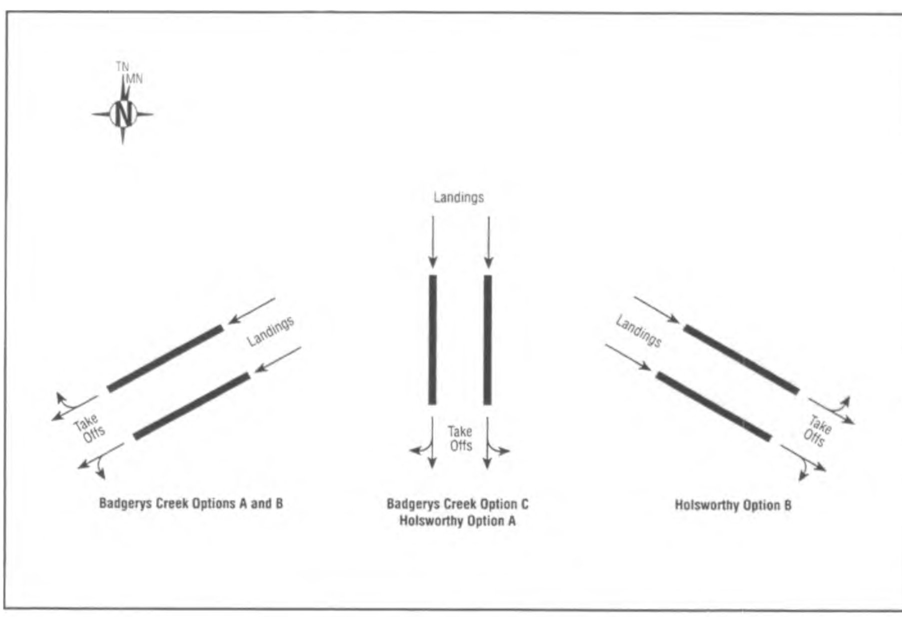


Figure 1.4
Predominant Directions of Movement of Aircraft for Airport Operation 2
Note: Cross wind runway used only when required because of meteorological conditions

CHAPTER 2 CONSULTATIONS

Preparation of this Draft EIS involved consultation with the community, other stakeholders, Commonwealth, State and local Governments and Government agencies.

2.1 COMMUNITY CONSULTATION

The primary role of the consultation process during the preparation of the Draft EIS was to provide accurate, up to date information on the proposals being considered and the assessment process being undertaken. From October 1996 to May 1997, ten separate information documents were released and over 400,000 copies distributed to the community. Four types of display posters were produced and 700 copies distributed. Over 140 advertisements were placed in metropolitan and local newspapers. Non English language documents were produced in 14 languages and over 20,000 copies distributed. Advertisements in seven languages were placed on ethnic radio.

Opportunities for direct contact and two way exchange of information with the community occurred through meetings, information days, displays at shopping centres, telephone conversations and by responding to written submissions. Through these activities over 20,000 members of the community directly participated in the consultation activities.

Written and telephone submissions received were incorporated into a database which grouped the issues in the same way as the chapters of the Draft EIS. The issues raised were progressively provided to the EIS study team to ensure that community input was an integral part of the assessment process.

Further details of consultation with the community and other stakeholders and its outcomes are contained in *Technical Paper No. 1 Consultation.*

2.2 OTHER CONSULTATION

Various Government departments and agencies were consulted during the preparation of the Draft EIS. These include the following:

Organisation	Information Obtained
Australian Nuclear Science and Technology Organisation	Consequences of an aircraft crash on various nuclear facilities on site
Bureau of Air Safety	Statistics on aircraft accidents
Civil Aviation Safety Authority	Restrictions of flight paths over Orchard Hills Defence Facilities
Department of Defence - Australian Ordnance Council	Restrictions of flight paths over Orchard Hills Defence Facilities
Department of Defence - Orchard Hills Defence Facilities	Hazards to/from flight paths over Orchard Hills Defence Facilities
Nuclear Safety Bureau	Risk assessment criteria for nuclear reactors (consequences of an aircraft crash on the nuclear reactor at Lucas Heights and identification of other nuclear facilities on site which also need to be considered)
NSW Department of Urban Affairs and Planning	Location of hazardous industries in the vicinity of the sites
Sydney Water	Location of water supply infrastructure assets in the vicinity of the five Second Sydney Airport options, consequences of loss of service from these assets
Airservices Australia	Aircraft crash risk assessment (provision of air traffic services for the Second Sydney Airport, Air Traffic Control procedures within a terminal area and implementation of airspace restrictions

CHAPTER 3 METHODOLOGY

3.1 BACKGROUND

People face many risks in daily life. Where risks are taken with free choice and with full knowledge, that risk is described as voluntary risk. Where the individual does not have the knowledge of the risk or is not entirely free to choose to avoid the risk exposure, then the risk is termed non-voluntary. In reality, most types of risk exposures have degrees of both the voluntary and non-voluntary.

The risk from a hazardous industrial development is usually perceived as a non-voluntary risk. The risk may be borne by some people more than others and the benefits may also be unevenly distributed. These risks are regulated by society as a whole with the aim of securing general benefit.

Over the years, government regulators in many countries have formulated criteria for acceptable levels of risk to the public for the purpose of decision-making. The general principles for acceptable risk criteria is that it should be low relative to other known and tolerated risks. The development of such risk criteria has made it possible to assess the risks from new proposals on a uniform basis. However, there is a need to balance risks against benefits, and hence any such standards, or criteria, are only one of the factors considered in the decision-making process.

When planning a new hazardous facility, it is now a requirement in many countries to consider risks to people outside the boundaries of the proposed facility so that the acceptability of risk levels can be judged in relation to the nature of land use in the vicinity. This process ensures that new hazardous industries are separated sufficiently from sensitive land uses. Similarly when planning new developments (for example residential developments) in the vicinity of existing hazardous facilities, it is a requirement to consider the acceptability of risk levels at new developments.

It is necessary to consider both individual risk as well as societal risk. Individuals are concerned about their own safety, and this concern is mostly independent of whether the risk is from an isolated incident or from a large-scale disaster. On the other hand, society's perception is mostly influenced by disasters involving many people.

In an accident, the level of physical harm to people could range from minor injury to fatality. Most assessments of individual or societal risk are in terms of human fatality.

Individual fatality risk is the risk of death per year to a person at a particular point outside the boundary of the facility. Individual risk is generally higher at locations that are closer to the facility, and reduce at a distance. One of the ways in which individual risk can be expressed is by means of iso-risk contours. The individual risk at points in the study area is calculated and contours for nominated individual risk levels are plotted on a map of the study area. The normal basis for the calculation assumes that an individual remains in a location constantly, thus allowing the reader to interpret the plot according to the proportion of time real individuals are actually present (the occupancy).

Societal risk considers the risk from an installation or activity to society as a whole, and takes into account the actual number of people exposed to levels of risk. On-site population or voluntary risk takers are generally excluded from such calculations. A number of measures or representations of societal risk are possible; the most commonly used is the Societal Risk or FN curve. The societal risk or FN curve expresses the risk to the population in the study area as a whole, independent of geographical location. It is a graphical representation on a log-log scale of the frequency, F, of N or more fatalities plotted against the number of fatalities, N. The shape of an FN curve and its level (that is, the F values for a given N) indicate the pattern and level of risk.

3.2 ISSUES INVESTIGATED

Hazard and risk issues investigated as part of preparing the Draft EIS were either investigated quantitatively (that is, generating probabilities of events and predicting numbers of crashes or potential fatalities) or qualitatively (that is, describing potential risks and consequences without numerical analysis). Quantitative risk assessments were used to investigate:

- the potential for aircraft crashes into industrial and residential areas;
- the potential for aircraft crashes into the Lucas Heights Science and Technology Centre;
- risks associated with aircraft from the Badgerys Creek options overflying the Orchard Hills Defence Facilities; and
- risks and potential consequences of aircraft crashes into Sydney's water supply infrastructure.

Qualitative risk assessment was used to investigate:

- adverse meteorology and potential for seismic activity at the sites of the airport options;

- potential risks of bird and bat strikes;
- potential safety and environmental risks associated with supply and storage of aircraft fuels;
- contaminated sites;
- potential risks associated with clearance of unexploded ordnance at the sites of the Holsworthy options; and
- bushfire risks associated with both Badgerys Creek and Holsworthy options.

3.3 SCOPE OF ASSESSMENT

3.3.1 QUANTITATIVE RISK ASSESSMENT OF AIRCRAFT CRASHES

The individual and societal fatality risk from aircraft crashes to people on the ground in a study area measuring approximately 45 kilometres by 45 kilometres centred around each airport option, has been assessed. This is covered in detail in the *Aircraft Crash Risk Assessment Report* contained in *Appendix A*.

The main steps in conducting a quantitative risk assessment are as follows:

- establish the context;
- identify hazards and risks;
- analyse risks to estimate the levels of risk; and
- assess risk levels against pre-established criteria.

The steps leading up to the risk assessment are part of the overall risk management process specified in the Australian Standard on risk management (AS/NZS 4360: 1995).

This study provides two types of risk results: individual risk contours as graphical representations of individual risks and F-N diagrams as graphical representations of societal risks.

Individual risk is the probability that, over a time span of one year, a particular geographical location is exposed to lethal consequences of an aircraft accident. Whether the area is actually populated or not is irrelevant to the calculation of individual risk.

Societal risk is the probability that, over a time span of one year, a group of more than N people are killed due to an aircraft accident. Societal risk calculations take into account the population density in the study area.

Preliminary analysis of the three air traffic scenarios indicated that Air Traffic Forecast 3 in the year 2016 would have the worst risk impacts. Therefore risk impacts for each airport option were investigated in detail for this air traffic forecast, in three possible modes of operation. Historical crash data from Australia and overseas was analysed to predict crash rates in the year 2016, and to determine the probability of crash at different locations relative to particular flight paths.

The consequences of a crash in general built-up areas were also analysed. Risk modelling considered factors specific to each airport option such as preliminary flight paths, the number and types of aircraft movements on each flight path and the predicted population densities in areas under the flight paths.

Figures showing the location of contours representing one in a thousand chance (1×10^{-3}), one in ten thousand chance (1×10^{-4}) and one in one hundred thousand chance (1×10^{-5}) of a crash per square kilometre per year were developed. Similarly, figures showing the location of contours representing individual fatality risk of 10 in a million (1×10^{-5}), one in a million (1×10^{-6}) and 0.1 in a million (1×10^{-7}) per year were developed. Societal risk to the population in the study area as a whole has been expressed as F-N curves showing the frequency per year (F) of crashes that result in N or more fatalities on the ground, and as a fatality rate (persons per 100 years).

3.3.2 LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE

Existing hazards and risks to communities in the vicinity of the Lucas Heights Science and Technology Centre were investigated and proposed flight paths and existing airspace constraints identified. This work was based on the scenarios considered in the main quantitative risk assessment for aircraft crashes. This is outlined in the *Aircraft Crash Risk Assessment Report* contained in *Appendix A*.

Potential frequency and consequences of aircraft crashes on the Centre from existing air traffic were analysed. Quantitative risk assessments were undertaken for proposed flight paths associated with both of the Holsworthy options and the likelihood of crashes into the nuclear facilities and off site health consequences of such an accident were analysed. Public health risks were assessed against Nuclear Safety Bureau risk criteria for nuclear facilities in Australia.

3.3.3 ADVERSE METEOROLOGY AND SEISMIC ACTIVITY

The likely prevalence of adverse meteorological conditions, which could potentially affect aircraft operations and ground traffic at the Badgerys Creek and Holsworthy options, was investigated by the Bureau of Meteorology (1997). This is discussed in *Technical Paper No.5 - Meteorology*. An assessment of the possible implications of adverse meteorology on aircraft movements was made. The potential for seismic activity at the sites of the airport options was investigated. Seismic potential was documented by Kinhill Stearns (1985). This work has been used as the basis for analysis undertaken for this Draft EIS.

3.3.4 BIRD AND BAT STRIKE

Potential hazards associated with bird and bat strike were investigated for each of the airport options. A Bird and Bat Strike risk report is contained in *Appendix B*. Information from the flora and fauna assessment work was used to provide site specific data on bird and bat species and physical inspections of the sites were undertaken. Output from this work was used to guide the airport planners in avoiding the creation of potential habitat for waterbirds. Factors that can be used to broadly classify bird and bat hazard risk at a particular location are the physical size of the birds or bats, their known movements and the likely size of the bird flocks or bat colonies.

There are a few limitations in trying to qualitatively assess the risk of bird or bat strike. For example, it is not possible to reliably quantify bird hazard risk or establish a valid measure which may be used to compare risk between different locations.

For locations where birdstrike reports and reliable aircraft movement data are available the birdstrike rate (number of birdstrikes per 10,000 specified aircraft movements) may be calculated. Due to large variations in the quality of birdstrike reports and reporting and other factors such as bird species and behaviour and aircraft types, comparing birdstrike rates between different locations is not necessarily valid.

There are no data on which birdstrike rates could be calculated for the Badgerys Creek and Holsworthy Airport sites, and no valid quantifiable bird hazard index is available.

Bird hazard may be subjectively classified as 'low', 'moderate' and 'significant'. The reliability of the subjective bird hazard classification depends on the classifier's depth of knowledge and experience of bird hazards to aircraft.

Hypothetically, the factors that can be used to broadly classify bird hazard risk at a particular location are shown in *Table 3.1*. For example, a moderate level of risk might arise from medium size birds or from birds which have seasonal movements, or from medium sized flocks.

For bats, less information is available on potential for collisions with aircraft than for birds. This is because bird strike is a much more common occurrence than bat strike. However a similar approach would be followed for assessing bat strike risk.

TABLE 3.1 BIRD HAZARD CLASSIFICATIONS

Factors	Level of Risk		
	Low	**Moderate**	**Significant**
Site of bird population	small	medium	large
Physical size of birds	small	medium	medium/large
Flocks	none/small	seasonal/medium	regular/large
Movements[2]	rare/seasonal	occasional/seasonal	frequent, may be seasonal

Note: 1. Species which are likely to be a hazard to aircraft
2. Likely to conflict with aircraft flight paths.

Classifying bird hazards to aircraft is, in practice more complicated than the above table indicates, due to the variability of the real world. This table takes no account of aircraft type and operation.

3.3.5 FUEL SUPPLY AND STORAGE

Risks associated with supply of fuel to the various airport options and the storage of fuel, oil and lubricants at the airport site have been assessed from a land use safety planning viewpoint. This is outlined in the *Fuel Supply and Storage Risk Report* contained in *Appendix C*.

3.3.6 SECURITY ISSUES

Security categorisation of existing airports in Australia was examined and the way that security issues would be handled at the Second Sydney Airport was examined, to a preliminary level of detail.

3.3.7 UNEXPLODED ORDNANCE

Assessment of risks associated with unexploded ordnance at the sites of the Holsworthy options was based upon investigations by Second Sydney Airport

Planners (1997a). Site inspections were undertaken, the Department of Defence was consulted and field trials of detection and cleanup technologies were organised with companies with international expertise in this field.

3.3.8 CONTAMINATED SITES

A preliminary assessment was undertaken of the potential for the sites of the Badgerys Creek and Holsworthy airport options to contain contaminated soils or other materials, due to previous and current activities. This comprised a review of existing and historical information including aerial photographs taken at different times, a recent environmental audit of the Holsworthy Military Area, commissioned by the Department of Defence (AXIS /Australian Museum Business Services, 1995) and contamination reports for a specific part of the Badgerys Creek site. Field inspections of the sites of the Badgerys Creek and Holsworthy options were undertaken and limited sampling and analysis of soils and surface waters was carried out for some areas of high activity within the Holsworthy Military Area.

A report covering this investigation is contained in *Appendix D*.

3.3.9 FIRE RISK

The existing potential for bush fires at Badgerys Creek and Holsworthy was investigated and current fire management practices were identified by reviewing historical records, conducting site inspections and interviewing people with local knowledge. The potential impact of airport construction and operations on bush fire risks and the potential affects of fires on airport construction and operations were examined with reference to construction plans and masterplans for the Airport options. Possible management strategies for fighting bush fires and site evacuation were also investigated and fire prevention measures were reviewed.

A report on Bushfire Risk is contained in *Appendix E*.

3.3.10 EMERGENCY PLANS

An aerodrome emergency plan details the procedures for dealing effectively with emergency situations, such as aircraft accidents, both on and off the airport site. The requirements for developing and implementing an emergency plan were examined including the range of the issues that needs to be addressed in the plan.

Information on emergency plans relating to Australian airports was provided by the Department of Transport and Regional Development, for inclusion in the Environmental Impact Statement.

3.3.11 OVERFLYING OF ORCHARD HILLS DEFENCE FACILITIES

Since the Badgerys Creek airport options involve establishing regular flight paths over the Defence Establishment Orchard Hills, a quantitative risk assessment of aircraft crashes into explosives storage facilities was conducted. The potential implications for existing air space restrictions were examined by consulting with regulatory bodies and the Department of Defence. All work was based on scenarios contained in the quantitative risk assessment for aircraft crashes. A quantitative risk assessment report for the Defence Establishment Orchard Hills is contained in *Appendix F*.

3.3.12 CRASHES INTO WATER SUPPLY INFRASTRUCTURE

The five airport options are located at different sites, which indicates that the risk impacts on particular facilities could be different for each option. Specific assessments of the risks associated with aircraft crashing into major water supply infrastructure have been undertaken for each of the five airport options. The assessments are based on Air Traffic Forecast 3 in the year 2016, which represent the worst-case impacts. For each airport option, three possible modes of operations were investigated.

Contours representing the frequency of aircraft crashes in the vicinity of each airport option in each mode of operation were examined to identify major water supply infrastructure that is exposed to different levels of aircraft crash frequency. The water supply infrastructure included Prospect Dam, Warragamba Dam, Woronora Dam and the major pipeline between Lake Burragorang and Prospect Reservoir. The consequences of aircraft crashes on these major infrastructure are described, and the risk levels are compared with the risk from other external hazards. This is outlined in the *Aircraft Crash Risk Assessment Report* contained in *Appendix A*.

Part B

Existing Environment

CHAPTER 4 EXISTING ENVIRONMENT

4.1 QUANTITATIVE RISK ASSESSMENT OF AIRCRAFT CRASHES

Some of the risks that people face in daily life are considered voluntary and others non-voluntary. The risk from a hazardous industrial development is generally perceived as a non-voluntary risk. The NSW Department of Urban Affairs and Planning has developed guidelines for acceptability of risk from hazardous industrial developments. The general principle for acceptable risk criteria is that it should be low relative to other known and tolerated risks.

In NSW the fatality risk in many everyday circumstances have been previously documented. Some of the risks faced by people in NSW include 110 in a million chances of fatality each year due to accidents at home, 60 in a million chances of fatality each year due to accidental falls, 35 in a million chances of fatality each year as a pedestrian struck by motor vehicles, and 18 in a million chances of fatality each year due to accidental poisoning. These risks are summarised in *Table 4.1*.

Taking into account these, and many other known and tolerated risks, the Department of Urban Affairs and Planning has suggested that people in residential areas should not be exposed to more than one in a million chance of fatality each year due to accidents at a hazardous industrial facility. People in more sensitive areas such as hospitals and schools should not be exposed to more than 0.5 in a million chance of fatality each year due to accidents at a hazardous industrial facility. The risk criteria for less sensitive commercial and industrial land uses are higher at five in a million and 50 in a million chances of fatality each year respectively. These risks are additional to those previously existing.

While the Department of Urban Affairs and Planning requires quantification of societal risk, it suggests that judgement on societal risk be made on the merits of each case, rather than by setting numerical values.

The Department of Planning (1990) stated that irrespective of the numerical value of any risk criteria, all avoidable risks from a major hazard should be avoided or reduced wherever practicable. This necessitates the investigation of alternative locations and alternative technologies, wherever applicable, to ensure that risks are not introduced in an area where feasible alternatives are possible and justified (Department of Planning, 1990).

Risk criteria are best implemented when used as targets rather than absolute levels. They provide a guide to judging the acceptability/tolerability of individual risk levels from the five Second Sydney Airport options. The guidelines emphasis that all criteria are advisory, rather than definitive, for a number of reasons, including the need to consider other factors and to balance risks against benefits. Hence any such standards, or criteria, are only one of the factors considered in the decision-making process.

TABLE 4.1 RISKS TO INDIVIDUALS IN NEW SOUTH WALES

Risks Averaged over the Whole Population	**Chances of Fatality per person per year (in a million)**
Cancers from all causes	1,800
Accidents at home	110
Accidental falls	60
Risk criteria for Industrial Land Uses[1]	50
Pedestrians struck by motor vehicles	35
Homicide	20
Accidental poisoning	18
Fires and accidental burns	10
Risk criteria for Commercial Land Uses[1]	5
Electrocution (non-industrial)	3
Falling objects	3
Therapeutic use of drugs	2
Risk Criteria for Residential Land Uses[1]	1
Risk Criteria for Hospitals, Schools etc[1]	0.5
Catacylsmic storms and storm floods	0.2
Lightning strikes	0.1
Meteorite strikes	0.001

Source: Department of Urban Affairs and Planning, 1990 and Kinhill, 1990.
Note: 1. Risk criteria relates to the risk generated from a particular hazardous facility or activity. It represents an additional level of risk above risks that already exist.

Existing air traffic in Sydney already imposes certain levels of risk on populated areas. Risks of aircraft crashes due to the Second Sydney Airport would be added to existing risk levels, although potential risks associated with existing flight paths are likely to be reduced, if flight paths are altered to accommodate aircraft using the Second Sydney Airport.

4.2 LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE

There are a number of facilities at the Lucas Heights Science and Technology Centre with the potential for off-site consequences. These include the HIFAR research reactor, fuel storage areas and radiopharmaceutical production activities. Of these facilities, the major off-site effect from an aircraft crash would come from a crash into the research reactor. Because of the physical separation of the buildings, there are few circumstances where simultaneous release might occur. Even if a crash occurred which simultaneously affected several adjoining facilities, the consequences would not be more than a factor of two greater than those calculated in the following sections.

The defences against health risks to the public from accidents at a nuclear reactor are dependent upon the design and engineering systems adopted, and the location of the reactor. The defence-in-depth approach adopted by the Australian Nuclear Science and Technology Organisation provides multiple layers of barriers such that as the protection provided by each safety feature is challenged in an accident, there will be a further safety feature to provide protection to the public. An exclusion zone of 1.6 kilometre, centred around the HIFAR reactor has been defined within which permanent residential development is not permitted. This exclusion zone provides a defence against risks to the public when all engineered safety features have been degraded.

The Nuclear Safety Bureau, the independent statutory organisation having the regulatory role for the safety of nuclear plants owned or operated by the Australian Nuclear Science and Technology Organisation, has developed in draft its Safety Assessment Policy for Australian Nuclear Facilities (Nuclear Safety Bureau, 1997). The draft Policy specifies criteria on the off-site health risks from reactor accidents and the siting of nuclear facilities.

4.3 ADVERSE METEOROLOGY AND SEISMIC ACTIVITY

The prevalence of adverse meteorological conditions such as fog, thunderstorms and lightning and high intensity rain at the sites of the Airport options is discussed in *Technical Paper No.5 - Meteorology*. There appears to be little difference between the Badgerys Creek and Holsworthy options in this regard.

Quantitative assessment of the extent to which adverse meteorological conditions occur at each of the airport sites was not undertaken by the Bureau of Meteorology (1996) due to the lack of site specific meteorological data. Therefore, only preliminary conclusions were able to be drawn about the likely incidence of these phenomena, especially at Holsworthy.

The area which includes the sites of the Badgerys Creek and Holsworthy options has not suffered from earthquakes associated with zones of significant crustal weakness in it's 200 year recorded history (Kinhill Stearns, 1985). It suffers occasional tremors, the origin of the strongest of which is inferred to be a zone of weakness in the south west Sydney Basin, in the vicinity of Moss Vale.

The Modified Mercallie scale is used to measure ground shaking effects (intensity) of an earthquake. For example, at an intensity level of IV, hanging objects swing, vibration is felt, stationary cars rock and windows rattle. Degrees of damage to various classes of masonry structures serve as criteria for identifying higher intensity levels.

4.4 BIRD AND BAT STRIKE

Collisions with individual birds, especially if large, or flocks of birds can result in damage to aircraft windscreens, wings, tail, aerials, lights and engines. Damage to structures and systems can cause control and visibility difficulties, sometimes resulting in the loss of the aircraft, especially if the bird strike occurs during critical phases of flight such as take-off and landing.

Likewise, ingestion of a bird or birds into a turboprop or turbo-fan engine can cause damage to fan blades and other components. In Australia, there have been a number of examples of birdstrikes in which all engines on a passenger aircraft have been damaged. World wide in 1988, one fifth of civil passenger aircraft losses and fatalities were related to bird strike incidents.

Bats, especially fruit bats or flying foxes, which may weigh up to 1.3 kilograms, can also cause significant damage to aircraft. However, unless they occur in very large numbers, small birds or bats are unlikely to cause damage to aircraft. Most birds fly at relatively low heights above the ground and thus about 80 percent of all birdstrikes occur below 70 metres, in the zone where civil passenger aircraft are taking off or landing.

Open grasslands, drainage systems, landscaping, sealed surfaces and buildings at an airport could provide food, shelter and sometimes breeding opportunities for particular species of birds. Land uses and habitats outside the airport, such as sewage treatment plants, garbage dumps, forests and wetlands may attract birds. Most forest birds are small, and apart from cockatoos, the larger birds such as owls and eagles do not occur in flocks. In contrast, many of the birds which frequent open grassland/woodland and open water/swamp are large and often occur in flocks.

Bats roost in lofts and roof spaces of buildings, as well as in tree hollows scattered throughout forest, or rock crevices and overhangs along gullies. No large micro bat roosts or breeding sites are known to occur within the sites of the Badgerys Creek and Holsworthy options. At dusk, large numbers of fruit bats leave their communal daytime camps to feed during the night on the nectar and fruits of flowering trees and shrubs. Bats rarely fly at heights greater than 50 metres above the ground, usually flying just above trees and other obstructions, often following concentrated flight paths. In the hours before dawn, fruit bats return to their camp individually and in small groups.

One fruit bat breeding colony is located at Cabramatta Creek, near Warwick Farm Racecourse. This is approximately 20 kilometres east of the Badgerys Creek sites, 16 kilometres north of Holsworthy Option A and 26 kilometres north of Holsworthy Option B. Fruit bats have been observed at Badgerys Creek, feeding in trees in gardens. A larger number of bats feed on eucalyptus flowers in the Holsworthy Military Area, especially during summer, and on fruit in orchards in Darkes Forest, to the south.

4.5 FUEL SUPPLY AND STORAGE

Options available for the supply of Jet A1 fuel to the airport options are by road rail or direct pipeline from the Clyde refinery near Parramatta or from the Plumpton storage facility near Blacktown. A pipeline may be required for the initial stage of the airport and would certainly be required before airport capacity reached 30 million passengers per annum. Some fuels such as AvGas would always be delivered by road tankers. Fuel storage facilities would be provided on the airport sites. The proposed location of the fuel storage depot is not beneath flight paths for any of the airport options.

The Department of Urban Affairs and Planning (1990) has developed guidelines for the identification of industrial developments which require a consideration of hazards and risks associated with road transport of hazardous materials (Department of Urban Affairs and Planning, 1994). For Class 3 Packaging Group III materials, transport risks are considered to be potentially significant where cumulative annual traffic movements are more than 1,000 and peak weekly traffic movements are more than 60. On that basis, the proposal to supply Jet A1 fuel by road during the initial phase would be considered to be potentially hazardous. For such proposals, the Department of Urban Affairs and Planning requires a route evaluation study to be completed in accordance with its route selection guidelines. This type of study has not been undertaken for preparation of this Draft EIS.

The objective of conducting a risk assessment at the planning stage is to assess the hazards and risks to various land uses in the vicinity of the pipeline route and the fuel storage facilities at the airport.

The Department of Planning (1990) developed qualitative and quantitative risk assessment criteria for land use safety planning. These criteria would be applicable to both the fuel supply pipeline along its route and the fuel storage facilities at the airport.

Different quantitative criteria are applicable to different land uses, as summarised in *Table 4.2*.

TABLE 4.2 SUGGESTED INDIVIDUAL FATALITY RISK CRITERIA

Land Use	Individual Fatality Risk (per million per year) should not exceed
Hospitals, schools, child-care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open spaces	10
Industrial	50

Source: Department of Planning, 1990.

The Department of Urban Affairs and Planning (1990) has also suggested risk assessment criteria for individual injury risk in residential areas, and for risk of property damage and accident propagation in a neighbouring industrial operation.

The airport fuel depot would cater for the requirements of jet and piston engined aircraft. Fuel, oil and lubricants would be stored at the depot. The depot would include the following major facilities:

- three 5 million litre Jet A1 fuel storage tanks in the first stage. Three additional 10 million litre storage tanks would be required for the masterplan airport. A containment bund would be sized to comply with the dangerous goods regulation of 100 percent of the largest storage tank capacity. State-of-the-art leak detection systems would be fitted to the system.

- pumping facilities for delivery of Jet A1 fuel to aircraft. Jet A1 fuel would be delivered to aircraft by a system of underground pipes with hydrant points at each aircraft gate and some or all stand-off positions;

- four underground AvGas storage tanks of 110, 000 litres capacity each. Tanks would be constructed in steel with fibreglass outer lining for corrosion protection. Supply to the tanks would be by road tankers;

- AvGas road tanker access, loading/unloading facilities and car park; and

- lubricating and hydraulic oil storage.

The design and operational requirements of such facilities are stringent and covered by relevant Australian Standards and Civil Aviation Regulations. These facilities would be operated under a joint operator arrangements similar to those existing at other major airports in Australia.

Fuelling facilities would also be provided on both airside and landside for airport based equipment and vehicles. In addition, there would be one or more service stations for public use. Such facilities would dispense LPG, petrol, diesel fuel and lubricating oils and may also undertake vehicle servicing. The design and operating standard of these facilities would be similar to a commercial service station.

For the masterplan stage development the total demand of 30,000 to 35,000 litres of AvGas per day could be met with less than one standard tanker per day. The small number of tanker movements indicates that the risks associated with AvGas road transport is unlikely to be significant.

The Department of Urban Affairs and Planning has developed guidelines for the identification of industrial developments which require a consideration of hazards and risks associated with road transport of hazardous materials (Department of Urban Affairs and Planning, 1994). For Class 3 Packaging Group I materials, transport risks are not considered to be significant where cumulative annual traffic movements are less than 500 and peak weekly traffic movements are less than 30. Therefore, AvGas transport risks are not considered any further.

4.6 SECURITY ISSUES

The Department of Transport and Regional Development develops, in consultation with the aviation industry, the national security agencies and other regulatory bodies, a policy framework for aviation security. This scheme applies a range of protective security measures on certain airports and airlines to deter and prevent acts on unlawful interference with aviation.

Concerning airports specifically, the Department has a security categorisation system which considers the type of operation at airports (whether charter or RPT), the size and frequency of aircraft operation and the total passenger throughput. The present regulatory framework applies different security measures for each security category of airport from 1 (the most stringent measures) to 5 (the least stringent). Additional security measures, over and above those normally occurring, are applied at times of higher threat (usually advised by national intelligence agencies) or to protect aviation against specific increases in threat, such as the visit of a particularly threatened VIP.

Presently there is only one airport in the Sydney basin which has a security category - Sydney (Kingsford Smith) Airport. It is a security category 1 airport owing to its significant passenger throughput (both domestic and international) and the frequent movement of very large passenger aircraft. No other Sydney airport currently has services by aircraft large enough to require security categorisation by the Commonwealth.

4.7 UNEXPLODED ORDNANCE

Information about the current situation within the sites of the Holsworthy airport options is contained in the Planning and Design Report (Second Sydney Airport Planners, 1997a).

4.8 CONTAMINATED SITES

The only known contaminated site within the sites of the Badgerys Creek options is at Lot 4, The Northern Road, Luddenham. Contamination occurred as a result of dumping of materials by a former liquid waste contractor. Remediation of the site is now completed (Department of Administrative Services, 1997).

Other activities which could have potentially contaminated soils at Badgerys Creek include market gardening, poultry farming, truck repair, and storage of fuel and chemicals. It is anticipated that soils at Badgerys Creek would contain low levels of agricultural pesticides and chemicals.

Streams and creeks on the sites provide potential contamination migration pathways. Low permeability of soils on the sites and great depth to groundwater indicate that the potential for significant migration of contamination through soil and/or groundwater is low.

The past and current use of the Holsworthy Military Area for military activities indicates that there is a high probability of contaminated soil existing on the sites of the airport options. The site of Option A contains two demolition ranges where a high intensity of explosives use occurred and firing of ordnance took place. The site of Option B contains a highly disturbed area known as Impact Area E, which had similar use. To the north of Holsworthy Option A, and well outside the areas considered for either the airport sites or potential transport corridors, are two engineered landfills, thought to contain contaminated soil excavated from the Wattle Grove area. The landfills are indicated to be on the north and south sides of the Complete Airfield (AXIS, Australian Museum Business Services, 1995).

Sampling and analysis of a small number of grab samples of soil and surface water from blast craters in these three areas indicated that high concentrations of particular heavy metals such as aluminium are likely to be present, but that other heavy metal and organic residues from explosives may not be at significant levels. Natural sources of aluminium are a possibility, however more comprehensive testing would be necessary to confirm this.

There is likely to be a number of undocumented landfills within the area, which potentially contain contaminated materials. Other potential sources of contamination include imported railway ballast and coal waste which have generally been used for road construction.

4.9 FIRE RISK

Badgerys Creek and Holsworthy are opposites in terms of the fire potential of their respective landscapes. The sites of the Badgerys Creek airport options have a grassy gently sloping landscape that does not have a history of wild fire and the overall bushfire threat is minimal. There is a potential for bushfire ignition as a result of vehicle accidents on rural roads, arson and careless use of equipment or fire on neighbouring lands, however the threat from such fires is easily managed by grazing animals and regular slashing or mowing of grasses.

In contrast, the Holsworthy Military Area is a dissected plateau with steep inaccessible terrain and a long history of uncontrolled bush fires, due to accidental fires from farm lands and garbage tips, and fires induced by exploding ordnance.

Holsworthy has an open landscape which enables wind to penetrate and fan fires and spread fires quickly. Inaccessible terrain and exposure of the plateau to winds makes fire control and prevention difficult. The fire history indicates that fires burn from west to east and smoke dispersal follows this direction. Exposure to bushland on the western side is considerably less for the site of Holsworthy Option B than for Holsworthy Option A, because of the closer proximity of the site of Option B to developed areas of Campbelltown.

Bush land within the Woronora Catchment is not seen as a significant threat to either option because of the tendency of fires to travel from west to east.

Fire fighting within the Military Area is hazardous because of the presence of unexploded ordnance, and limited access has meant that rapid response has not been possible. Activities such as backburning have had to be conducted from a network of internal roads and fire trails, using natural boundaries such as cliffs or creek lines.

The Volunteer Bush Fire Service, National Parks and Wildlife Service and Sydney Water carry out fire fighting in the areas bordering the Holsworthy Military Area. The Army currently responds to fires within it's boundary, and sometimes requires external assistance.

4.10 EMERGENCY PLANS

Regulations issued by the Civil Aviation Safety Authority require an aerodrome emergency plan to be prepared by the airport operator prior to the commencement of airport operations. The objective of the emergency plan is to ensure a timely and effective response to an emergency situation by relevant agencies, primarily with regard to saving lives and maintaining aircraft operations. The emergency plan needs to be commensurate with the scale and type of aircraft operations, the surrounding geography and other activities conducted at the airport.

An emergency plan developed by the Federal Airports Corporation is currently in place for Sydney Airport.

4.11 OVERFLYING OF DEFENCE ESTABLISHMENT ORCHARD HILLS

The Defence Establishment Orchard Hills area contains approximately 150 purpose built buildings that are licensed to store Explosive Ordnance. The aggregate licence quantity for all Explosive Ordnance storage buildings in the Navy area, known as RANAD Kingswood, is 200 tonnes Net Explosive Quantity of ammunition. However this quantity of Explosive Ordnance is not present at all times.

The types of Explosive Ordnance stored includes all types of Explosive Ordnance used by the Australian Defence Forces, for example, guided weapons, gun ammunition, demolition and pyrotechnic stores, and small arms ammunition.

Some buildings are surrounded by a mound, while others are not. The roofs of these buildings are of lightweight construction and are designed to vent the effects of an explosion upwards instead of outwards.

While no explosives are manufactured on the site, Explosive Ordnance is assembled, repaired, inspected and proof-tested. Certain operations require the removal of electro-explosive devices from their packaging. During this time these devices may be susceptible to electromagnetic radiation.

Testing of the initiating devices of guided weapons is undertaken in special buildings on the site.

There is also a demolition range at the site which was not being used at the time of the site inspection. The range remains active and is licensed to dispose of high explosive bombs which are unstable. The rifle range on site was only operating between 10am and 5pm, three days a week for similar reasons.

There are no existing permanent flight paths over the Defence Establishment Orchard Hills. Airspace between 0-1,5000 feet within one nautical mile radius of the Defence Establishment Orchard Hills is permanently restricted from Monday to Friday during daylight hours. Airspace between 0-4,500 feet within 1 nautical mile radius of the facility is permanently restricted from Monday to Friday between 10am-12 noon and 3-5pm. Both of these restrictions are based upon demolition activities on site, rather than storage of Explosive Ordnance.

Airservices Australia has stated that if the current permanent airspace restrictions over the facilities remain, the operation of a Second Sydney Airport at Badgerys Creek could be constrained.

The Department of Defence has indicated that permanent flight restrictions relating to demolition of explosives could possibly be removed. However, as there is an ongoing need to demolish small quantities of Explosive Ordnance from time to time, the Department of Defence and Airservices Australia have discussed the possibility of such demolition activities being undertaken with temporary airspace restrictions.

The Civil Aviation Safety Authority has indicated that all airspace restrictions must be observed. However, if current permanent airspace restrictions were to be removed, the Civil Aviation Safety Authority would have no further requirements regarding flight paths over the Orchard Hills Defence Facilities.

Flight of an aircraft over an explosives storage facility are a potentially a hazard to both the explosives and to the aircraft. It is Defence policy to protect the utility of a licensed facility from the adverse effects of developments outside Defence-controlled property. The process used to provide the required protection is known as safeguarding. The Australian Ordnance Council has developed guidelines on the Control of Airspace above Explosives Facilities and Sites of Planned Detonation. This is commonly known as Australian Ordnance Council Pillar Proceeding 205.92 (Australian

Ordnance Council, 1992). This document provides guidance on calculating relevant safeguarding heights.

The Australian Ordnance Council has recommended that:

- flights over explosives facilities should be restricted to essential transit;
- where flights over explosives facilities cannot be avoided, they should not normally be permitted to heights lower than the minimum heights already stipulated for the surrounding urban or rural areas (1,000 feet or 500 feet respectively);
- restrictions should apply for flights over planned detonations. Safety heights should be calculated as shown on Pillar Proceedings 205.92.

In separate communications, the Australian Ordnance Council has provided further guidance, as follows:

- permanent flight paths associated with the operation of a major airport are not considered to be essential transit;
- if it is necessary to have flight paths, holding patterns, or approach or departure routes passing over the Orchard Hills Defence Facilities at heights less than those calculated by applying formulae in the guidelines, a full hazard and risk analysis would need to be conducted.

Australian Ordnance Council's main concern is the risk of an aircraft crash on Explosive Ordnance storage buildings and the possible consequences of such an incident.

4.12 CRASHES INTO WATER SUPPLY INFRASTRUCTURE

Sydney's water supply infrastructure includes major dams and storage reservoirs, major above-ground pipelines and canals, water filtration plants, water pumping stations and service reservoirs.

Major water supply infrastructure assets that are located within approximately 20 kilometres of the sites for the three Badgerys Creek options are Warragamba Dam and reservoir, Prospect Reservoir and dam, Warragamba Pipelines, Upper Canal, Prospect Water Filtration Plant, and Orchard Hills Water Filtration Plant. A water filtration plant is proposed at South Creek in the future. The Warragamba Dam, Warragamba Pipelines and the Prospect Water Filtration plant are part of Sydney's largest water supply system, accounting for almost 80 per cent of the region's drinking water supply. The Orchard Hills

Water Treatment Plant supplies water to a population of about 192,000 in Penrith, Emu Plains and lower Blue Mountains.

Major water supply infrastructure assets that are located within approximately 20 kilometres of the sites for the two Holsworthy options are Woronora Dam and reservoir, Cataract Dam and reservoir, Cordeaux Dam and reservoir, Woronora Pipelines, Upper Canal, Woronora Water Filtration Plant and Macarthur Water Filtration Plant. The northernmost Illawarra towns around Helensburgh are supplied from Woronora Dam. Much of the Sutherland Shire is also supplied from Woronora Dam, although most parts of the Shire can also be supplied from Prospect. Cataract Dam, Cordeaux Dam and the Upper Canal are part of the system that supplies the Camden and Campbelltown areas.

Infrastructure facilities are generally designed and operated to achieve certain levels of reliability and safety. Although a high level of reliability and safety can be achieved, the state of absolute reliability and safety is neither achievable nor economically viable. There will always be some risk that water supply would be interrupted due to internal initiating events, such as equipment failure, or due to external initiating events, such as extreme weather conditions and earthquakes. In the case of dams, there is also some risk to downstream public and property from dam failures due to extreme floods or earthquakes.

Operations at the Second Sydney Airport options could potentially increase the risk of an aircraft crash on some of the water supply infrastructure. As a consequence, the risk of water supply interruption could potentially increase. The risk to people and property downstream of dams could also potentially increase.

Both qualitative and quantitative criteria are adopted in assessing the acceptably or tolerability of this increase in risk from the Second Sydney Airport options. Some of the qualitative criteria are:

- all avoidable risks should be avoided; and
- irrespective of the numerical value of the risk, the risk should be reduced wherever practicable.

Quantitatively, the increase in risk is compared with some existing catastrophic risks. This would allow judgement to be made regarding the tolerability of risk from the Second Sydney Airport options.

Risk of dam failure from floods is assessed in terms of Imminent Failure Flood and Probable Maximum Flood. The Imminent Failure Flood is the flood which just threatens dam failure, and depends on the design of the dam. The

Probable Maximum Flood is a credible but extremely rare event, which depends on the characteristics of the catchment. For many older dams, the Imminent Failure Flood is small in comparison with the Probable Maximum Flood, that is, dams could fail during the Probable Maximum Flood (or in fact during all floods larger than the Imminent Failure Flood). While it is not possible theoretically to calculate the frequency of the Probable Maximum Flood, a notional value of one in a million (1×10^{-6}) per year is a reasonable assumption (Pearce, 1994).

In the case of Warragamba Dam, upgrades have been proposed to mitigate the effects of flooding in the Hawkesbury-Nepean Valley (ERM Mitchell McCotter, 1995a), and to protect the dam wall during the Probable Maximum Flood (ERM Mitchell McCotter, 1996).

The risk of Prospect Dam wall failure due to an earthquake was estimated to be 10 in a million chance (1×10^{-5}) per year (ERM Mitchell McCotter, 1995b). It was estimated that failure of the Prospect Dam wall could cause the loss of nearly 1,440 lives. This risk was considered to be unacceptable, and remedial work was proposed to improve dam safety.

Failure rates of transmission pipelines could differ significantly, depending on operating conditions, age and maintenance regimes. For oil and gas transmission pipelines, rupture frequencies used in most risk assessments fall within the range one in ten thousand chance (1×10^{-4}) to one in one hundred thousand chance (1×10^{-5}) per kilometre.

The frequency of aircraft crashes in the vicinity of each airport option was analysed as part of aircraft crash quantitative risk assessment. Figures showing the location of contours representing one in a thousand chance (1×10^{-3}), one in ten thousand chance (1×10^{-4}), and one in one hundred thousand chance (1×10^{-5}) of a crash per square kilometre per year were developed for each airport option in three modes of operations. Risks to major water supply assets that are located within the three contours are discussed below.

Small aircraft are more than four times more likely to crash around the Second Sydney Airport than larger aircraft. The frequency of large aircraft crashes, which have the greater potential for damage, would be only a small proportion of the total frequency represented by the contours.

Part C

Assessment of Impacts

CHAPTER 5 IMPACTS OF BADGERYS CREEK OPTIONS

5.1 QUANTITATIVE RISK ASSESSMENT OF AIRCRAFT CRASHES

Of all the potential hazards and risks impacts associated with the establishment of the Second Sydney Airport one of the most obvious is the risk of an aircraft crashing onto a populated area. Quantitative risk assessment of aircraft crashes was undertaken for both the Badgerys Creek and Holsworthy options. This has been based on previous data on aircraft crashes in Australia and overseas.

The risk of aircraft crashes to people on the ground has been expressed in three different ways in this technical paper. The first way is that contours which show the probability of an aircraft crash per square kilometre per year in the areas surrounding the various airport options have been produced. These probability contours, which are shown as *Figures 3.2, 3.3* and *3.4* in *Appendix A*, for the various airport options, are based upon a worst case scenario, Air Traffic Forecast 3, in the year 2016.

The second way of representing hazards and risks associated with aircraft crashes has been to produce contours showing individual fatality risks for each of the airport options. Contours showing individual fatality risks of 10 in a million, one in a million and 0.1 in a million per year are shown in *Figures 3.7, 3.8* and *3.9* in *Appendix A*. The individual fatality risk is the risk of death per year to a person at a particular point outside the boundary of the airport. Individual fatality risk levels less than one in a million per year would meet the Department of Planning (1990) criteria for location of residential areas near hazardous industries.

Predicted fatality rates have also been calculated for the Badgerys Creek options. Predicted fatality rates represent the average number of fatalities over a number of years. These figures are shown in *Table 5.1* below.

TABLE 5.1 PREDICTED FATALITY RATE (PERSONS PER 100 YEARS) FOR BADGERYS CREEK OPTIONS

Badgerys Creek Option	**Airport Operation 1**	**Airport Operation 2**	**Airport Operation 3**
Option A	2.5	1.8	n/a
Option B	2	1.5	2.2
Option C	4	5	4.6

The predicted fatality rates for the Badgerys Creek options range between 1.5 and 5.0 persons per 100 years.

Among the two operating modes investigated for Badgerys Creek Option A, Airport Operation 1 (preferred landings from the South West and take-off to the North East) has the higher fatality rate. *Figure 3.7* in *Appendix A* shows that no major residential areas are enclosed within the one in a million per year (1×10^{-6}) per year individual fatality risk contours, which generally enclose areas along runway extended centrelines only.

Among the three operating modes investigated for Badgerys Creek Option B, Airport Operation 3 (share the noise) has the highest fatality rate, although the rate in Airport Operation 2 (preferred landings from the south west and take-off to the north east) is not much lower. *Figure 3.8* in *Appendix A* shows that no major residential areas are enclosed within the one in a million (1×10^{-6}) per year individual risk contours, which generally enclose areas along runway extended centrelines only.

Among the three operating modes investigated for Badgerys Creek Option C, Airport Operation 2 (preferred landings from the north and take-off to the south) has the highest predicted fatality rate. *Figure 3.9* in *Appendix A* shows that the one in a million per year (1×10^{-6}) individual fatality risk contours generally enclose areas along extended runway centrelines only, which include some existing residential areas towards the north of the site of Badgerys Creek Option C.

Table 5.2 shows the population exposed to a level of individual fatality risk of more than one in a million for the various Badgerys Creek options. It shows that between 2,500 and 9,000 people would be exposed to such a risk level. The Department of Urban Affairs and Planning guidelines state that risk levels of more than one in a million per year are not acceptable for residential areas located close to hazardous industries.

TABLE 5.2 POPULATION EXPOSED TO LEVELS OF INDIVIDUAL FATALITY RISK OF MORE THAN ONE CHANCE IN A MILLION PER YEAR FOR BADGERYS CREEK OPTIONS

Badgerys Creek Option	Populations Exposed to More Than One in a Million Chances of Fatality per year
Option A	2,500
Option B	2,500
Option C	9,000

Societal risk curves have been developed for all the airport options for the mode of operation shown to have highest fatality rate. These curves are shown in *Figure 3.12* in *Appendix A*. Also shown for comparison is the societal risk curves for Sydney Airport in the year 2010. It can be seen that the societal risk for Badgerys Creek options are considerably lower than the societal risk from Sydney Airport for the entire range of crashes.

5.2 ADVERSE METEOROLOGY AND SEISMIC ACTIVITY

Due to modern navigation aids, adverse meteorological conditions such as high intensity rainfall, thunderstorms, low cloud and fog may be able to be overcome by large commercial aircraft. The impacts of such phenomena for other aircraft may be significant.

Air traffic procedures for dealing with poor visibility at an airport such as in fog or heavy rain are developed by Airservices Australia in conjunction with the Civil Aviation Safety Authority. The procedures are specified in aeronautical information publication documents and are based on prescribed visibility minima for landings or takeoffs.

The decision to proceed with a landing or takeoff in conditions of poor visibility rests with the individual pilot concerned and is usually based on the pilots training, experience, aircraft type, standard of electronic navigation equipment aboard the aircraft and the requirement specified in the company operations manual.

Modified Mercallie ground intensities plotted for south western Sydney (Kinhill, 1985) show that the sites of the Badgerys Creek options lie in an area approximately 20 kilometres north of the MM V contour line. This infers that a tremor with a ground intensity of less than MM V, is expected to occur once every one hundred years on average.

According to the SAA Loading Code - Part 4, all of the Sydney metropolitan area has the same acceleration coefficient (Standards Association of Australia, 1993). The risk of earthquakes at the Badgerys Creek sites is not considered to be any different than in other parts of Sydney.

5.3 BIRD AND BAT STRIKE

At Badgerys Creek, there are no known defined regular significant bird or bat movements which may conflict with any of the runway orientations. Therefore it is concluded that the bird and bat hazard is moderate at Badgerys Creek and no special bird or bat hazards are anticipated. There is no significant difference between the three options, however problems could potentially occur in future if waste disposal facilities are established in the vicinity of the sites of the airport options.

5.4 FUEL SUPPLY AND STORAGE

The population group closest to the potential pipeline would be the road users. Although some road users could be present at any given time, no single road user is likely to be exposed to risks from the pipeline continuously.

Table 5.3 shows the land uses and sensitive environmental receptors along various sections of the fuel supply pipeline for the Badgerys Creek Options.

TABLE 5.3 PIPELINE TO BADGERYS CREEK OPTIONS - LAND USES AND SENSITIVE RECEPTORS

Section No.	Section	Approximate length (kilometres)	Land Use	Receptor
1	From Clyde Refinery in Parramatta to Eastern Creek via M4	18.5	suburban	Prospect Reservoir (500 metres)
1'	From Plumpton storage facility to Eastern Creek	8	suburban	None identified
2	From Eastern Creek to Cecil Park via Western Sydney Orbital	10	mostly rural	Warragamba pipeline upper canal (crosses)
3	From Cecil Park to Badgerys Creek via Elizabeth Drive	11	mostly rural	None identified

Notes:
1. Source: Land uses identified from Cities for 21st Century, DOP, 1995
2. Section 1' is alternative to Section 1.

Pipelines are a safe and conventional mode of transporting petroleum. The engineering technology is well understood. However, hazardous incidents could occur if the pipeline leaks, and if the spilled fuel is ignited. Leaks from properly designed, constructed, operated and maintained pipeline are rare and are primarily caused by inadvertent damage by third parties using earth moving equipment. Other less likely causes include external, internal and stress corrosion, material and construction defects, weather, ground movement, incorrect operation, equipment failure, and sabotage.

Pipeline leaks or ruptures are rare. An estimate of historical frequency of major leaks and ruptures is 5×10^{-4} per kilometre per year and 5×10^{-5} per kilometre per year respectively. New pipelines that are designed, installed and operated to similar or improved standards are expected to have a lower failure rate.

A previous risk analysis of a jet fuel pipeline in Sydney indicated that directly above the pipeline the fatality risk was less than 0.5 in a million (0.5×10^{-6}) per year (Cleland, 1990) and was thus well within the Department of Urban Affairs and Planning's criteria.

Based on past risk assessments and preliminary estimates of consequences and likelihood of flammable incidents, it is concluded that the proposed Jet A1 fuel pipeline could be designed, constructed and operated such that risk levels are within acceptable limits for various land uses in the vicinity of the pipeline. The risk to sensitive environmental receptors could also be controlled within acceptable limits.

For the preliminary study of fuel storage risks, only the more serious incidents, such as Jet A1 tank fire and bund fire are considered.

Comparing the separation between the airport fuel depot and people on and off site, the chance of fatality during a tank or bund fire outside the fuel depot is low.

The tank farm would be provided with state-of-the-art leak detection systems. In the event of a tank fire, base foam injection systems and deluge systems are provided for fire fighting. In view of these safeguards, the likelihood of tank or bund fires would be low.

Based on preliminary estimates of consequences and likelihood of flammable incidents, it is concluded that the proposed fuel storage depot could be designed, constructed and operated such that risk levels are within acceptable limits for various land uses in the vicinity of the depot. The risk to sensitive environmental receptors could also be controlled within acceptable limits.

5.5 SECURITY ISSUES

At the design limits proposed under the EIS, the airport would be categorised as a security category 1 airport and attract the highest security measures. The initial development of the airport may well be such as to require a lower category. Consistent with the aviation security methodology, the security categorisation would be based on a consideration of traffic type, frequency of aircraft operation and passenger throughput, with a separate consideration of any overriding considerations determined by Australia's intelligence agencies.

5.6 CONTAMINATED SITES

No significant differences in terms of potential for contamination exist between Badgerys Creek Option A, B and C. This is because the sites of Options B and C include the site of Option A and similar activities have been conducted on all sites.

It is likely that the amount of contaminated soil with concentrations exceeding acceptable levels for commercial use would not be significant in comparison with the volume of earthworks proposed. Therefore the impact of this contamination would not be significant.

Further investigations would need to be carried out prior to redevelopment of the area for use as an airport. These would identify specific areas where localised contamination might exist, for example, hydrocarbon contamination in the vicinity of underground fuel tanks, and where specific remediation might be necessary.

On site disposal of contaminated soils by using them as fill material may be viable, provided steps are taken to minimise future risks to environmental and human health.

A detailed testing program would be necessary, after the use of the sites for agricultural purposes has ceased. This would ensure that concentrations of heavy metals and organic compounds present would not exceed acceptable standards. If only small amounts of soil were found to exceed acceptable concentrations for commercial use, offsite disposal could be considered. Larger volumes may require special on-site containment cells to be constructed, and integrated into the airport design.

5.7 FIRE RISK

The risk of fire at the sites of the Badgerys Creek options would slightly increase during airport construction, due to use of machinery and improved access to the areas containing fuels such as grass or vegetation. Stockpiled vegetation that has been cleared could pose an increased fire risk.

Impacts of fire would be to generate sufficient smoke to limit visibility on roadways within and outside the sites, and to potentially destroy fuel and combustible materials stored on site. The level of risk to construction staff is not predicted to be very high, because of the large number of potential escape routes from the site. Fires would be easily controlled and total extinguishment may be possible.

The risk of bush or grass fires occurring during operation of the airport is considered to be minimal, due to the nature of the landscape following development. Fires occurring within airport facilities are unlikely to spread beyond the boundary, however lands external to the airport remain a potential fire hazard, if current land use continues.

Grass fires can produce dense dark coloured smoke which could impact on visibility for aircraft and ground operations. This could cause restrictions on vehicle access and egress from the airport, operational problems with air conditioning systems, potential loss of night time vision by pilots and increased risk of aircraft crashes due to smoke being drawn into jet engines.

5.8 EMERGENCY PLANS

An aerodrome emergency plan would be prepare prior to the commencement of airport operations. Given the planned airport capacity and the nature of the anticipated activities on the airport, the preparation of the emergency plan would be a complex task involving extensive consultations with local, State and Commonwealth agencies. Examples of agencies that may be involved are:

- On-airport agencies - airport operator, air traffic services, rescue and fire fighting services, airlines and other aircraft operators, security services, etcetera; and

- Off-airport agencies - fire brigades, police, medical and ambulance services, hospitals, defence forces, State emergency services, transport authorities, volunteer rescue services, refuelling agents, etcetera.

The emergency plan would comply with Civil Aviation Regulations and would include the following:

- plans for dealing with emergencies or possible emergencies on or near the airport that are caused by or may affect aircraft operations;

- details of tests for airport facilities and equipment to be used in emergencies, including the frequency of those tests;

- details of exercises to test emergency plans, including the frequency of those exercises;

- arrangements for reviewing the effectiveness of responses in emergencies or exercises;

- the establishment of an airport emergency committee to deal with emergencies and organise training and other preparation for emergencies; and

- a list or organisations represented on the emergency committee and the powers and functions of the committee.

The emergency plan for the Second Sydney Airport would be consistent with the emergency plan for Sydney Airport.

5.9 OVERFLYING OF DEFENCE ESTABLISHMENT ORCHARD HILLS

Flight Tracks

The parallel runways for Badgerys Creek area Option A are not in a direct line with the Defence Establishment Orchard hills. Only two out of the fifteen assumed departure flight tracks for this option pass over parts of the facilities area. No arrival tracks pass over the facilities.

The parallel runways for Badgerys Creek Option B are not in a direct line with the Defence Establishment Orchard hills. However, the cross runway is in line with the south-west corner of the site.

Two assumed departure flight tracks from the parallel runways pass over parts of the facility. In addition, approximately four departure tracks and three arrival tracks for the cross runway pass over the Defence Establishment Orchard Hills.

One of the parallel runways for Badgerys Creek Option C is in direct line with the south-east part of the Defence Establishment Orchard Hills. The arrival and departure tracks associated with one of the parallel runways, and some departure tracks associated with the cross runway, pass over the Defence facilities.

Distraction of Personnel

Defence personnel working with explosives could potentially become distracted, if aircraft pass overhead. This could increase the possibility of an accident.

Electromagnetic Radiation

Electromagnetic radiation could accidentally detonate electrically initiated explosive devices, leading to an explosion. Radio and radar transmissions from aircraft can affect electro-explosive devices. There is normally little risk to electro-explosive devices installed in weapons because of the shielding provided by the casing. However electro-explosive devices removed from weapons during maintenance are susceptible for the short time they remain outside a protective shield. Removal of electro explosive devices is carried out within buildings which provide some level of protection, although they are not designed to provide complete protection.

A review by the Electrical Explosives Hazards Committee of the Australian Ordnance Council showed that even the most sensitive electro-explosive device in service is not at risk from direct exposure to the most powerful airborne emitters in civilian and military uses over the frequency spectrum from 3 megahertz to 20 gigahertz, at distances of greater than 300 feet. No allowance was made for any shielding of the electro explosive devices in these calculations (Australian Ordnance Council, 1992).

During an inspection of the Defence Establishment Orchard Hills site personnel indicated that the human body and other objects in the vicinity can act as antennae during the handling of exposed electro explosive devices and could potentially amplify transmissions. This phenomenon has not been examined in this risk assessment.

Other fixed sources of transmissions exist at airports. These include Terminal Area Radar and other communication systems. Potential hazards to explosives from such fixed sources have not been examined in this risk assessment.

Considering the short time that electro-explosive devices remain outside their protective shield, the height of the aircraft above the facility, the location of flight tracks in relation to maintenance areas, and the Electrical Explosives Hazards Committee test results, the risks to electro explosive devices from aircraft operations from Badgerys Creek Option A, B and C appear to quite be low. Such risks could be reduced by additional engineering and procedural controls.

Airborne lasers may be a hazard to explosives devices, however aircraft operations at the Second Sydney Airport would not present such hazards.

Consequences of Explosions

Explosive Ordnance present in many buildings on site could escalate the consequences of an aircraft crash. The quantity of Explosive Ordnance kept within maintenance buildings is relatively small, therefore the secondary consequences of an aircraft crash on a maintenance building would most likely be within the scale of the direct consequences.

Many storage buildings contain Explosive Ordnance of Hazard Division 1. This particular Explosive Ordnance is susceptible to ground shock, blast flame and high velocity projectiles. It is prone to mass explosion, which means that the entire stored amount can explode virtually instantaneously. This can give rise to a blast and high and low velocity projectiles.

Explosive Ordnance of other Hazard Divisions may also present in storage buildings. Explosive Ordnance of Hazard Division 1.2 is susceptible to blast, flame and projectiles. It causes a projection hazard but not a mass explosion hazard. That means it may explode, but the explosion would involve a few items at a time, rather than the entire stored amount. Explosive Ordnance of

Hazard Division 1.3, which can also be stored on the site, is a mass fire hazard.

Therefore direct consequences of an aircraft crashing into Explosive Ordnance storage areas include ground shocks, high velocity projectiles, and fire. The exposure of Explosive Ordnance to such effects could result in a series of explosions involving Hazard Division 1.1 and 1.2, consequent blasts and projectile generation, and mass fire.

The severity of any explosion depends on the quantity of explosives involved. Since Hazard Division 1.1 is the only hazard division which has the potential for mass explosion, the most severe single explosion that could occur would require the entire quantity of Hazard Division 1.1 Explosive Ordnance present in the building to explode.

The maximum quantity of Hazard Division 1.1 Explosive Ordnance that is licenced to be stored in any single building on site is approximately 50,000 kilograms (TNT equivalent). Away from the direct blast area, the consequences of an explosion are determined by the overpressure wave generated. This is a pressure wave which travels away from the centre of the explosion and decreases in intensity with increasing distance.

The secondary consequences of an aircraft crashing on an Explosive Ordnance storage building are likely to be more severe than the direct consequences of the crash. However, considering the location of Explosive Ordnance storage facilities in relation to the site boundaries, injuries or fatalities outside the site boundary of the Defence Establishment Orchard Hills would not be expected.

This analysis shows that the increase in crash risk for aircraft overflying the Defence Establishment Orchard Hills Defence is insignificant for Badgerys Creek Options A, B and C shows that increased risk for people inside and living outside is insignificant.

Hazards to Overflying Aircraft

Hazards to overflying aircraft from the Defence Establishment Orchard Hills have also been considered. Demolition activities were suspended at the facilities at the time when this investigation was undertaken. It is understood that if such activities are resumed, only minor quantities of Explosive Ordnance (approximately 5 kilograms at a time) would be demolished, and this would only occur infrequently.

Temporary airspace restrictions have been discussed between with Airservices Australia and the Department of Defence. These restrictions would be determined using the methodology recommended in Pillar Proceeding 205.92 (Australian Ordnance Council, 1992), which takes into account both the fragment and the blast hazard to aircraft. In view of these arrangements, risks to overflying aircraft would be low.

Aircraft flying over, or in the vicinity of an accidental explosion at the site could be affected by blast, fragments or both. Two types of assessments are relevant in this situation. The first is an assessment of risk to an aircraft each time it flies over, or is in the vicinity of the Defence Establishment Orchard Hills, while the second is the assessment of total risk to all aircraft that fly over, or are in the vicinity of the facilities.

The consequences of an explosion on ground for an aircraft flying overhead depend on a number of factors, including the quantity of explosives involved in the explosion and the separation between the centre of the explosion and the aircraft, at the time of the explosion.

Fragments could also be projected from explosions on the ground, but fragment effects at a particular distance are somewhat different from blast wave effects. Although fragments may travel great distances, they have to hit the 'target' (aircraft in this case) for them to have an effect, unlike a blast wave which will 'hit' everything in its path. While there is a chance that a fragment may hit an aircraft, there is conversely a much greater chance that it may not hit the target. However it is difficult to determine the probability of a 'hit'.

In view of the uncertainty in both the blast and fragment effects on aircraft, a conservative approach has been adopted for this risk assessment. The preliminary analysis undertaken assumes that all explosions at the Defence Establishment Orchard Hills involve the worst-case explosives quantity of 50,000 kilograms and that aircraft within four kilometres of the centre of the facilities at the time of explosion would crash. If this analysis shows that the level of risk is unacceptable, then more detailed analysis maybe justified.

Accidental detonation of the contents of explosives storehouses, or of explosives in other facilities, are very uncommon (Australian Ordnance Council, 1992). None of the Department of Defence staff consulted as part of this study could recall an explosion in a Department of Defence explosives storage building in Australia although a recent case in the USA was mentioned. While the frequency of such accidents is low, such an accident could occur at any storage facility, including at the Orchard Hills Defence Facilities.

An examination by Menz (Menz, 1984) concluded that civilian storage magazines explode with a frequency of between one in ten thousand (1×10^{-4}) and one in a million (1×10^{-6}) per year. Other estimates have placed the figure nearer to 2.5 in ten thousand (2.5×10^{-4}) per annum. The actual mechanisms which caused such detonations are not recorded by Menz or other analysts.

The probability of more than one aircraft being present within the four kilometre radius effect zone of the Defence Establishment Orchard Hills worst-case explosion at the same time has not been evaluated in this risk assessment.

Summary of Hazards and Risks To and From Aircraft

Table 5.4 provides a summary of the proposed use of airspace above the Defence Establishment Orchard hills and the hazards and risks arising from the three Badgerys Creek options.

TABLE 5.4 COMPARISONS OF HAZARDS AND RISKS TO AND FROM AIRCRAFT FLYING OVER DEFENCE ESTABLISHMENT ORCHARD HILLS

Issue	Badgerys Creek Option A	Badgerys Creek Option B	Badgerys Creek Option C
Parallel runway alignment	▪ not in line with the Defence Establishment Orchard Hills	▪ not in line with the Defence Establishment Orchard Hills	▪ one parallel runway in line with the Defence Establishment Orchard Hills
Cross runway alignment	▪ n/a	▪ in line with the SW corner of the Defence Establishment Orchard Hills	▪ not in line with the Defence Establishment Orchard Hills
Flight paths over the Defence Establishment Orchard Hills	▪ two indirect departure flight paths from a parallel runway	▪ two indirect departure flight paths from a parallel runway ▪ all arrival and most of the departure tracks from one end of the cross runway	▪ all arrival and departure tracks on one end of a parallel runway ▪ two indirect departure tracks from the cross runway
Probability of a crash at the Defence Establishment Orchard Hills	▪ no area within the 10^{-3} or 10^{-4} crash per square km per year contour ▪ 1 to 3 square km site area (NE corner) within the 10^{-4} - 10^{-5} zone ▪ 5 to 7 square km site area (NE half) within the 10^{-5} - 10^{-6} zone ▪ 67% probability that the crash would be of a small aircraft	▪ no area within the 10^{-3} or 10^{-4} crash per square km per year contour ▪ 3 to 6 square km site area (NE and SW corners) within the 10^{-4} - 10^{-5} zone ▪ 5 to 9 square km site area within the 10^{-5} - 10^{-6} zone ▪ 67-82% probability that the crash would be of a small aircraft	▪ no area within the 10^{-3} crash per square km per year contour (Modes - North or South) ▪ about 2 square km site area (SE corner) within the 10^{-3} zone (Mode - South) ▪ 5 to 9 square km site area within the 10^{-3} - 10^{-4} zone ▪ rest of site within the 10^{-5} - 10^{-6} zone ▪ 84% probability that a crash would be of a small aircraft

Issue	Badgerys Creek Option A	Badgerys Creek Option B	Badgerys Creek Option C
Crash risk per year cumulative over all flights due to an explosion at the Defence Establishment Orchard Hills	▪ estimated to be less than 1.15×10^{-4} per year ▪ this would represent an increase of less than 0.11% to the total crash risk per year	▪ estimated to be less than 1.51×10^{-4} per year ▪ this would represent an increase of less than 0.14% to the total crash risk per year	▪ estimated to be less than 7.43×10^{-4} per year ▪ this would represent an increase of less than 0.69% to the total crash risk per year

The arrival and departure tracks associated with one of the parallel runways and some departure tracks associated with the cross runway pass over the facility, thus Defence personnel working with explosives could potentially become distracted if aircraft pass overhead. This could increase the possibility of an accident.

Analysis shows that the risk of an aircraft crash on one of the explosives storage buildings is insignificant. The secondary consequences of an aircraft crashing on an explosives ordnance storage building are likely to be more severe than the direct consequences of the crash. Considering the location of explosives ordnance storage facilities in relation to the site boundaries, injuries or fatalities outside the site boundary of the Defence Establishment Orchard Hills would not be expected even if such a crash occurred.

Aircraft flying over or in the vicinity of an accidental explosion at the site could be affected by glass, fragments or both. The consequences of an explosion on ground for an aircraft flying overhead depend on a number of factors including the quantity of explosives involved in the explosion and the separation between the centre of the explosion and the aircraft, at the time of the explosion.

In the worst case, the risk of an aircraft flying over the Defence Establishment Orchard Hills, crashing due to an accidental explosion at the facilities is approximately would be 8.6 in a billion. This is considered to be very low.

5.10 CRASHES INTO WATER SUPPLY INFRASTRUCTURE

The potential for aircraft to crash into water supply infrastructure is also of concern, for Badgerys Creek Options A and B in particular. *Figures 3.2* and *3.3* in *Appendix A* show the location of crash frequency contours for Badgerys Creek Options A and B.

The parallel runways for the Badgerys Creek Options A and B are in direct line with the Prospect Dam. Two approach and two departure tracks from the parallel runways pass over the Prospect Dam. Three departure tracks and two arrival tracks are positioned over the Warragamba Dam.

No major water supply facilities are located within the one in 1,000 chance (1×10^{-3}) contours.

In all the operating modes investigated for Badgerys Creek Options A and B, the one in 10,000 chance (1×10^{-4}) contours enclose the Warragamba Dam, parts of the Warragamba pipelines, and parts of the Prospect Dam.

Some additional length of the Warragamba pipelines, and parts of the Orchard Hills Water Filtration Plant are enclosed within the one in 100,000 chance (1×10^{-5}) contours in all the operating modes investigated, although the exposure is comparatively less for Airport Operation 2 (landings from the North East and take-offs to the South West).

The frequency of an aircraft crash on the Prospect Dam wall is estimated to be about 25 in a million (25×10^{-6}) per year for Badgerys Creek Options A and B. This is based on the area of the dam wall and the location of the dam wall near the one in 10,000 chance contour. The likelihood of dam failure following an aircraft crash has also not been investigated. However, this preliminary analysis indicates that the increase in risk could be significant in comparison with existing risk.

The frequency of an aircraft crash on the Warragamba Dam wall is estimated to be about 19 in a million chance (1.9×10^{-5}) per year for Badgerys Creek Options A and B. The likelihood of dam failure following an aircraft crash has also not been investigated in this study.

A potential problem is the failure of one of the gates resulting from a crash directly on the gates. Under this scenario, a significant flood wave would be released and almost half the present stored capacity of the dam would be lost. The impact of the wave of water to downstream public and property has not been investigated. Although the gates could potentially be repaired within a few months, it would take several years to build up the water levels.

Water stored in Lake Burragorang (formed by Warragamba Dam) is gravity fed to the Prospect Dam through parallel 3,000 millimetre diameter and 2,100 millimetre diameter above-ground Warragamba Pipelines. These pipelines could be damaged if an aircraft crashes directly on them, or skids into them. The distance to which a crashing aircraft could skid depends on a the size of the aircraft and the angle of crash.

The frequency of aircraft crash into a five kilometre length of the Warragamba pipeline is estimated to be 50 in a million chance (5×10^{-5}) per kilometre per year. The frequency is estimated to be five in a million chance (5×10^{-6}) per kilometre per year, for a second five kilometre length.

For Badgerys Creek Option C, only the Warragamba Pipeline and the Orchard Hills Filtration Plant are located within the one in 1,000 chance and one in 10,000 chance contours. Warragamba Dam is located at the boundary of the one in 100,000 chance contours. Thus the probability of an aircraft crash into Warragamba Dam is approximately 1.9 in a million chances.

Approximately one kilometre of the length of the Warragamba Pipeline is located within the one in 1,000 chance contours. Thus the average crash risk for this section of the pipeline is approximately 500 in a million per kilometre per year. For other sections of the pipeline, which are contained within the one in 10,000 and one in 100,000 chance contours, the predicted crash risks are 50 in a million and five in a million chances per kilometre per year respectively.

The risk of aircraft crashing into a particular critical item of water supply would be substantially less than the risks expressed above due to the area of the infrastructure being less than one square kilometre. An aircraft crashing into a dam wall would also not necessarily result in dam failure, although dam stability under such conditions has not been quantified. It should also be noted that small aircraft are almost four times more likely to crash than large aircraft. The consequences of small aircraft crashing would be far less severe than a crash involving a large aircraft.

The consequences of aircraft crashes into critical elements such as dam walls and pipelines could be catastrophic, as well as causing long term difficulties with water supply to the Sydney region. A crash directly on the gates of a dam wall could result in a significant floodwave being released and a large amount of the present stored capacity of the dam could be lost.

It could take several years to build up water levels to the current levels. The floodwave could cause massive damage to public property and private property downstream of the dam and fatalities could result. It should be recognised however that not all aircraft crashes on the dam wall would not necessarily result in damage to critical elements of the dam, which present a relatively small target.

In the event of an aircraft crash into the Warragamba pipeline, the water supply to Prospect Water Filtration Plant serving 2.9 million people would be affected. Minimal services could be provided using the Upper Canal. Some areas may not receive any supply. If short lengths of the pipelines, say approximately 10 metres are damaged, they could potentially be repaired within two or three weeks. Damage to longer lengths would take approximately two to three months.

CHAPTER 6 IMPACTS OF HOLSWORTHY OPTIONS

6.1 QUANTITATIVE RISK ASSESSMENT OF AIRCRAFT CRASHES

The same measures of risk assessment of aircraft crashes have been used for Holsworthy as for the Badgerys Creek options. Contours for the probability of an aircraft crash have been produced and are shown as *Figures 3.5* and *3.6* in *Appendix A* for Holsworthy Options A and B respectively.

The contours shown are based on a 30 million passenger per year scenario. *Figures 3.10* and *3.11* in *Appendix A* show contours representing individual fatality risks of 10 in a million, 1 in a million and 0.1 in a million chances per year for Options A and B respectively. These have been generated for the modes of operation that have the highest fatality rates. Individual fatality risk levels outside the one in a million per year contours would meet the Department of Urban Affairs and Planning's criteria for development of residential areas near hazardous industrial industries.

Figure 3.10 in *Appendix A* shows that areas enclosed within the one in a million per year individual fatality risk contours are generally located along extended runway centrelines only. This includes some existing residential areas towards the north of the site of Holsworthy Option A.

Similarly for Holsworthy Option B, areas enclosed within the one in a million per year individual fatality risk contours are generally located along extended runway centrelines only. Some existing residential areas towards the west of the site of Holsworthy Option B are also included.

Predicted fatality rates for the two Holsworthy options in various modes of operation are summarised in *Table 6.1*. Predicted fatality rates represent the average number of fatalities over a number of years.

TABLE 6.1 FATALITY RATE (PERSONS PER 100 YEARS) FOR HOLSWORTHY OPTIONS

Holsworthy Option	Airport Operation 1	Airport Operation 2	Airport Operation 3
Option A	7.1	13	9
Option B	5	6.4	5.5

Fatality rates for the Holsworthy options range between five persons per 100 years and 13 persons per 100 years.

Table 6.2 summarises the number of people who are exposed to levels of individual fatality risk of more than one in a million per year. The Department of Urban Affairs and Planning's guidelines are that risk levels of more than one in a million per year are not acceptable for residential areas located close to hazardous industrial facilities.

Populations exposed to more than one in a million chances of a fatality per year range from 60,000 for Holsworthy Option A to 21,000 for Holsworthy Option B. The difference in these figures arises from one in a million contours for Holsworthy options enclosing heavily populated parts of the Campbelltown local government area.

TABLE 6.2 POPULATIONS EXPOSED TO LEVELS OF INDIVIDUAL FATALITY RISK OF MORE THAN ONE IN A MILLION CHANCES PER YEAR FOR HOLSWORTHY OPTIONS

Holsworthy Option	Populations Exposed to More Than One in a Million Chances of Fatality per year
Option A	60,000
Option B	21,000

Societal risk curves for all the airport options for the mode of operations that have the highest fatality rates are shown in *Figure 3.12* in *Appendix A*. Also shown for comparison is the societal risk curve for Sydney Airport in the year 2010. In comparison with the societal risk from Sydney Airport, the societal risks for Holsworthy Options A and B are lower for the entire range of crashes.

6.2 LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE

The potential for aircraft crashes into the Lucas Heights Science and Technology Centre is of concern for the Holsworthy options.

The parallel runways for Holsworthy Option A are located west of the Lucas Heights Science and Technology Centre, and are orientated in a near north-south direction. This location and orientation of the parallel runways avoids the need for flight paths over the Lucas Heights Science and Technology Centre. The cross wind runway is located south of the Lucas Height Science and Technology Centre and is oriented in an east-west direction. The location and orientation of the cross wind runway also avoids the need for flight paths over the Lucas Heights Science and Technology Centre.

None of the proposed arrival or departure tracks for Holsworthy Option A or Option B pass over or within one nautical mile of HIFAR, and therefore, the removal of existing airspace restrictions over the Lucas Heights Science and Technology Centre is not proposed.

The airport and nuclear facilities at Lucas Heights, could be sources of risks to one another. The interaction between the two facilities could be a source of risk to the surrounding communities. Therefore the following types of risks are considered relevant for consideration:

- risk to people at the airport from accidents at the nuclear facilities at Lucas Heights;

- risk to surrounding communities, including people at the airport, from an aircraft crash on the nuclear facilities at Lucas Heights.

Accidents at the Lucas Heights Science and Technology Centre could be initiated either due to internal or external initiating events. The frequency of internal and external initiating events, except aircraft crashes, is not expected to increase as a result of construction and operation of an airport at the site of Holsworthy Option A.

No part of the airport at Holsworthy Option A is located within the 1.6 kilometre radius exclusion zone centred around HIFAR. The terminal and apron area, which would have a concentration of population, is not located within 2.5 kilometres of HIFAR.

The low frequency of accidents at HIFAR indicates that risks to people at the airport from accidents at HIFAR would be low for Holsworthy Options A and B.

The site for Holsworthy Option B is located about 10 kilometres south-west of the Lucas Heights Science and Technology Centre. The location and orientation of the parallel runways avoids the need for flight paths over the Lucas Heights Science and Technology Centre. Similarly, the location and orientation of the cross wind runway also avoids the need for flight paths over the Lucas Heights Science and Technology Centre.

The crash frequency on the reactor containment building of large aircraft operating from Holsworthy Option A or Option B would be less than 1.77 in one billion (1.77×10^{-9}) per year. This frequency is the same for both options because none of the proposed flight paths pass within the 1.6 kilometre exclusion zone around the reactor. The total crash frequency on the reactor containment building of large aircraft, calculated by adding the crash frequency of aircraft using the airway to the Sydney Airport and operating from Holsworthy Option A or B would be less than 2.45 in one billion chances (2.45×10^{-9}) per year.

Holsworthy Option A is located within a few kilometres of the Lucas Heights Science and Technology Centre whereas Holsworthy Option B is more than 10 kilometres away. Although quantitative risk assessment does not indicate significant differences in the hazards and risk implications for the two Holsworthy options, an examination of risk contours indicates that the contours are much closer to the Lucas Heights Science and Technology Centre for Holsworthy Option A than for Holsworthy Option B.

6.3 ADVERSE METEOROLOGY AND SEISMIC ACTIVITY

Due to modern navigation aids, adverse meteorological conditions such as high intensity rainfall, thunderstorms, low cloud and fog may be able to be overcome by large commercial aircraft. The impacts of such phenomena are small and medium sized aircraft may be significant.

Air traffic procedures for dealing with poor visibility at an airport such as in fog or heavy rain are developed by Airservices Australia in conjunction with the Civil Aviation Safety Authority. The procedures are specified in aeronautical information publication documents and are based on prescribed visibility minima for landings or takeoffs.

The decision to proceed with a landing or takeoff in conditions of poor visibility rests with the individual pilot concerned and is usually based on the pilots training, experience, aircraft type, standard of electronic navigation equipment aboard the aircraft and the requirement specified in the company operations manual. It is therefore not possible to estimate the proportion of time that an airport would not be usable due to weather conditions other than wind.

Modified Mercallie ground intensities plotted for south western Sydney (Kinhill, 1985) show that the site of Holsworthy Option A lies in an area approximately 10 kilometres north of the MM V contour line. This infers that a tremor with a ground intensity of less than MM V, is expected to occur once every one hundred years on average at the site of Holsworthy Option A. In contrast, the site of Option B lies less than five kilometres south of the MM V contour line. This infers that a tremor with a ground intensity of slightly more than MM V, is expected to occur once every one hundred years on average at the site of Holsworthy Option B.

According to the SAA Loading Code - Part 4, all of the Sydney metropolitan area has the same acceleration coefficient (Standards Association of Australia, 1993). The risk of earthquakes at the Holsworthy sites is not considered to be any different than in other parts of Sydney.

6.4 BIRD AND BAT STRIKE

For Holsworthy Option A, hazards from birds would be moderate and are likely to be less than at Badgerys Creek, however, existing waste disposal facilities at Lucas Heights could potentially attract birds and increase bird strike risk. For Holsworthy Option B, fewer grassland birds would be expected than for Holsworthy Option A due to lack of suitable habitat nearby.

Hazards posed by fruit bats at night, especially during the summer months, are likely to be significant for both Holsworthy options. This is because destruction of all food sources in the Holsworthy area may be difficult and conventional means of scaring birds such as shooting and cracker shells may have very limited effectiveness on fruit bats.

The same situation would occur for Holsworthy Option B, however, removal of potential food sources in line with the runways of the Holsworthy option due to Obstacle Limitation Surface clearing could potentially reduce the risk of bat strike.

6.5 FUEL SUPPLY AND STORAGE

Land uses and sensitive environmental receptors along various sections of the fuel supply pipeline for the Holsworthy Options are shown on *Table 6.3.*

TABLE 6.3 PIPELINE TO HOLSWORTHY OPTIONS - LAND USES AND SENSITIVE RECEPTORS

Section No.	Section	Approximate length (kilometres)	Land Use	Receptor
1	From Clyde Refinery in Parramatta to Eastern Creek via M4	18.5	Suburban	Prospect Reservoir (500 metres)
1'	From Plumpton storage facility to Eastern Creek	8	suburban	None identified
2	From Eastern Creek to Cecil Park via Western Sydney Orbital	10	mostly rural	Warragamba pipeline upper canal (crosses)
4	From Cecil Park to Casula via Western Sydney Orbital	22	Suburban	Non identified
5A	From Casula to Holsworthy Option A	12	rural	Georges River (crosses)
5B	From Casula to Gilead via Hume Highway	47	suburban	Upper canal (crosses)
6	From Gilead to Holsworthy Option B	10	rural	Georges River (crosses)

Notes:
1. Source: Land uses identified from Cities for 21st Century, DOP, 1995
2. Section 1' is alternative to Section 1.

Pipelines are a safe and conventional mode of transporting petroleum. The engineering technology is well understood. However, hazardous incidents could occur if the pipeline leaks, and if the spilled fuel is ignited. Leaks from properly designed, constructed, operated and maintained pipeline are rare and are primarily caused by inadvertent damage by third parties using earth moving equipment. Other less likely causes include external, internal and stress corrosion, material and construction defects, weather, ground movement, incorrect operation, equipment failure, and sabotage.

Pipeline leaks or ruptures are rare. An estimate of historical frequency of major leaks and ruptures is five in ten thousand chance (5×10^{-4}) per kilometre per year and five in one hundred thousand chance (5×10^{-5}) per kilometre per year respectively. New pipelines that are designed, installed and operated to similar or improved standards are expected to have a lower failure rate.

A previous risk analysis of a jet fuel pipeline in Sydney indicated that directly above the pipeline the fatality risk was less than 0.5 in a million chance (0.5×10^{-6}) per year (Cleland, 1990) and was thus well within the Department's criteria.

Based on past risk assessments and preliminary estimates of consequences and likelihood of flammable incidents, it is concluded that the proposed Jet A1 fuel pipeline could be designed, constructed and operated such that risk levels are within acceptable limits for various land uses in the vicinity of the pipeline. The risk to sensitive environmental receptors could also be controlled within acceptable limits.

For the preliminary study of fuel storage risks, only the more serious incidents, such as Jet A1 tank fire and bund fire are considered.

Comparing the separation between the airport fuel depot and people on and off site, the chance of fatality during a tank or bund fire outside the fuel depot is low.

The tank farm would be provided with state-of-the-art leak detection systems. In the event of a tank fire, base foam injection systems and deluge systems are provided for fire fighting. In view of these safeguards, the likelihood of tank or bund fires would be low.

Based on preliminary estimates of consequences and likelihood of flammable incidents, it is concluded that the proposed fuel storage depot could be designed, constructed and operated such that risk levels are within acceptable limits for various land uses in the vicinity of the depot. The risk to sensitive environmental receptors could also be controlled within acceptable limits.

6.6 SECURITY ISSUES

At the design limits proposed under the Draft EIS, the airport would be categorised as a security category 1 airport and attract the highest security measures. The initial development of the airport may well be such as to require a lower category. Consistent with the aviation security methodology, the security categorisation would be based on a consideration of traffic type, frequency of aircraft operation and passenger throughput, with a separate consideration of any overriding considerations determined by Australia's intelligence agencies.

6.7 UNEXPLODED ORDNANCE

Cost estimates and methodologies proposed to be used for detection and clearance of unexploded ordnance are outlined in the *Planning and Design Report* (Second Sydney Airport Planners, 1997a).

To achieve 100 percent clearance of unexploded ordnance, and thereby minimise the risk of an explosion occurring during bulk earthworks on site preparation, every precaution possible (commensurate with available technology and practices) would need to be taken.

Experience suggests, however, that even with a program designed to achieve 100 percent clearance, there would be a probability of the order of one in ten thousand of an item of unexploded ordnance remaining on the site. The probability of making contact with it during construction is small but not quantifiable, and even if contact is made, experience suggests that there is a probability of one in five that the device would not be sufficiently sensitive to explode on contact. If an explosion did occur, it would not necessarily result in injury, loss of life or damage to plant and equipment.

The probability of loss of life and/or damage to plant and equipment resulting from such an explosion is assessed to be no greater than the risk of similar outcomes from normal construction activities (Second Sydney Airport Planners, 1997a). However, if such an event occurred, time would most likely be lost while construction activities were suspended, and the situation was reassessed. More stringent construction methods might need to be employed. The consequential losses from such a situation could be very significant and not necessarily fully insurable. It might therefore be necessary for the Commonwealth to share the risks with the insurance and construction industry by way of warranty or covenant upon transfer of the land from the Department of Defence to the airport owner for the construction period.

It is most likely that potential hazards and risks associated with unexploded ordnance after the construction period would be minimal, within the airport boundaries.

However some potential risks from unexploded ordnance could occur during airport operations, due to activities occurring outside of the cleared airport zone. These include fire fighting and fire management activities, environmental monitoring outside the airport boundaries and in water courses that may be impacted by the airport, rescue operations for aircraft crashes and potential random entry of civilians into areas adjacent to access roadways.

A combination of additional clearance and security fencing may overcome the majority of these potential risks. Rescues from crashed aircraft and fire fighting/management are potentially the most difficult issues to address, because they cannot be solved by simply limiting access to certain areas.

6.8 CONTAMINATED SITES

The two engineered landfills containing contaminated soils that exist in the northern part of the Holsworthy Military Area, near the Complete Airfield are outside of the sites of the airport options and are not likely to be affected by the currently proposed transport corridors.

Preliminary sampling and chemical analysis of soil and surface water samples from highly impacted areas within the sites of the airport options suggested that concentrations of contaminants associated with present and past activities would not be high.

Since firing of ordnance has not been restricted to particular areas of the Holsworthy Military Area, both sites have equal probability of being contaminated from past activities. Chemical residues could have been washed into watercourses by rain and may have collected in sediments.

It is likely that the amount of contaminated soil with concentrations exceeding acceptable levels for commercial use would not be significant in comparison with the volume of earthworks proposed. Therefore the impact of this contamination would not be significant.

Further investigations would need to be carried out prior to redevelopment of the area for use as an airport. These would identify specific areas where localised contamination might exist, for example, undocumented landfills, and where specific remediation measures might be necessary.

On site disposal of contaminated soils by using them as fill material may be viable, provided steps are taken to minimise future risks to environmental and human health.

A detailed testing program would be necessary, after the use of the sites for military purposes has ceased. This would ensure that concentrations of heavy metals and organic compounds present would not exceed acceptable standards. If only small amounts of soil were found to exceed acceptable concentrations for commercial use, offsite disposal could be considered. Larger volumes may require special on-site containment cells to be constructed, and integrated into the airport design.

6.9 FIRE RISK

At Holsworthy, there is an increased risk of bush fires occurring during the construction period. Stockpiling of cleared vegetation could cause fire hazards, sparks caused by scraping of sandstone rocks during site clearing could ignite vegetation, and fires could occur because of human related causes such as cigarettes and sparks from machinery and equipment. Clearance of unexploded ordnance during high fire danger periods could also result in fires.

The degree of impact of a bushfire on airport construction activities would depend upon wind direction and speed. Construction activities are likely to be stopped due to extensive smoke and heat. Impacts of fire would be to generate sufficient smoke to limit visibility on roadways within and outside the sites, and to potentially destroy fuel and combustible materials stored on site.

Isolation of the construction site from fire fighting services would create some concerns for the safety of workers, however large dams proposed to provide water for construction would provide adequate supplies of water for fire fighting.

The risk of bush or grass fires occurring due to operations of the airport is considered to be minimal, due to the nature of the landscape following development. Fires occurring within airport facilities are unlikely to spread beyond the boundary, however bushland external to the airport will remain a potential fire hazard.

Bush fires are able to generate significant plumes of dark coloured smoke which would impact on visibility for aircraft and ground operations. This could cause restrictions on vehicle access and egress from the airport, operational problems with air conditioning systems, potential loss of night time vision by pilots and increased risk of aircraft crashes due to smoke being drawn into jet engines.

The airport may have to be closed as a result of these impacts or to permit fire fighting to proceed in a safe manner. In this case, aircraft may need to be diverted to other airports or flights cancelled.

6.10 EMERGENCY PLANS

An aerodrome emergency plan would be prepare prior to the commencement of airport operations. Given the planned airport capacity and the nature of the anticipated activities on the airport, the preparation of the emergency plan would be a complex task involving extensive consultations with local, State and Commonwealth agencies. Examples of agencies that may be involved are:

- On-airport agencies - airport operator, air traffic services, rescue and fire fighting services, airlines and other aircraft operators, security services, etc; and

- Off-airport agencies - fire brigades, police, medical and ambulance services, hospitals, defence forces, State emergency services, transport authorities, volunteer rescue services, refuelling agents, etcetera.

The emergency plan would comply with Civil Aviation Regulations and would include the following:

- plans for dealing with emergencies or possible emergencies on or near the airport that are caused by or may affect aircraft operations;

- details of tests for airport facilities and equipment to be used in emergencies, including the frequency of those tests;

- details of exercises to test emergency plans, including the frequency of those exercises;

- arrangements for reviewing the effectiveness of responses in emergencies or exercises;

- the establishment of an airport emergency committee to deal with emergencies and organise training and other preparation for emergencies; and

- a list or organisations represented on the emergency committee and the powers and functions of the committee.

The emergency plan for the Second Sydney Airport would be consistent with the emergency plan for Sydney Airport.

6.11 CRASHES INTO WATER SUPPLY INFRASTRUCTURE

Crashes into water supply infrastructure are also of concern for the Holsworthy options. The parallel runway for Holsworthy Option A are in direct line with the Woronora Dam. Almost all approach and departure tracks from one of the parallel runways pass over the dam area. *Figure 3.5* in *Appendix A* shows the location of crash frequency contours for Holsworthy Option A in one of the three modes investigated. The Woronora Dam is located near the one in 10,000 chance contours for all of the modes of operation investigated. Thus the frequency of aircraft crash in the Woronora Dam area would be approximately one in 10,000 crashes per square kilometre per year.

For Holsworthy Option B, the Woronora Dam wall is not beneath any proposed flight paths, but one departure flight path is positioned over the Cataract Dam area. The location of contours indicates that the frequency of aircraft crash in the dam area would be around one in 100,000 crashes per square kilometre per year.

The risk of aircraft crashing into a particular critical item of water supply would be substantially less than the risks expressed above due to the area of the infrastructure being less than one square kilometre. An aircraft crashing into a dam wall would also not necessarily result in dam failure, although dam stability under such conditions has not been quantified. It should also be noted that small aircraft are almost four times more likely to crash than large aircraft. The consequences of small aircraft crashing would be far less severe than a crash involving a large aircraft.

Part D
Environmental Management

CHAPTER 7 ENVIRONMENTAL MANAGEMENT

7.1 QUANTITATIVE RISK ASSESSMENT OF AIRCRAFT CRASHES

The risk of an aircraft crash on a populated area could be mitigated by adopting appropriate measures during the planning, design, and operational stages of the project. Some of the options for risk mitigation are outlined below. Normal risk mitigation measures, such as existing regulations and safety standards have not been outlined.

One risk mitigation measure would be to select the airport option with the least risk impact. For an identical aircraft fleet mix, the risk of an aircraft crash varies in direct proportion to the annual number of aircraft movements at the airport, therefore, the reduction in total annual traffic movements would result in a reduction in risk.

The quantitative risk analysis in this study is based on Air Traffic Forecast 3, which gives the worst-case risk impact. Risk in Air Traffic Forecast 1 would be relatively lower. Therefore, a possible risk mitigation option would be to restrict the scale of the airport to Air Traffic Forecast 1.

Operational measures could be adopted to further mitigate the risk of an aircraft crash at specific locations. Quantitative risk analysis shows that areas exposed to individual fatality risk levels greater than one in a million chances (1×10^{-6}) per year are different under different mode of operations at each airport option. One of the risk mitigating measures would therefore be to select the mode of operation that minimises the total residential area enclosed within the one in a million (1×10^{-6}) per year individual risk contours.

Individual as well as societal risk could be mitigated further by more detailed planning of flight paths to minimise concentrated movements over densely populated areas in close proximity of the airport. Complex flight paths to avoid populated areas at longer distances from the airport would not be very effective in reducing the risk.

For development proposals in the vicinity of the selected airport option, there would be a need to consider the compatibility of each development proposal with the risk level at the proposed location.

Individual risk contours developed as part of this study show the risk levels at different locations around each airport option. Individual fatality risk criteria for various land uses have been suggested by the Department of Planning (1990). The compatibility of a development proposal at a particular location should be assessed by comparing the risk levels at the location with the acceptable risk criteria for that type of land use.

There would generally be no constraint to any type of development outside the one in ten million chances (1×10^{-7}) per year individual risk contours.

In the region between the one in ten million chance (1×10^{-7}) per year and one in a million chance (1×10^{-6}) per year individual risk contours, there would generally be no constraint to any type of development except for sensitive developments, such as schools, hospitals, child-care facilities and old age homes. If sensitive developments are to be located in this region, then they should be located as far away as possible from the one in a million chances (1×10^{-6}) per year contours, and as close as possible to the one in ten million chances (1×10^{-7}) per year contours, ie., where risk levels are below 0.5 in a million chances (0.5×10^{-6}) per year. In order to mitigate societal risks, population density in this region should also not increase significantly. Therefore consideration should be given to not locating high density residential, hotel or motel developments within this region.

Sensitive, residential, hotel and motel developments should not be located in the region between one in a million chances (1×10^{-6}) per year and ten in a million chances (1×10^{-5}) per year individual risk contours. Commercial developments including retail centres, offices and entertainment centres could be located away from the ten in a million chances (1×10^{-5}) per year contour and closer to the one in a million chances (1×10^{-6}) per year contour, ie., where risk levels are below five in a million chances (5×10^{-6}) per year. There would be no constraints to sporting complex and industrial developments in this region.

Only industrial land use is compatible in the region within the ten in a million chances (1×10^{-5}) per year individual risk contours.

7.2 LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE

Management of risk of an aircraft crash at the Lucas Heights Science and Technology Centre encompasses the planning, design, and operational stages of the project. General measures that reduce the overall frequency of aircraft crashes would also reduce the frequency of aircraft crashes on the Lucas Heights Science and Technology Centre.

Runways at the two Holsworthy Options are oriented in directions that obviate the need for establishing flight paths over the Lucas Heights Science and Technology Centre. With these runway orientations and the assumed flight paths, the risk of an aircraft crash at the Lucas Heights Science and Technology

Centre, and the consequential risk to public health has been assessed to be within the Nuclear Safety Bureau's draft criteria.

Notwithstanding the low assessed public health risk, there could be significant social and economic consequences of such an accident. Such risks could largely be avoided by selecting one of the Badgerys Creek Options instead of the Holsworthy Options.

Aircraft operating from the two Holsworthy options would not need to enter the currently restricted airspace above the Lucas Heights Science and Technology Centre. The current airspace restrictions would therefore remain during the operational phase of the Holsworthy options.

Special instructions should be developed and published so that arriving and departing aircraft are aware of the location and significance of the Lucas Heights Science and Technology Centre.

Airspace restrictions should be enforced by the air traffic control and the restricted zone should be marked on air traffic control radar screens, as is marked now on the radar screens at the Sydney Airport. All aircraft movements in the vicinity of the airport would be monitored by air traffic control, and appropriate instructions would be given to any aircraft heading into the restricted airspace.

Procedures should be developed for abnormal operations, such as missed approaches and aborted take-offs, so that aircraft avoid entering the restricted airspace during such abnormal circumstances.

The effectiveness of air traffic control in implementing the airspace restriction should be monitored continually and audited periodically as part of its safety management system.

In some crashes, pilots tend to have a degree of control and manage to direct their crashing aircraft away from buildings. All pilots should be made aware of the location and significance of the Lucas Heights Science and Technology Centre, and in particular the location of the reactor containment building, so that they avoid that building if they can.

For Holsworthy Option A, a dedicated telephone line or other suitable means of communication between the Lucas Heights Science and Technology Centre and air traffic control at the airport is proposed.

Emergency plans for the Lucas Heights Science and Technology Centre would have to be expanded to take into account the presence of the Second Sydney Airport if one of the two Holsworthy Options is selected. Similarly, emergency plans for the airport would have to take into account the proximity to Lucas Heights Science and Technology Centre.

7.3 ADVERSE METEOROLOGY AND SEISMIC ACTIVITY

Further scientific investigation of the prevalence of adverse meteorological conditions such as fog and wind shear would be necessary to provide a greater level of certainty than exists at present. There is a lack of data about Holsworthy Option B in particular, however specific research is necessary at all airport sites.

Surface observations would include wind velocity, temperature, dewpoint, rainfall and horizontal visibility. Ceilometer and vertical wind profiling/radio acoustic sounding would be necessary to assess boundary layer meteorology (Bureau of Meteorology, 1997).

All major structures should be designed in accordance with the SAA Loading Code (Australian Standard AS 1170.4-1993 Part 4: Earthquake loads), which takes into account the potential earthquake hazard of each of area in which construction is to take place. This means that risk of injury would be minimised in the event of a seismic event.

7.4 BIRD AND BAT STRIKE

At the Badgerys Creek and Holsworthy sites, there is a moderate level of risk associated with bird strike. At both sites bird hazards to aircraft could be minimised by reducing bird activity near the airport. This would be achieved through careful airport site selection, and design of buildings, landscaping and drainage facilities and through appropriate waste disposal procedures, and effective airport bird management procedures.

A normal level of bat hazard is expected for the Badgerys Creek airport options. However hazards posed by fruit bats at night, especially during the summer months are likely to be significant for the Holsworthy options. These hazards are likely to be difficult to manage, because a large colony of bats exists at Cabramatta Creek and destruction of all food sources in the Holsworthy area would be difficult and unacceptable. Shooting and cracker shells have very limited effectiveness on fruit bats in flight.

Clearing of areas in the vicinity of the airport runways should be examined as a possible means of reducing bat strike hazard for Badgerys Creek and Holsworthy options.

Once an airport is operational, land use planning should be monitored in the vicinity of the site and all land use applications which might result in hazardous bird and bat activity should be opposed. Civil Aviation Regulation 96 should be applied if necessary, to control waste foodstuffs in the vicinity of the airport.

Additional investigation is needed into bird and bat movements in the vicinity of both Badgerys Creek and Holsworthy, as currently there is little data available. This would be necessary to develop effective management measures. Research into the likely effects of drainage detention design options on bird populations would also be necessary, to provide a sound basis for selecting appropriate designs.

A site specific airport bird and bat management strategy and plan, which includes procedures for monitoring and assessing bird and bat activity on or near the airport site should be prepared. Regular independent review of bird and bat hazard management procedures is recommended.

7.5 FUEL SUPPLY AND STORAGE

The requirements for hazard and risk management for hazardous facilities and pipelines are well understood. These requirements encompass the planning, design, construction, and operational stages of the project, and are detailed in Statutory Regulations, Government Guidance Notes, Australian and International Standards, and industry practices. Some relevant documents include the National Standard for the Control of Major Hazard Facilities (NOHCS:1014, 1996), and the New South Wales Department of Urban Affairs and Planning's Hazard Industry Planning Advisory Papers.

The requirement at the planning stage is to ensure that the location of the pipeline and fuel storage facilities are compatible with land uses in the vicinity. The preliminary assessment undertaken here indicates that it would be possible to design and locate the pipeline and fuel storage facilities such that risk levels are within appropriate limits. As part of the Environmental Impact Statement for the pipeline, a quantitative risk assessment would be required to confirm that risks levels are acceptable at various land uses and sensitive environmental receptors in the vicinity of the pipeline route. Societal risk levels from the pipeline may also need to be considered in that quantitative risk assessment. The preliminary assessment undertaken here indicates that risk levels at residential areas from the fuel storage depot are within limits. A quantitative risk assessment may be required to confirm that the risk levels from the fuel storage depot are within limits for other land uses planned in the vicinity.

The NSW Department of Urban Affairs and Planning requires certain studies to be undertaken in conjunction with the design of the facilities. The purpose of these studies is to ensure that the facilities are designed to appropriate standards and can be operated safely. These studies include:

- Hazard and Operability Study;
- Updated Hazard Analysis; and
- Fire Safety Study.

Such studies should be undertaken as part of the design of the pipeline and fuel storage facilities.

The Department of Urban Affairs and Planning also requires that hazards associated with construction activities be addressed in a construction safety study prior to construction. Such a study should be undertaken prior to construction of the pipeline and fuel storage facilities.

The National Standard for the Control of Major Hazard Facilities specifies its requirements for Major Hazard Facilities. The requirements of this Standard should be complied with. A preliminary review of the requirements of this Standard indicate that the operator of fuel storage facilities would be required to notify the relevant public authority at least six months before construction commences.

The Department of Urban Affairs and Planning requires that a comprehensive emergency plan and detailed emergency procedures be prepared prior to operations. It also requires the operator to prepare a safety management system to ensure ongoing safety. This document specifies all safety related procedures, responsibilities and policies, along with details of mechanisms for ensuring adherence to procedures.

There is also the requirement for periodic independent hazard audit, and for reporting of incidents and near-misses. The requirements of the Department of Urban Affairs and Planning should be complied with.

The National Standard for the Control of Major Hazard Facilities specifies its requirements for Major Hazard Facilities. The requirements of this Standard should be complied with. If the fuel storage facilities are classified as Major Hazard Facilities, the operator of fuel storage facilities would be required to submit a safety report prior to commencement of operation, among other requirements.

7.6 SECURITY ISSUES

There are well developed and tested response procedures for handling any incidents at an airport resulting from terrorist or other criminal activity. These arrangements, which are developed between the airport operator, airlines, State police and interested Commonwealth agencies, are designed to contain the incident and resolve it with the minimum impact on the airport and its surrounds.

7.7 UNEXPLODED ORDNANCE

Detection and clearance of all items of unexploded ordnance cannot be guaranteed. A small residual risk remains that such items will be present on the site during construction activities, even if procedures designed for 100 percent detection of unexploded ordnance are employed. Since this potentially small residual risk cannot be eliminated, steps must be taken to prevent an explosion or to deal with potential consequences of an explosion.

Steps taken to minimise the occurrence and consequences of an explosion could include:

- training of all construction staff involved in bulk earthworks in recognising items of unexploded ordnance, and in procedures for summarising assistance;

- modification of earthmoving machinery to protect the operator from possible injury in the event of an explosion;

- avoiding non-essential construction staff from being in close proximity to areas where earth is being excavated, if not protected in an earthmoving machine; and

- undertaking further investigation work prior to construction, to assess the practical difficulties of unexploded ordnance clearance in inaccessible areas.

Steps taken to deal with the potential financial consequences of an unexpected explosion, such as the substantial consequential costs which would result from suspension of construction activities and potential requirements to employ more stringent (and possibly slower) construction methods, could include:

- undertaking further work to define appropriate performance specifications for clearance of unexploded ordnance, taking into account;

- further assessment of the potential consequences of less than complete certainty of clearance on all parties involved, and their insurers;

- an understanding of the relationship between decontamination costs and the agreed performance criteria for the decontamination;

- the potential consequences of any unexploded ordnance related incidents on the airport construction program, and the contractual implications to all parties; and

- the inter-relationships between the attitudes of the insurers to each of the parties, the warranties and liabilities required to be assumed by each party, and the issues listed above.

As outlined previously, due to the nature and extent of possible consequential losses and the potential difficulties to insure for them, it may also be necessary for the Commonwealth to share the risks with the insurance and construction industry by way of warrant or covenants upon transfer of the land from the Department of Defence to the airport owner for the construction period. In addition, some negotiate agreement would need to be reached with insurers before the project could proceed.

To minimise the hazards and risks of unexploded ordnance outside the airport boundary, the following steps could be undertaken:

- implementation of a similar detection and clearance program for all routes of access roads, pipelines and other infrastructure;

- security fencing of areas that have not been cleared of unexploded ordnance, with appropriate warning signs placed within such areas;

- clearance of unexploded ordnance from fire trails outside of the airport options that need to be used for bushfire fighting and fuel management;

- developing bushfire management techniques that avoid the need for fire fighters to enter uncleared areas, such as aerial fire fighting; and

- preparing realistic emergency plans for potential aircraft crash scenarios outside the airport boundaries, but within areas containing unexploded ordnance.

7.8 CONTAMINATED SITES

On the basis of preliminary investigations, the impact of soil contamination at the sites of the Badgerys Creek and Holsworthy airport options would not be significant, but further contamination assessment work should be undertaken after agricultural or military activities have ceased. This would avoid recontamination of areas that had been assessed. This further assessment work would aim to identify any potential contamination that was not apparent during the preliminary investigation, and to identify specific localised contamination sources such as underground fuel storage tanks (at Badgerys Creek) and undocumented landfills (at Holsworthy).

It would also enable statistical data to be obtained on the likely contaminant concentrations in material that could potentially be used as fill beneath the airport sites and any material which could possibly be disposed of offsite, and identify levels of potential health and environmental risks.

At Holsworthy, clearing of unexploded ordnance would be required prior to intrusive investigations associated with drilling or sampling subsurface soils or groundwater. Specific occupational health and safety procedures would need to be developed prior to commencing fieldwork, and strictly adhered to.

7.9 FIRE RISK

At the sites of the Badgerys Creek options, fire fighting is likely to be fast and effective during the construction period. There would be easy access for vehicles and equipment and a ready supply of water in nearby dams and storages. Water tanker trucks normally used for dust suppression would be able to be used for fire fighting activities. Emergency evacuation, if ever necessary, could occur through many informal entry/exit points.

At Holsworthy, access for fighting fires outside the boundary would be severely hampered by steep slopes, inaccessible terrain and the presence of unexploded ordnance. To overcome this problem, roads used for construction access would need to be maintained in good condition and additional fire trails may need to be created, outside the airport site boundaries. All roads and infrastructure such as pipelines should be surrounded by fire breaks and fire trails. These would provide a safe base from which to control fires and a means of emergency evacuation. Total extinguishment would be an appropriate policy for most fires. In areas where access to fires is difficult or time consuming, aerial fire fighting methods may be necessary to achieve this.

At both Badgerys Creek and Holsworthy sites, fires could be prevented within the airport construction zone by storing flammable liquids, fuels and other materials in cleared areas, mowing or otherwise keeping grasses under control and ensuring that fire extinguishers are used when hot work such as welding or metal cutting is being undertaken. All construction staff would need to be trained in basic fire fighting techniques and in procedures for summoning help if small fires get out of control. These risk reduction principles would apply equally to operation of the airport.

During construction and operation of the airport, management of fuels and fire hazards outside the airport boundary would not be within the power of the airport operator. To overcome this, agreements could be made with surrounding land owners about regular hazard reduction activities, or the local Council could be requested to invoke it's powers under the Bushfires Act, 1949, and ensure that bush fire hazard reduction is carried out in a given period and to a certain standard.

For the Badgerys Creek options, this may be straightforward, but for the Holsworthy options the situation is potentially more complicated. This is due to differences in fire prevention and control philosophies and governing legislation between the Army, NSW National Parks and Wildlife Service, Sydney Water and the Sutherland, Liverpool and Campbelltown Councils.

A high level of coordination and cooperation would be necessary to overcome differences in training standards, expertise, communications systems and resources. Creation of a single agency to manage all bushfire areas surrounding an airport at Holsworthy or a management committee with representatives from each organisation may be necessary.

In order to develop effective fire fighting strategies for the Holsworthy Options, modelling of fire behaviour should be carried out using available software. A number of possible scenarios would need to be assessed. Prescriptive burning of the surrounding landscape is one means of reducing the amount of fuel present. Fuel management plans incorporating prescriptive burning would need to take into account the likely impacts on ecological species, communities and habitats.

7.10 EMERGENCY PLANS

The aerodrome emergency plan will address a wide range of possible emergencies including aircraft crash, aircraft crash alert, bomb scare, disabled aircraft, spillage of hazardous material, fire and natural disaster. The plan would be based on the worst type of emergency situation which might conceivably occur with respect to size, location, timing and weather.

7.11 OVERFLYING OF ORCHARD HILLS DEFENCE FACILITIES

One risk at the Defence Establishment Orchard Hills which cannot be easily quantified is the risk of distraction of explosives technicians while doing sensitive work. It is understood that the majority, if not all of the activities involving the handling of explosives are carried out indoors. Therefore it would be feasible to reduce noise levels inside sensitive buildings by noise insulation, if required. This would reduce or eliminate the hazard of distraction.

7.12 CRASHES INTO WATER SUPPLY INFRASTRUCTURE

The likelihood of Warragamba Dam failure following an aircraft crash should be investigated. If the likelihood is high, options to reduce the frequency of aircraft crash at the dam should be investigated, including re-positioning flight tracks and minimising aircraft movements on tacks in the vicinity of the dam. If the likelihood of dam failure following an aircraft crash is determined to be low, and flight paths above the dam cannot be avoided, then the hazard to the dam gates from an aircraft crash, and options to reduce the consequences should be investigated.

The likelihood of Prospect dam wall failure following an aircraft crash should be investigated. If the likelihood is high, options to reduce the consequences of an aircraft crash should be investigated. The frequency of aircraft crashes at the Prospect Complex could also be reduced by reducing the number of movements. Options to reduce the impact of an aircraft crash on the Warragamba Pipelines and the Prospect Complex should also be investigated.

Options to reduce the impact of an aircraft crash on the Warragamba Pipelines should be investigated. The frequency of aircraft crashes on the pipelines could be reduced by reducing the number of aircraft movements.

The likelihood of Warragamba Dam failure following an aircraft crash should be investigated. If the likelihood is high, options to reduce the frequency of aircraft crash at the dam should be investigated, including re-positioning flight tracks and minimising aircraft movements on tracks in the vicinity of the dam.

The frequency and the consequences of aircraft crashes on the Woronora Dam should be further investigated, and risk mitigation measures implemented if risks are considered high.

The frequency and the consequences of aircraft crashes on the Cataract Dam should be further investigated, and risk mitigation measures implemented if risks are considered high.

Part E

Summary of Impacts

CHAPTER 8 SUMMARY OF POTENTIAL IMPACTS OF HAZARDS AND RISKS

The impacts of the various airport options on hazards and risks are summarised in this section.

The Quantitative Risk Assessment for aircraft crashes predicts certain maximum fatality rates per 100 years and populations exposed to risks of greater than one in a million chance of an aircraft crash, which are illustrated in *Table 8.1*.

TABLE 8.1 SUMMARY OF FATALITY RATES IN 2016 AND POPULATIONS EXPOSED TO LEVELS OF MORE THAN ONE IN A MILLION PER YEAR INDIVIDUAL FATALITY RISK

Option	Fatality Rate (per 100 years)[1]	Population Affected by Greater than One in a Million Chance of a Fatality per year[2]
Badgerys Creek Option A	2.5	2,500
Badgerys Creek Option B	2.2	2,500
Badgerys Creek Option C	5	9,000
Holsworthy Option A	13	60,000
Holsworthy Option B	6.4	21,000

Notes:
1. Fatality rate means the average number of people living in the vicinity of the airport options who would potentially be killed by aircraft crashing into them from above, for 100 years of operations, for 30 million passengers per annum.
2. The population who live within the area where the chance of being killed by an aircraft crash is one in a million per year or greater. This area is defined by individual fatality risk contours. A chance of greater than one in a million per year is considered by the NSW Department of Urban Affairs and Planning to be inappropriate for industrial developments adjacent to residential areas.

Risks of aircraft crashing on areas could be mitigated by selection of the airport option that has the lowest potential fatality rate, reducing the total number of aircraft movements, selection of the mode of operation which minimises the population exposed to a fatality risk of more than one in a million, or controlling future development and types of sensitive land uses (such as residential areas and hospitals) in the vicinity of the airport options.

Quantitative Risk Assessment of aircraft crashes into Lucas Heights Science and Technology Centre showed no significant risk because none of the flight paths passes through the restricted airspace around the facility, however a qualitative assessment suggests that the risk of an aircraft crash into the facility is much greater for Holsworthy Option A than for Holsworthy Option B. This is because of the closer proximity of the facility to the site of Holsworthy Option A.

Little data is available on adverse meteorological conditions at the various airport sites. Due to modern navigation aids, adverse meteorological conditions such as high intensity rainfall, thunderstorms, low cloud and fog may be able to be largely overcome by large commercial aircraft. The impacts of such phenomena on other aircraft may be significant. Wind shear and mechanical turbulence affects aircraft of all sizes and is not able to be measured or predicted as readily as other phenomena. More monitoring is needed to fully quantify the potential occurrence of adverse meteorological conditions.

There is no significant difference between the sites of the Badgerys Creek options and the Holsworthy options in terms of risk of earthquakes. All locations in Metropolitan Sydney are assessed to have an equal risk factor when designing for earthquake protection.

Bird strike is considered to be a moderate risk at Badgerys Creek and a normal level of bat hazard is expected at Badgerys Creek. At Holsworthy, bird hazards are moderate, but potential hazards posed by fruit bats at night, especially during the summer months, could be difficult to manage. Removal of habitats and feeding areas from the vicinity of the airport runways due to obstacle limitation clearing, is likely to reduce bat strike risks to a manageable level. Research into bird and bat movements and populations is needed to determine suitable management measures.

Risks associated with a proposed fuel pipeline and a fuel storage facility are considered to be low for all airport options. Accidents at the storage facility are not likely to have risk implications outside the immediate area.

Terrorist sabotage bombing of aircraft is generally aimed at aircraft in flight. If sabotage were to be directed at aircraft at the airport, it is unlikely that its effects would extend beyond the airport boundary. Airports have not previously been the prime target for terrorist vehicle bombs. If such a bomb were detonated on an airport, its effects would depend on its size. The impact on the community outside the airport would most likely be minimal and certainly less severe than the effect on the community of a strategically placed bomb directed at other targets.

Preventative security measures have been in place for some time to deter and prevent terrorist activity directed against large passenger aircraft and airport terminals at major airports. Contingency planning including exercises of various kinds involving key stakeholders have also been a feature of these arrangements for many years.

As there is a small residual risk that an item of unexploded ordnance could remain undetected on the site of the airport options, despite a program aimed at achieving 100 percent clearance, steps would need to be taken prior to and during construction to minimise the risk of unexpected explosions and to reduce their potential impacts. Insurance of consequential losses from such a situation may be significant and not necessarily fully insurable. It may be necessary for the Commonwealth to share the risk with the insurance and construction industry. More investigation into potential risks is necessary. Steps must also be taken to minimise risks due to activities occurring outside of the airport boundaries, such as additional clearing of infrastructure corridors and fencing of uncleared areas.

Health and environmental risks associated with contaminated soil at Badgerys Creek and Holsworthy have not been assessed fully, but the volume of contaminated soil is expected to be insignificant in comparison with the amount of earthworks proposed.

Preliminary assessment of soils at Holsworthy indicates that concentrations of heavy metals and explosives residues are not as elevated as would be expected in areas of high military activity.

Management or disposal of contaminated material could easily be incorporated into construction planning. More detailed investigation into the extent and level of contamination is required.

Bushfire risk at Badgerys Creek is considered to be a relatively low risk and this would be unlikely to change as a result of construction and operation of an airport. Firefighting and fire prevention at Badgerys Creek would be easy and effective.

At Holsworthy, bushfires are very common and would pose a continual risk during construction and operation of an airport. Activities conducted within the airport boundaries are unlikely to cause bushfires to occur, but externally generated fires could potentially close the airport due to potential smoke impacts. Fire fighting and fire prevention would be problematic at Holsworthy.

The development of an aerodrome emergency plan is a normal practice for all major airports and is a statutory prerequisite for commencement of airport operations. Responsibility for preparing the emergency plan would rest with the future operator of the Second Sydney Airport.

No significant risks of aircraft crashes into the Defence Establishment Orchard Hills were identified , but potential impacts of aircraft flights over the facility on Defence activities and consequential risks associated with explosive handling could not be quantified. The risk of an aircraft crash due to an accidental explosion at the facility was assessed to be insignificant.

Risks of aircraft crashes associated with aircraft flight tracks over the Warragamba, Prospect, Woronora and Cataract Dams and major pipelines are not insignificant. Since the potential consequences of such crashes into dam walls or pipelines could be catastrophic, flight tracks should be designed to avoid such risks.

References

REFERENCES

ACARRE (1990). *Third Runway Proposal, Sydney (Kingsford Smith) Airport, Draft Environmental Impact Statement: Hazard Analysis and Risk Assessment.* Australian Centre of Advanced Risk and Reliability Engineering Ltd.

Airservices Australia (1996), *The Long Term Operating Plan for Sydney (Kingsford Smith) Airport and Associated Airspace - Report Summary,* Commonwealth of Australia, Canberra.

Australian Ordnance Council (1992). *Pillar Proceeding 205.92 Control of Airspace Above Explosives Facilities and Sites of Planned Detonations* (U). Department of Defence, Canberra.

Australian and New Zealand Environmental Conservation Council and National Health and Medical Research Council, (1992) *Australian and New Zealand Guidelines for the Management of Contaminated Sites.*

AXIS/Australian Museum Business Services Consulting (undated), *Holsworthy Training Area Environmental Audit, Main Report for the Department of Defence.*

Benson, and Howell, J. (1995). *Taken for Granted. The Bushland of Sydney and its Suburbs.* Kangaroo Press.

Bureau of Air Safety Investigations (1992). Abbreviated Investigation Report (ICAO Style): British Aerospace BAe146 VH-NJQ, Adelaide Airport, South Australia. Department of Transport and Communications Bureau of Air Safety Investigation Report B/924/1007. 3 February 1992.

Bureau of Meteorology, (1993), Weather Records.

Bureau of Meteorology (1997). *Climatological Review for Holsworthy and Badgerys Creek New South Wales - Part II - Aerodrome Useability Based Upon Meteorological Parameters Other Than Wind,* Report No. SSU97-1, Final Report, Special Services Unit, Melbourne, Vic, April 1997.

Christidis, L., & W.E. Boles. 1994. *The Taxonomy and Species of Birds of Australia and its Territories.* Royal Australasian Ornithologists Union Monograph No.2. RAOU, Melbourne.

Coalition of Liberal and National Parties (1996), *Putting People First, Coalition Policy on Sydney Airport and Sydney West Airport,* Commonwealth of Australia, Canberra.

Commonwealth Environment Protection Authority (1996). *Guidelines for and EIS on Sydney's Second major airport.*

Cullis, Sharyn. 1996. Cabramatta Creek Flying Foxes. Unpublished note dated 25 November 1996.

Cullis, Sharyn. 1997. Cabramatta Creek Flying Foxes. Unpublished note dated 30 January 1997.

Department of Administrative Services, Centre for Environmental Management (1995), *Explorative Excavation of Buried Materials at Lot 4 The Northern Road, Luddenham, NSW.*

Department of Administrative Services (1996), Centre for Environmental Management December 1996, *Status Report No. 4 (CL228): Badgerys Creek.*

Department of Bush Fire Services (1991). *Planning for Bush Fire Protection - A Guide for Land Use Planners, Home Owners, Planners and Fire Authorities.* Edited by Tony Gates. Department of Bush Fire Services.

Department of Bush Fire Services (1992). *Fire Coordination Manual - Model S41A Plan Guidelines.*

Department of Bush Fire Services (1996). *Draft. Planning for Bush Fire Protection - A Guide for Land Use Planners, Home Owners, Planners and Fire Authorities.* Edited by Tony Gates.

Department of Defence (1994). *Defence Explosives Safety Manual OPSMAN 3.* Edition One. Directorate of Publishing, Defence Centre, Canberra.

Department of Planning (1984). *Building in Fire Prone Areas.* Circular C10.

Department of Planning (1984). *Planning in Bush fire Prone Areas.* G20 Direction - Ministerial 117 Direction.

Department of Planning (1990). *Risk Criteria for Land Use Safety Planning.* Hazardous Industry Planning Advisory Paper No.4.

Department of Planning (1994). *Applying SEPP 33.* Hazardous and Offensive Development Application Guidelines.

Department of Transport and Regional Development (1996), *Location and Development of the Second Sydney Airport, The Proposal*, 5 August 1996, Sydney West Airport Taskforce, Canberra.

Disaster Management (1994). Senate Standing Committee Parliament of Commonwealth of Australia, Canberra, 1988.

Draft Rural Fires Bill, 1997; Exposure Draft Bill and Regulations. (dated 21.3.97).

ERM Mitchell McCotter (1995a). *Proposed Warragamba Flood Mitigation Dam Environmental Impact Statement.* Prepared for Sydney Water Corporation Limited.

ERM Mitchell McCotter (1995b). *Environmental Assessment of Proposed Remedial Works at Prospect Dam.* Prepared for Sydney Water Corporation Limited.

ERM Mitchell McCotter (1996). *The Proposed Warragamba Dam Auxiliary Spillway Environmental Impact Statement.* Prepared for Sydney Water Corporation.

Fairfield City Council (1995), *Report on the Current State of the Flying Fox Colong at Cabramatta Creek Habitat.* Environmental Control Branch, Fairfield City Council, August 1995.

Frikken, A.J and Westall, D.J (1995). *Re-Assessment of the Siting of HIFAR.* Nuclear Safety Bureau.

Health and Safety Executive (1988). *The Tolerability of Risk from Nuclear Power Stations.* HSMO, London.

Health and Safety Commission (1991). *Major hazard aspects of the transport of dangerous substances.* HSMO, London.

Higgins, P.J. and S.J.J.F Davies, (eds.). 1996. *Handbook of Australian, New Zealand & Antarctic Birds, Volume 3.* Oxford University Press. Melbourne.

House of Representatives Standing Committee on Environment and Conservation (1984). *Bush Fires and The Australian Environment.* Aust Gov. Publishing Service Canberra 1984.

Humbley, D.I (1997). *Estimation of Consequences of an Aircraft Crash Involving HIFAR.* Draft. Australian Nuclear Science and technology Organisation.

Kinhill Stearns (1985). *Second Sydney Airport Site Selection Programme, Draft Environmental Impact Statement,* Kinhill Stearns and the Department of Aviation.

Lommers, G.C.M, and Bottleberghs, P.H (1995). *External Safety Policy in the Netherlands.* IPSG, 5 October.

Marchant, S. and P.J. Higgins, (eds.). 1990. *Handbook of Australian, New Zealand & Antarctic Birds, Volume 1.* Oxford University Press. Melbourne.

Marchant, S. and P.J. Higgins, (eds.). 1993. *Handbook of Australian, New Zealand & Antarctic Birds, Volume* 2. Oxford University Press. Melbourne.

McArthur, AG (1967). *Leaflet 107 Fire Behaviour in Eucalypt Forest AG McArthur, Canberra. Commonwealth of Australia Department of National Development. Forestry and Timber Bureau (and reprinted later by) CSIRO Div. Forestry - Bush Fire Research Unit.1967.*

Minister for Transport and Regional Development (1996), *Media Release,* "Environmental Impact Statement for Holsworthy", 21 May, 1996.

Ministry of Housing, Spatial Planning and the Environment, (1994) *Risk Assessment and Environmental Quality Division Directorate of Chemicals, External Safety and Radiation Protection, Environmental Quality Objectives in the Netherlands.*

National Transportation Safety Board (1996). *Aviation Accident Statistics,* Accidents, Fatalities and Rates, Tables 1 to 10.

National Transportation Safety Board (1996). *Accident Synopses,* 1982-1995.

National Occupational Health and Safety Commission (1996). *National Code of Practice for the Control of Major Hazard Facilities* NOHSC:2016.

National Occupational Health and Safety Commission (1996). *National Standard for the Control of Major Hazard Facilities.* NOHSC:1014.

National Parks and Wildlife Service (1990). *Fire Management Manual.* NSW National Parks and Wildlife Service. NSW.

NSW Clean Waters Act, (1970) - Regulations Schedule 2.

Nuclear Safety Bureau (1997). *Safety Assessment Policy for Australian Nuclear Facilities.* Draft (Rev.1).

Peddle Thorp Architects, (1995), *Military Area Master Plan.*

Philips, D.W (1987). *Criteria for the Rapid Assessment of the Aircraft Crash Rate onto Major Hazards Installation According to their Location.* UK Atomic Energy Authority Safety and Reliability Directorate, R435.

Piers, M.A, et al (1993). *The Development of a Method for the Analysis of Societal and Individual Risk Due to Aircraft Accidents in the Vicinity of Airports.* National Aerospace Laboratory NLR. NLR CR 93372 L.

Purdy, G (1994). *Manchester Airport Proposed Second Runway: Rebuttal Proof of Evidence, Third Party Risks.* DNV Technica Limited, Manchester.

Research Report 38 of 1993 prepared by G Barclay, Conservation and Natural Resources (Victoria).

Schodde, R. and I.J. Mason. 1980. *Nocturnal Birds of Australia*. Lansdowne. Melbourne.

Senate Select Committee on Aircraft Noise in Sydney (1995), *Falling on Deaf Ears? Report of the Senate Select Committee on Aircraft Noise in Sydney,* Commonwealth of Australia.

Spencer, H.J., C. Palmer and K. Parry-Jones. 1991. Movements of Fruit-bats in Eastern Australia, Determined by Using Radio-tracking. Wildl. Res. 18:463-8.

Standards Australia/Standards New Zealand (1995). *Australian/New Zealand Standard AS/NZS 4360: 1995 Risk Management.*

Strahan, R. (ed). 1983. *Complete book of Australian Mammals.* Angus & Robertson, Sydney.

Sydney Water and NSW National Parks and Wildlife Service (1997). *Special Areas Draft Plan of Management - Woronora, O'Hares Creek and Metropolitan.*

Technica (1990). *Risk Analysis of Aircraft Impacts at Shipol Airport.* Confidential Report to the Dutch Government, VROM, Technica Project no.C1884.

Technica (1991). *Extension to Risk Analysis of Aircraft Impacts at Schipol Airport.* Confidential Report to the Dutch Government, VROM, Technica Project No.C2475.

Tidemann, C.R., and J.A. Spence. 1995. Flying-fox Camp on Cabramatta Creek. Research Report. School of Resource and Environmental Management, Australian National University. March 1995.

Travers, J (1994). *Hazard and Threat Assessment Training Module.*

Travers, J (1990). *The Use of Siro-Plan in Fire Management Planning*. Unpublished report.

Van Tets, G.F., W.J.M. Vestgens, A.H. D'Andria and R. Barker. 1977. *Guide to the Recognition and Reduction of Aerodrome Bird Hazards*. Australian Government Publishing Service. Canberra.

Walker, J. (1984). *Fuel Dynamics in Australian Vegetation*. In "Fire and the Australian Biota" Australian Academy of Science.

Wilson A.A.G (1984). *Assessing the Bush fire Hazard of Houses; A Quantitative Approach*. Rural Fire Research Centre. Technical Paper Number 6.

Appendices

Appendix A

Aircraft Crash Risk Assessment Report

Second Sydney Airport Environmental Impact Statement Hazard and Risk - Aircraft Crash Risk Assessment Report

---

Department of Transport and Regional Development

Prepared by
Four Elements

Edited by PPK Environment & Infrastructure Pty Ltd

9 Blaxland Road
Rhodes NSW 2138

PO Box 248
Concord West NSW 2138
Australia

Telephone (61 2) 9743 0333
Facsimile: (61 2) 9736 1568

A NATA Certified Quality Company

25 August, 1997
58H233A PR_1367

CONTENTS

Page Number

1 INTRODUCTION	1-1
2 BACKGROUND	2-1
2.1 RISKS ASSOCIATED WITH AIRCRAFT CRASHES	2-1
2.1.1 RISK CRITERIA	2-1
2.1.2 TYPICAL COMMUNITY RISK LEVELS	2-2
2.2 RISK CRITERIA FOR HAZARDOUS INDUSTRIES IN NSW	2-3
2.3 OVERSEAS RISK CRITERIA	2-5
3 QUANTITATIVE RISK ASSESSMENT	3-1
3.1 METHODOLOGY	3-1
3.1.1 AIMS	3-1
3.1.2 SCOPE OF WORK	3-1
3.1.3 INFORMATION SOURCES	3-3
3.1.4 REVIEW OF PREVIOUS WORK	3-4
3.1.5 ASSESSMENT PROCESS	3-4
3.1.6 TYPES OF RISK RESULTS PROVIDED	3-4
3.1.7 RISK ANALYSIS METHODOLOGY	3-5
3.2 EXISTING ENVIRONMENT	3-6
3.2.1 RISKS ASSOCIATED WITH EXISTING SYDNEY AIRPORT	3-6
3.2.2 RISK ASSESSMENT CRITERIA FOR THE SECOND SYDNEY AIRPORT	3-7
3.2.3 LAND USE	3-7
3.3 PRELIMINARY DATA ANALYSIS	3-9
3.3.1 INTRODUCTION	3-9
3.3.2 AIRCRAFT TRAFFIC FORECAST	3-9
3.3.3 CLASSIFICATION OF AIRCRAFT MOVEMENTS	3-9
3.3.4 SUMMARY OF AIRCRAFT MOVEMENTS	3-11
3.3.5 PRELIMINARY RISK ANALYSIS	3-11

3.4 CRASH RATE ANALYSIS 3-13

3.4.1 INTRODUCTION 3-13
3.4.2 DATA SOURCES 3-14
3.4.3 CATEGORIES OF OPERATION 3-14
3.4.4 DATA SELECTION AND ANALYSIS METHODOLOGY 3-14
3.4.5 AUSTRALIAN CRASH RATES 3-15
3.4.6 US CRASH RATES 3-20
3.4.7 TREND IN ACCIDENT RATES 3-24
3.4.8 SUMMARY OF CRASH RATES PREDICTED FOR 2016 3-25
3.4.9 SUMMARY OF CRASH RATES USED IN PREVIOUS STUDIES 3-26

3.5 CRASH LOCATION PROBABILITY DISTRIBUTION ANALYSIS 3-27

3.5.1 INTRODUCTION 3-27
3.5.2 HISTORICAL CRASH LOCATION DATA 3-27
3.5.3 INFERENCES FROM HISTORICAL CRASH LOCATION DATA 3-28
3.5.4 MODELLING APPROACH 3-28
3.5.5 MODELLING PARAMETERS 3-30
3.5.6 MODELLING DETAILS 3-31

3.6 CRASH CONSEQUENCE ANALYSIS 3-32

3.6.1 INTRODUCTION 3-32
3.6.2 OVERVIEW OF CONSEQUENCE ANALYSIS 3-32
3.6.3 FACTORS INFLUENCING THE SIZE OF IMPACT DAMAGE AREA 3-33
3.6.4 FACTORS INFLUENCING THE SIZE OF HEAT RADIATION AFFECTED AREA 3-33
3.6.5 SCENARIOS CONSIDERED 3-34
3.6.6 REPRESENTATIVE AIRCRAFT 3-35
3.6.7 ESTIMATED EFFECT AREAS 3-35
3.6.8 ESTIMATED FATALITIES ON THE GROUND 3-36
3.6.9 RISK SUMMATION 3-37
3.6.10 RISK SUMMATION 3-37

3.7 RISK RESULTS AND ASSESSMENT 3-38

3.7.1 PREDICTED CRASH FREQUENCIES 3-38
3.7.2 INDIVIDUAL RISK 3-39
3.7.3 SOCIETAL RISK 3-42

3.8 RISK MITIGATION 3-44

3.8.1 INTRODUCTION 3-44
3.8.2 SELECTION OF OPTION 3-44
3.8.3 SCALE OF DEVELOPMENT 3-44
3.8.4 SAFETY STANDARDS AND REGULATIONS 3-44
3.8.5 SAFETY MANAGEMENT SYSTEM 3-45
3.8.6 MODES OF OPERATION AND FLIGHT PATHS 3-46
3.8.7 LAND USE SAFETY PLANNING 3-46

4 AIRCRAFT CRASHES INTO LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE 4-1

4.1 METHODOLOGY 4-1

4.1.1 AIMS 4-1
4.1.2 SCOPE OF WORK 4-1
4.1.3 INFORMATION SOURCES 4-2
4.1.4 CONSULTATIONS 4-3

4.2 EXISTING ENVIRONMENT 4-3

4.2.1 DESCRIPTION OF FACILITIES 4-3
4.2.2 EXISTING SAFEGUARDS 4-3
4.2.3 CONSEQUENCES OF A LARGE AIRCRAFT CRASH 4-4
4.2.4 LIKELIHOOD OF A LARGE AIRCRAFT CRASH 4-4
4.2.5 EXISTING AIRSPACE AND LAND USE CONSTRAINTS 4-7

4.3 IMPACTS OF HOLSWORTHY OPTION A 4-7

4.3.1 PROPOSED FLIGHT PATHS 4-7
4.3.2 HAZARDS AND RISKS IDENTIFIED 4-8
4.3.3 RISK ASSESSMENT 4-8
4.3.4 SOCIAL AND ECONOMIC CONSEQUENCES 4-11

4.4 IMPACTS OF HOLSWORTHY OPTION B 4-11

4.4.1 PROPOSED FLIGHT PATHS 4-11
4.4.2 HAZARDS AND RISKS IDENTIFIED 4-11
4.4.3 RISK ASSESSMENT 4-12
4.4.4 SOCIAL AND ECONOMIC CONSEQUENCES 4-14

4.5 RISK MITIGATION 4-14

4.5.1 INTRODUCTION 4-14
4.5.2 SELECTION OF OPTION 4-15
4.5.3 AIRSPACE RESTRICTIONS 4-15
4.5.4 PILOT AVOIDANCE 4-16
4.5.5 COMMUNICATION 4-16
4.5.6 INTEGRATED EMERGENCY PLANS 4-16

5 CRASHES INTO WATER SUPPLY INFRASTRUCTURE 5-1

5.1 METHODOLOGY 5-1

5.1.1 AIMS 5-1
5.1.2 SCOPE OF WORK 5-1
5.1.3 INFORMATION SOURCES 5-1

5.2 EXISTING ENVIRONMENT 5-1

5.2.1 INTRODUCTION 5-1
5.2.2 RISK ASSESSMENT CRITERIA 5-2

5.3 IMPACT ASSESSMENT 5-3

5.3.1 INTRODUCTION 5-3
5.3.2 BADGERYS CREEK OPTIONS A AND B 5-4
5.3.3 BADGERYS CREEK OPTION C 5-7
5.3.4 HOLSWORTHY OPTION A 5-8
5.3.5 HOLSWORTHY OPTION B 5-9

5.4 RISK MITIGATION 5-10

LIST OF FIGURES

		Following Page No.
Figure 3.1	Fatal Accident Rate Trends	3-24
Figure 3.2	Predicted Maximum Frequency of Aircraft Crashes for Badgerys Creek Option A	3-38
Figure 3.3	Predicted Maximum Frequency of Aircraft Crashes for Badgerys Creek Option B	3-38
Figure 3.4	Predicted Maximum Frequency of Aircraft Crashes for Badgerys Creek Option C	3-38
Figure 3.5	Predicted Maximum Frequency of Aircraft Crashes for Holsworthy Option A	3-38
Figure 3.6	Predicted Maximum Frequency of Aircraft Crashes for Holsworthy Option B	3-38
Figure 3.7	Individual Fatality Risk Contours for Badgerys Creek Option A	3-39
Figure 3.8	Individual Fatality Risk Contours for Badgerys Creek Option B	3-39
Figure 3.9	Individual Fatality Risk Contours for Badgerys Creek Option C	3-40
Figure 3.10	Individual Fatality Risk Contours for Holsworthy Option A	3-41
Figure 3.11	Individual Fatality Risk Contours for Holsworthy Option B	3-41
Figure 3.12	Societal Risk Comparison for Airport Options	3-43

1 INTRODUCTION

Four Elements, part of the ERM Mitchell McCotter Consulting Group, was engaged by PPK Environment & Infrastructure to undertake quantitative risk assessment studies on aircraft crashes, for the Second Sydney Airport Draft EIS.

This work was undertaken in accordance with Guidelines developed for the EIS by Environment Australia (formerly Commonwealth Environment Protection Authority). According to the Guidelines (pp.14) a quantitative risk assessment had to be undertaken to assess the impacts on individual and societal risk levels, including:

- 'probability analysis of aircraft accidents with reference to aircraft incidents within Australia and, to the extent relevant, world-wide;
- consequences of aircraft accidents (including crashes on the airport, crashes in residential areas, crashes in industrial areas, crashes with other aircraft, crashes into water storage reservoirs, aircraft fuel spills);
- the effect of flight paths and frequency of aircraft movements on the risk of accidents involving residential and industrial areas, including the management of aircraft utilising the proposed airport, KSA and other regional airports;
- for the Holsworthy site, discuss the risk and safety implications of flight paths over the Lucas Heights Science and Technology Centre, including implications for existing airspace restrictions.'

The scope of this part of the Hazard and Risk study was based on addressing these elements of the guidelines. The findings of this study have been summarised in *Technical Paper No. 10 - Hazards and Risks*, and in the Draft EIS.

2 BACKGROUND

2.1 RISKS ASSOCIATED WITH AIRCRAFT CRASHES

2.1.1 RISK CRITERIA

People face many risks in daily life. Where risks are taken with free choice and with full knowledge, that risk is described as voluntary risk. Where the individual does not have the knowledge of the risk or is not entirely free to choose to avoid the risk exposure, then the risk is termed non-voluntary. In reality, most types of risk exposures have degrees of both voluntary and non-voluntary components.

The risk from a hazardous industrial development is usually perceived as a non-voluntary risk. Such risk may be borne by some people more than others and the benefits may also be unevenly distributed. These risks are regulated by society as a whole with the aim of securing general benefit.

Over the years, government regulators in many countries have formulated criteria for acceptable levels of risk to the public for the purpose of decision-making. The general principles for acceptable risk criteria is that it should be low relative to other known and tolerated risks. The development of such risk criteria has made it possible to assess the risks from new proposals on a uniform basis. However, there is a need to balance risks against benefits, and hence any such standards, or criteria, are only one of the factors considered in the decision-making process.

When planning a new hazardous facility, it is now a requirement in many countries to consider risks to people outside the boundaries of the proposed facility so that the acceptability of risk levels can be judged in relation to the nature of land use in the vicinity. This process ensures that new hazardous industries are separated sufficiently from sensitive land uses. Similarly when planning new developments (for example residential developments) in the vicinity of existing hazardous facilities, it is a requirement to consider the acceptability of risk levels at new developments.

It is necessary to consider both individual risk as well as societal risk. Individuals are concerned about their own safety, and this concern is mostly independent of whether the risk is from an isolated incident or from a large-scale disaster. On the other hand, society's perception is mostly influenced by disasters involving many people.

In an accident, the level of physical harm to people could range from minor injury to fatality. Most assessments of individual or societal risk are in terms of human fatality.

Individual fatality risk is the risk of death per year to a person at a particular point outside the boundary of the facility. Individual risk is generally higher at locations that are closer to the facility, and reduce at a distance. One of the ways in which individual risk can be expressed is by means of iso-risk contours. The individual risk at points in the study area is calculated and contours for nominated individual risk levels are plotted on a map of the study area. The normal basis for the calculation assumes that an individual remains in a location constantly, thus allowing the reader to interpret the plot according to the proportion of time real individuals are actually present (the occupancy).

Societal risk considers the risk from an installation or activity to society as a whole, and takes into account the actual number of people exposed to levels of risk. On-site population or voluntary risk takers are generally excluded from such calculations. A number of measures or representations of societal risk are possible; the most commonly used is the Societal Risk or FN curve. The societal risk or FN curve expresses the risk to the population in the study area as a whole, independent of geographical location. It is a graphical representation on a log-log scale of the frequency, F, of N or more fatalities plotted against the number of fatalities, N. The shape of an FN curve and its level (that is, the F values for a given N) indicate the pattern and level of risk.

2.1.2 TYPICAL COMMUNITY RISK LEVELS

Table 2.1 illustrates risks from all causes, including health, for males in various age groups in Australia.

TABLE 2.1 FATALITY RISK - AUSTRALIA - ALL CAUSES

Age Range (years)	Risk of Fatality (for males) per million person-years
10-14	320
15-19	950
20-24	1,460
25-29	1,130
30-34	1,280
35-39	1,380
40-44	2,360
45-49	3,690
50-54	6,610
55-59	11,568

Source: ACARRE 1990.

Table 2.2 indicates a range of risks to individuals in NSW from various activities.

TABLE 2.2 RISKS TO INDIVIDUALS IN NEW SOUTH WALES

	Chances of Fatality per million person years
Voluntary Risks (average to those who take the risk)	
Smoking	5,000
Drinking alcohol	380
Swimming	50
Playing rugby football	30
Owning firearms	30
Transportation Risks (average to travellers)	
Travelling by motor vehicle	145
Travelling by train	30
Travelling by aeroplane	10
Risks Averaged over the whole population	
Cancers	1,800
Accidents at home	110
Accidental falls	60
Pedestrians struck by motor vehicles	35
Homicide	20
Accidental poisoning	
▪ total	18
▪ venomous animals and plants	0.1
Fires and accidental burns	10
Electrocution (non-industrial)	3
Falling objects	3
Therapeutic use of drugs	2
Cataclysmic storms and storm floods	0.2
Lightning strikes	0.1
Meteorite strikes	0.001

Source: Department of Planning, 1990.

2.2 RISK CRITERIA FOR HAZARDOUS INDUSTRIES IN NSW

The NSW Department of Urban Affairs and Planning has published *Hazardous Industry Planning Advisory Paper No 4: Risk Criteria for Land Use Safety Planning* (Department of Planning, 1990). Both qualitative and quantitative criteria are suggested in the guidelines. The Department of Urban Affairs and Planning takes the view that irrespective of the numerical value of any risk criteria, certain qualitative principles should be adopted concerning the land use safety acceptability of development.

These are as follows:

- all avoidable risks should be avoided. This necessitates the investigation of alternative locations and alternative technologies, wherever applicable, to ensure that risks are not introduced in an area where feasible alternatives are possible and justified;
- the risk from a major hazard should be reduced wherever practicable, irrespective of the numerical value of the cumulative risk level from the whole installation. The assessment process should address the adequacy and relevancy of safeguards as they relate to each risk contributor;
- the consequences (effects) of the more likely hazardous events (that is, those of high probability of occurrence) should, wherever possible, be contained within the boundaries of the installation; and
- where there is existing high risk from a hazardous installation, additional hazardous developments should not be allowed if they add significantly to that existing risk.

Quantitative risk assessment criteria have been suggested for Individual Fatality Risk for various land uses. These are summarised in *Table 2.3*.

TABLE 2.3 SUGGESTED INDIVIDUAL FATALITY RISK CRITERIA

Land Use	Individual Fatality Risk (per million per year) should not exceed
Hospitals, schools, child-care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open spaces	10
Industrial	50

Source: Department of Urban Affairs and Planning, 1990.

The Department of Urban Affairs and Planning has also suggested risk assessment criteria for individual injury risk in residential areas, and for risk of property damage and accident propagation in a neighbouring industrial operation.

There are difficulties in the development and implementation of societal risk criteria. While the Department of Urban Affairs and Planning requires quantification of societal risks, it suggests that judgement on societal risk be made on the merits of each case rather than by setting numerical values. In general, the individual fatality risk criteria for particular land uses have been set with regards to the lower end of the range of typical population densities for that use. Careful consideration is required where population densities are higher and where individual fatality risks are close to the suggested individual fatality risk criteria for that land use.

The guidelines emphasise that all criteria are advisory, rather than definitive, for a number of reasons, including the need to consider a range of other factors.

2.3 OVERSEAS RISK CRITERIA

United Kingdom

Within the United Kingdom, a three tier approach has been adopted for the purposes of risk-based decision making. This distinguishes three regions of risk on the basis of two defined quantitative limits:

- an upper level of risk above which risks are unacceptable or intolerable, often referred to as the tolerability limit;
- a lower level of risk beneath which risks are acceptable and do not warrant the attention of regulators, often referred to as an acceptability limit; and
- a region between the two limits within which risks may be tolerated provided that actions have been taken to ensure risks are As Low As Reasonably Practicable (ALARP).

Over the years, the Health and Safety Executive and other committees and bodies have published their views on what they consider to be the criteria for negligible and intolerable risk. The most recent views of the Health and Safety Executive are published in the document *The Tolerability of Risk From Nuclear Power Stations* (Her Majesty's Scientific Office, 1988). This document discusses how all risks, nuclear and non-nuclear, are controlled in the United Kingdom.

The Health and Safety Commission has proposed that a risk of one in 10,000 per annum to any member of the public is the maximum that should be tolerated from any large industrial plant in any industry with, of course, the ALARP principle applying to ensure that risk from most plant is in fact lower or much lower. The Health and Safety Executive has also proposed a value of one in a million per year as a level of risk that would be 'broadly acceptable' to the members of the public.

The Health and Safety Commission has proposed societal risk criteria for the assessment of risks from ports handling dangerous substances in bulk. The upper 'just tolerable' limit is set at the level of risk that was judged to be just tolerable from the Canvey Island complex of chemical plants after exhaustive analysis and explicit discussion by Ministers in Parliament. The lower 'negligible' level corresponds to a predicted frequency a thousand times lower. The societal risk criteria are often shown graphically. The slope of lines representing the criteria is usually chosen on the assumption that if a likelihood of more than 10 fatalities is tolerable at a particular level, a risk of 100 fatalities will be tolerable only if it is 10 times less likely. Thus the slope of these lines is -1 on the log-log scale of an FN graph, and indicates a linear tolerance of risk across all number of fatalities.

Netherlands

The original Dutch policy on external safety involved the definition of maximum tolerable risk and negligible risk. Between the two levels an As Low As Reasonably Achievable approach was required. In 1993-1994 the use of acceptability criteria in the Netherlands changed somewhat, the most important aspect of which was that the concept of negligible risk was no longer used. The revised scheme thus places more emphasis on reducing risks to the point where they are demonstrated to be an As Low As Reasonably Achievable than was previously the case.

Under the revised scheme, the calculation of individual risk and the societal risk is somewhat different. The calculations for individual risk assume that an individual remains at a location constantly and is not protected by any shelters or buildings that may be present at that location. For a new industry, the maximum tolerable individual risk criteria is set at 10^{-6} per year.

In the calculation of societal risk the actual average presence of persons at different locations is taken as the basis for calculation, and any protection offered by buildings is also taken into account. A acceptability criteria for societal risk is often shown graphically. The slope of the line representing the criteria is -2, that is, it is assumed that if a likelihood of more than 10 fatalities is tolerable at a particular level, a risk of 100 fatalities will be tolerable only if it is 100 times less likely. This indicates a non-linear tolerance of risk, that is, an aversion to risks involving large number of fatalities.

Schipol Airport (Amsterdam)

External safety around Schipol Airport has been the subject of extensive studies. Safety zones have been determined to limit the risk to people living around Schipol. Within the 10^{-5} per annum risk zone new construction of housing as well as other dwellings is prohibited. Within the 5×10^{-5} risk zone, existing housing will even be 'closed down' on the longer term. Within the 10^{-6} contour area an overall risk policy has been adopted aimed at a stand-still in the development of the risk in the contour area. In an even larger area the construction of dwellings is restricted to a certain extent.

3 QUANTITATIVE RISK ASSESSMENT

3.1 METHODOLOGY

3.1.1 AIMS

The aim of aircraft accident quantitative risk assessment is to quantify and assess the impacts on individual and societal risk levels, including:

- probability analysis of aircraft accidents with reference to aircraft incidents within Australia, and to extent relevant, world-wide;
- consequences of aircraft accidents (including crashes on the airport, crashes in residential areas, crashes in industrial areas, crashes with other aircraft, crashes into water storage reservoirs, aircraft fuel spills)
- the effect of flight paths and frequency of aircraft movements on the risk of accidents involving residential and industrial areas, including management of aircraft utilising the proposed Second Sydney Airport, Sydney Airport and other regional airports.

3.1.2 SCOPE OF WORK

Airport Options Considered

Five runway location and alignment options are considered for this Draft EIS. Three of these, designated as Badgerys Creek Options A, B and C, are located approximately at the previously-selected airport site at Badgerys Creek. Two others, designated Holsworthy Options A and B, are at separate locations within the Holsworthy Military Area. Specific quantitative risk assessments were undertaken for each of the five options.

Air Traffic Forecast Scenario Considered

The role of the Second Sydney Airport in supplying the overall airport needs within the Sydney basin has not been decided at this stage. The Draft EIS process considered three possible planning scenarios as follows:

Air Traffic Forecast 1 - Overflow Scenario

This scenario allows for 10 percent of all Sydney basin traffic to be moved to the Second Sydney Airport in the year 2006. After 2006, all growth in the Sydney basin would be accommodated at the Second Sydney Airport.

Air Traffic Forecast 2 - Equal Growth Scenario

This scenario allows for 10 million passengers from the Sydney basin to be accommodated at the Second Sydney Airport in the year 2006. After 2006, all growth in the Sydney basin would be accommodated at the Second Sydney Airport.

Air Traffic Forecast 3 - Additional Noise Scenario

This scenario allows for the majority of the Sydney basin wide body aircraft to be located at the Second Sydney Airport from 2006. After 2006, all growth in the Sydney basin would be accommodated at the Second Sydney Airport for the year 2016 scenario.

Risk of aircraft accidents depend on a range of factors, including the number of traffic movements per year. Risk levels in year 2016 would be higher than risk levels in year 2006 on account of higher traffic levels in year 2016. Risk assessments were undertaken for year 2016 scenarios, since they represent the "worse-case" impacts.

A preliminary analysis of all three forecasts, for the year 2016, is outlined in *Section 3.3*. This analysis has indicated that Air Traffic Forecast 3 would present a relatively higher risk impact than the other two forecasts. Therefore, detailed quantitative risk assessments are undertaken for Air Traffic Forecast 3, in the year 2016 only.

Airport Modes of Operation Considered

The likely pattern of runway usage at the airport, in terms of operating modes and preferred runways, has not been decided at this stage. For year 2016, the risk associated with three possible scenarios are investigated:

Airport Operation 1 - Preferred Northerly Takeoffs

This operating mode allows for aircraft movements occur to on the parallel runways in one specified direction (arbitrarily chosen to be the direction closest to north), unless this is impossible due to meteorological conditions. Under this operating mode, aircraft take-off predominantly to the North and land from the South. Second priority is given to operations in the other direction on the parallel runways, with operations on the cross runway occurring only if necessitated by meteorological conditions.

Airport Operation 2 - Preferred Southerly Takeoffs

As for North Mode above, but with the preferred direction of movements on the parallel runways reversed; and

Airport Operation 3 - Share the Noise Scenario

This operating mode allows for a deliberate implementing of a "noise sharing" policy under which a certain number of movements are directed to occur on the cross runway (with equal numbers in each direction), with the remainder distributed equally between the two parallel runway directions. Airservices Australia indicated that the maximum number of movements which is likely to occur on the cross runway is seven percent of total traffic. Analysis of meteorological data indicated that such a scenario would be within the allowed meteorological parameters for all airport sites.

For the Badgerys Creek Option A, only Preferred Northerly takeoff and Preferred Southerly takeoff modes were considered, since no cross runway exists.

3.1.3 Information Sources

Air Traffic Forecast

Aircraft movement data for the three air traffic forecast scenarios were supplied by Second Sydney Airport Planners (1997d). Movement forecasts were broken down by aircraft type, domestic or international movements, direction of origin or destination, and stage length (a value from 1 to 7 representing the distance to the aircraft's point of origin or destination).

A set of preliminary approach and takeoff flight tracks were defined for each airport option for noise impact studies. The same set of tracks were used in risk impact studies.

Allocation of Aircraft Movements to Tracks

The likely number of aircraft movements on each track in each operating mode was modelled as part of noise impact studies. This modelling took into account a wide range of factors, including the origin/destination of various aircraft types and the likely use of each runway based on operating mode and meteorological constraints. The same model was used for allocating aircraft to tracks for risk impact studies.

Aircraft Accident Data

The Bureau of Air Safety Investigation provided Australian historical aircraft accident data. US accident data were obtained from the US National Transport Safety Bureau's internet website. Worldwide airline accident data were obtained from Flight International Magazine (Flight International, 1980-1997).

3.1.4 REVIEW OF PREVIOUS WORK

Risk impact studies were not included in the Second Sydney Airport Site Selection Program Draft EIS (Kinhill Stearns, 1985).

A number of previous risk assessment studies for airports in Australia and overseas were referred to during the course of this study. These included risk assessments for

- the proposed third runway at Kingsford Smith (Sydney) Airport;
- the proposed second runway at Manchester Airport;
- the proposed Kuala Lumpur International Airport; and
- the Schipol Airport (Amsterdam).

3.1.5 ASSESSMENT PROCESS

The main elements of the risk assessment methodology were as follows:

- establish the context;
- identify hazards and risks;
- analyse risks to estimate the levels of risk; and
- assess risk levels against pre-established criteria.

The steps leading up to risk assessment are part of the overall risk management process specified in the Australian Standard on risk management (AS/NZS 4360: 1995).

3.1.6 TYPES OF RISK RESULTS PROVIDED

This study provides two types of risk results: individual risk contours as graphical representations of individual risks and FN diagrams as graphical representations of societal risks.

Individual risk is the probability that, over a time span of one year, a particular geographical location is exposed to lethal consequences of an aircraft accident. Whether the area is actually populated or not is irrelevant to the calculation of individual risk.

Societal risk is the probability that, over a time span of one year, a group of more than N people are killed due to an aircraft accident. Societal risk calculations take into account the population density in the study area.

Detailed explanations on risk contours and F-N diagrams are provided in *Section 2.1.1*.

There are an infinite number of scenarios in which aircraft accidents could cause harm to people. The level of harm could range from temporary discomfort to multiple fatalities. The type of people harmed could include aircrew, passengers or members of the public. The accident site could be within the perimeter of the airport, or outside the perimeter of the airport. People could be harmed directly by an aircraft accident, or as a result of secondary incidents initiated by an aircraft accident. The impact on people could be more or less immediate (acute), or spread over a long time (chronic).

Individual and societal risk calculations undertaken are based on the following:

- Risks are defined in terms of immediate human fatalities. While consequences of aircraft accidents could include injuries or property damage as well, calculation of risk levels in terms of fatalities provides, in most cases, sufficient information for decision making.
- The only risks considered are those to the members of the public on the ground, that is, to third party. Risks to aircrew and passengers are not included in calculations. While aircrew and passengers are obviously exposed to risk as well, they derive a direct benefit from this activity and are generally considered to be voluntary risk takers, whereas members of the public generally do not derive any direct benefit from the activity and may be considered to be exposed to risks involuntarily. It is not appropriate to combine involuntary risks with voluntary risks.
- Aircraft accidents or the effects of aircraft accidents which occur at the airport are not considered a risk to the population in the area outside the airport perimeter, and are therefore not included in risk assessment.
- Only direct effects of aircraft accidents are taken into account in risk analysis. Indirect effects such as those possibly occurring after an aircraft accident on a chemical plant are not discussed.

3.1.7 RISK ANALYSIS METHODOLOGY

The broad approach to calculating the risk to individuals and society in the vicinity of the airport is given below. Further details of the methodology and assumptions are provided in separate sections on each part of the analysis.

Calculation of Aircraft Crash Rates

The rate (probability per approach or take-off) at which aircraft may crash in the vicinity of the Second Sydney Airport in the year 2016 was estimated. This was based on an analysis of historical crash rates.

Crash Location Probability Distribution Modelling

If an aircraft were to crash in the vicinity of the airport, the probability that it will crash at say location 'x' is not the same as the probability at another location 'y'. An aircraft is more likely to crash close to the runway than at larger distances from the runway. Also, aircraft arrive and depart along particular tracks and the probability of crashes is higher at locations closer to tracks than far from tracks. Computer models are developed to determine how the crash probability would be distributed over the area in the vicinity of the airport. These models are based on relationships derived from historical crash location data and on the location of the arrival and departure tracks assumed for each airport option.

Consequence Analysis

The consequences of aircraft crashes were analysed to estimate the likely area of impact and the probability of fatality in the impact area. This analysis took into account a number of factors, such as the size of the aircraft, its likely fuel load at the time of impact, and whether the crash occurred at a steep or a shallow angle.

Risk Summation

The results of the three steps above were integrated together with the forecast number of aircraft movements using a dedicated computer program *Airport Risk* to calculate individual risk levels in the vicinity of the airport options. The predicted population densities at different locations were taken into account in the calculation of societal risk levels.

3.2 EXISTING ENVIRONMENT

3.2.1 RISKS ASSOCIATED WITH EXISTING SYDNEY AIRPORT

Risk levels around the existing Sydney Airport were estimated as part of the Draft EIS of the proposed Third Runway. The individual fatality risks in selected areas were calculated for the existing airport (1990), the airport without the third runway in 1995, and with the third runway in 1995 and 2010. The results are summarised in *Table 3.1*.

TABLE 3.1 RISKS AROUND EXISTING SYDNEY AIRPORT

Suburb	Individual Fatality Risk (per million per year)			
	1990	1995 Without Third Runway	1995 With Third Runway	2010 With Third Runway
Botany	0.08	0.13	0.003	0.003
Mascot	0.05	0.082	0.00	0.00
Sydenham	42.00	43.00	83.00	102.00
Arncliffe	0.08	0.13	0.003	0.003
Rockdale	1.00	1.10	0.02	0.002
Marrickville	42.00	43.00	83.00	103.00
Stanmore	4.00	4.10	8.00	10.00
Kingsford	2.00	4.20	4.20	0.04
Petersham	2.00	4.10	6.00	8.00
Kingsgrove	0.20	0.50	0.006	0.005
Randwick	0.20	0.20	0.005	0.005
Hurstville	0.20	0.20	0.003	0.002

Source: ACARRE 1990.

3.2.2 RISK ASSESSMENT CRITERIA FOR THE SECOND SYDNEY AIRPORT

This study establishes the individual and societal risk levels from the Second Sydney Airport at five alternative locations in the year 2016. Individual fatality iso-risk contours are shown on maps of the areas, and both existing and proposed residential areas within the 10^{-6} contour are identified. Societal risks of all options have been calculated and are shown as F-N curves.

Information on normal community risks and acceptable risk criteria suggested by government regulators is provided in this chapter so that interested individuals and decision-makers can not only compare the options on the basis of risk but also judge the acceptability of risk levels from each option.

3.2.3 LAND USE

Badgerys Creek Options

Land use in the immediate vicinity of the sites for the three Badgerys Creek options is rural with low population density. Residential areas with higher population densities are located about seven kilometres towards the north and about 10 kilometres towards the east. Industrial areas are located about 10 kilometres from the sites.

Residential Areas

The main residential areas towards the north include Erskine Park, St Clair, Colyton, Oxley Park, St Marys, Claremont Meadows, Werrington, Glenmore Park, Jamisontown, Penrith, Kingswood and Mount Druitt. Towards the north east, the main residential areas include Prospect, Girraween, Seven Hills and Blacktown. The main residential areas towards the east include Abbotsbury, Bossley Park, Greenfield Park, Cecil Hills, Bonnyrigg Heights, Green Valley, and Hinchinbrook. Pockets of residential areas are located in the immediate vicinity of the sites towards the west in Luddenham. Other pockets of residential areas towards the west include Wallacia, Silverdale, Warragamba and Mulgoa. Towards the south east, the main residential areas include Kearns, Raby, Eschol Park, St Andrews, Eagle Vale and Claymore. The residential areas towards the south include Narellan, Camden, Elderslie, South Camden, Narellan Vale and Mount Annan.

Industrial Areas

The main industrial areas towards the north east and East include Wetherill Park, Greystanes, Huntington, Arndell Park, and Hoxton Park. Towards the south east and South, the main industrial areas include Ingleburn, Minto and Smeaton Grange. Industrial areas of Minchinbury, St Marys, Werrington, Penrith, and Jamisontown are located towards the north.

Holsworthy Options

The sites of the two Holsworthy options are located within the Holsworthy Military Area. There are no urban developments in the immediate vicinity of the sites. In relation to the site for Holsworthy Option A, residential areas are located about three kilometres to the east and about four kilometres to the north west. Residential areas are located about four kilometres to the north west and about seven kilometres to the south east of the site of Holsworthy Option B. Industrial areas are located about six kilometres to the east of the site of Holsworthy Option A, and about seven kilometres to the north east of the site of Holsworthy Option B site.

Residential Areas

The main residential areas to the east of the Holsworthy Military Area include Heathcote, Engadine, North Engadine, Lucas Heights, Menai, Bangor, Alfords Point, Illawong Woronora, Yarrawarrah and Loftus. Towards the north, the main residential areas include Sandy Point, Picnic Point, Pleasure Point, Panania, East Hills, Revesby, Milperra, Holsworthy, Wattle Grove, Moorebank, Chipping Norton, Liverpool, and Casula. The main residential areas towards the west include Macquarie Fields, Ingleburn, Minto, Leumeah, Ruse, Campbelltown, Airds, Bradbury, St Helens Park, Rosemeadow, and Ambervale. Towards the south east, the main residential areas include Waterfall, Helensburg, Helensburg North, Helensburg West and Stanwell Park. Residential areas to the south include Darkes Forest and Appin.

Industrial Areas

The main industrial areas towards the north include Chipping Norton, Moorebank, and Hoxton Park. Towards the west, the main industrial areas include Ingleburn, Minto, and Campbelltown.

3.3 PRELIMINARY DATA ANALYSIS

3.3.1 INTRODUCTION

This section provides a preliminary analysis of aircraft types and the three air traffic scenarios at the Second Sydney Airport in the year 2016. The purpose of this analysis is to identify the broad basis for categorising aircraft movements for risk analysis, and to undertake a preliminary analysis to determine which of the three air traffic forecast scenarios would present the highest risk to people on the ground. Detailed risk analysis has been undertaken for the scenario that presents the highest impact on risk levels.

3.3.2 AIRCRAFT TRAFFIC FORECAST

The annual number of aircraft movement in the three air traffic forecast scenarios were supplied by Second Sydney Airport Planners in spreadsheet form. Movement forecasts were broken down by aircraft type (203 different types specified), domestic or international movements, direction of origin or destination (north, east, south, west or north-west), and stage length (a value from one to seven representing the distance to the aircraft's point of origin or destination).

3.3.3 CLASSIFICATION OF AIRCRAFT MOVEMENTS

The risk to people on the ground is not the same for each type of aircraft. Risk depends both on the likelihood and the consequences of crash. For the purpose of risk analysis, it is necessary to differentiate between categories of aircraft that have different crash rates. Similarly, it is necessary to differentiate between categories of aircraft that have different scales of consequences.

There are three distinct categories of operations in Australia:

- High Capacity Air Transport, that is, high capacity aircraft (more than 38 seats/4,200 kilograms payload) operated by agencies which hold an Australian airline licence;

- Low Capacity Air Transport, that is, low capacity aircraft (38 seats/4,200 kg payload or less) operated by agencies which hold an Australian airline licence; and
- General Aviation, that is, all flying by civil aircraft other than airline operations, gliders and sport aviation.

Different safety and operational standards apply to each category of operations. The most stringent standards apply to High Capacity Air Transport operations, whereas the standards applicable to general aviation are the least stringent. Historical crash rates for High Capacity Air Transport are much lower than those for Low Capacity Air Transport, which in turn are much lower than those for general aviation. Therefore, the different aircraft types are categorised into one of the three categories of operation for the purpose of crash rate analysis. Historical data also show that crash rates during landing are somewhat different from those during take-off. Therefore, landings and take-off movements are considered separately.

The consequences of aircraft crash depend upon a number of factors, including the size of the aircraft and the fuel load at the time of crash. There would be a multitude of aircraft sizes at the Second Sydney Airport, ranging from those with a few seat aircraft to the new large aircraft with around 600 seats. To reduce the complexity of computations, aircraft have been categorised into three sizes on the basis of seat capacity. The following categories are used:

- small aircraft (less than 70 seats);
- medium aircraft (71 to 180 seats); and
- large aircraft (more than 180 seats).

Another consideration in consequence estimation is the fuel present at the time of crash. Fuel load is more important for the large aircraft category because of the larger fuel carrying capacities. The fuel load of a large aircraft depend on whether the aircraft is landing or taking-off, and in the case of departing aircraft, whether the destination point is near or far. Large aircraft departing for long overseas destinations carry a larger fuel load than those departing for shorter destinations. The fuel load on arrival is generally low. Thus for consequence analysis, the large category is subdivided into two categories:

- Large - stage length one to four departure movements; and
- Large - Increased Fuel Load: stage length five to seven departure movements.

Table 3.2 shows the categories of aircraft movements necessary to account for the differences both in crash rates and crash consequences.

TABLE 3.2 CATEGORIES OF AIRCRAFT MOVEMENTS

Risk Category	Crash Rate Category	Crash Consequence Category
Low Capacity	Low Capacity Air Transport	Small
High Capacity - Small	High Capacity Air Transport	Small
High Capacity - Medium	High Capacity Air Transport	Medium
High Capacity - Large	High Capacity Air Transport	Large
High Capacity - Large- Increased Fuel Load	High Capacity Air Transport	Large - Increased Fuel Load
General Aviation	General Aviation	Small

3.3.4 SUMMARY OF AIRCRAFT MOVEMENTS

Summary of movement data for the three air traffic forecast scenarios, classified according to the six risk categories is shown on *Table 3.3*.

TABLE 3.3 FORECAST ANNUAL AIRCRAFT MOVEMENTS

Risk Category	Air Traffic Forecast 1	Air Traffic Forecast 2	Air Traffic Forecast 3
Low Capacity	29,162	36,463	33,028
High Capacity - Small	18,188	23,599	20,274
High Capacity - Medium	56,632	74,242	65,310
High Capacity - Large	56,512	71,073	92,247
High Capacity - Large- Increased Fuel Load	8,967	11,037	18,359
General Aviation	15,119	16,022	15,538
Total Movements	184,580	232,436	244,756

3.3.5 PRELIMINARY RISK ANALYSIS

A preliminary analysis was undertaken to determine which air traffic forecast scenario would present the highest risk to people on the ground. Detailed analysis was then undertaken for the case that presents the highest risk impact.

Table 3.3 shows that the number of movements in Air Traffic Forecast 1 scenario is lower in comparison with those in the other two scenarios for each risk category. Therefore, Air Traffic Forecast 1 Scenario would present the lowest risk impact amongst the three scenarios. The difference in the risk impact of the other two scenarios is not obvious.

These differences could be in terms of individual risk levels at particular locations or in terms of societal risk. Such differences could be revealed, for example, by comparing the individual risk levels at a particular location in the two scenarios. However, it is not feasible to determine the individual risk level at any particular location without undertaking a full risk analysis of both the cases. Moreover, the choice of location at which the levels ought to be compared is also not that obvious.

An alternative is to compare the two cases on the basis of societal risk, expressed in terms of Potential Loss of Life - also referred to as Rate of Death. This comparison also requires full modelling, but it is feasible to undertake a simple analysis that would allow comparison on the basis of a measure indicative of the relative societal risks.

Rate of Death (per year) depends on:

- crash rate per movement;
- number of movements per year;
- probability of crash at different locations;
- the effect area of each crash; and
- the population density at each crash location.

For a particular Second Sydney Airport option, the flight tracks would be the same for all the air traffic forecast scenarios. Therefore the probability distribution of crashes at different locations in the vicinity would be almost identical. For the purpose of comparison, the Rate of Death could be considered to be independent of the location of the crash. Therefore a notional Rate of Death could be calculated without considering the actual probability of crash at different location, and the population density at these locations. Differences in the notional Rate of Death would then indicate which scenario would have the higher risk impact.

Details of crash rate and crash effect area analyses are provided in *Sections 3.4 to 3.6*. The results of those analyses are used here to calculate a notional Rate of Death, assuming that the population density at all locations is one person per square kilometre area. A notional Rate of Death has been calculated as follows:

1. Half of the movements are assumed to be approach, and the other half, take-off.
2. Frequency (per year) of crash is calculated by multiplying the number of movements per year with the crash rate per movement.
3. Probability of fatality in the event of a crash within a one kilometre square area is calculated as the proportion of the area within the fatal effect area of that crash.

4. Rate of Death (per year) for a population density of one person per square kilometre is calculated by multiplying the frequency (per year) of crash with the probability of fatality in that crash, and by calculating the aggregate over all movements.

Table 3.4 shows the results of notional Rate of Death calculations.

TABLE 3.4 COMPARATIVE SOCIETAL RISKS - AIR TRAFFIC FORECASTS 2 AND 3

	Air Traffic Forecast 2		Air Traffic Forecast 3	
Risk Category	**Crash Frequency (per year)**	**Notional Rate of Death (per year)**	**Crash Frequency (per year)**	**Notional Rate of Death (per year)**
Low Capacity	0.029	0.64×10^{-4}	0.026	0.58×10^{-4}
High Capacity - Small	0.0024	0.05×10^{-4}	0.002	0.05×10^{-4}
High Capacity - Medium	0.0076	0.49×10^{-4}	0.0066	0.43×10^{-4}
High Capacity - Large	0.0072	1.39×10^{-4}	0.0094	1.81×10^{-4}
High Capacity - Large- Increased Fuel Load	0.0011	0.24×10^{-4}	0.0019	0.40×10^{-4}
General Aviation	0.063	1.41×10^{-4}	0.061	1.37×10^{-4}
Total	**0.111**	$\mathbf{4.23 \times 10^{-4}}$	**0.108**	$\mathbf{4.64 \times 10^{-4}}$

The above analysis shows that although the frequency (per year) of crashes in Air Traffic Forecast 2 would be marginally higher than in Air Traffic Forecast 3, the risks would be marginally higher in Air Traffic Forecast 3 on account of the relatively higher frequency of the large aircraft crashes.

Therefore, the Air Traffic Forecast 3 scenario has been considered for detailed analysis. It should be noted that risks in Air Traffic Forecast 2 would not be very different.

3.4 CRASH RATE ANALYSIS

3.4.1 INTRODUCTION

This section provides an analysis of the rate at which aircraft may crash in the vicinity of the Second Sydney Airport in the year 2016. Crash rate refers to the probability of crash in the vicinity of the airport each time an aircraft takes-off or lands.

Predictions about the future crash rate are made on the basis of historical crash rates. Historical crash rates are derived by dividing the number of aircraft crashes in the vicinity of an airport with the number of aircraft movements over which these crashes occurred.

The results of crash rate analysis are used in the calculation of individual and societal risk levels.

3.4.2 DATA SOURCES

The Bureau of Air Safety Investigation is the agency of the Australian Government responsible for the investigation of accidents occurring to civil aircraft in Australia and its territories. The Bureau of Air Safety Investigation provided all the Australian accident data used in this analysis. AVSTATS Aviation Policy Division provided movement data used in the calculation of crash rates.

In the US, the National Transportation Safety Board (National Transportation Safety Board) is the authority responsible for recording and investigating accidents involving US registered civil aircraft. The US accident data used in this analysis were all obtained from the National Transportation Safety Board.

3.4.3 CATEGORIES OF OPERATION

As outlined before, there are three distinct categories of aircraft operations in Australia:

- High Capacity Air Transport;
- Low Capacity Air Transport; and
- General Aviation.

Air traffic movements at the Second Sydney Airport would include each of the above categories of operations. Different safety and operational standards apply to each category of operations. Therefore, crash rates were calculated for each of these three categories of operation.

Historical data indicates that crash rates during landing and final approach phase are somewhat different from those during take-off and initial climb phase. Therefore separate crash rates have been calculated for landing and take-off movements.

3.4.4 DATA SELECTION AND ANALYSIS METHODOLOGY

Authorities responsible for investigating aircraft accidents publish statistics primarily as an aid to improving safety. Although such statistics are useful, they cannot be directly used for the purpose of this risk analysis for a number of reasons.

Firstly, the classification of accidents is not suitable for this analysis. Generally, the authorities publish two types of rates: *accident* rate, and *fatal accident* rate. Accidents refers to all incidents occurring between the time of boarding and the time of disembarking which result in a fatal or serious injury to a person, or substantial damage or destruction of the aircraft. *Fatal accidents* are those accidents in which a person is fatally injured. The main type of accident that could result in fatal injuries to people on the ground is when an aircraft crashes into the ground, that is, there is an uncontrolled or unintentional impact with the ground. The analysis of risk to people on the ground therefore requires an estimate of the *crash rate*. It is not possible to determine a *crash rate* from *accident* or *fatal accident* rates, because accidents or fatal accidents do not refer specifically to aircraft crashes.

Secondly, crashes may occur at the airport, in the vicinity of the airport, or en-route. Crashes that occur at the airport are not considered to be a risk to the population in the vicinity of the airport. Similarly, people in the vicinity of the airport are not considered to be at risk from crashes that occur en-route.

Therefore it is necessary to investigate accident records in further depth to estimate the historical crash rates, within the time and resource constraints of the study. Data search included 'fatal accidents' and, where possible, 'aircraft destroyed'. Other accidents were not considered to be severe enough to contribute significantly to fatality risk on the ground. Brief investigation reports for 'fatal accidents' and 'aircraft destroyed' accidents, were reviewed to judge whether the aircraft crashed or not, and whether the crash was in the 'vicinity' of the airport or en-route. A crash within 20 kilometres of an airport has been considered to be in the 'vicinity' of the airport.

3.4.5 AUSTRALIAN CRASH RATES

High Capacity Air Transport

Table 3.5 shows the relevant accident and movement data for the High Capacity Air Transport operations in Australia from 1981-1995.

There were no fatal accidents or aircraft destroyed for Australian High

TABLE 3.5 HIGH CAPACITY AIR TRANSPORT - ACCIDENT AND MOVEMENT DATA 1981 - 1995

Year	Fatal Accidents	Fatalities	Aircraft Destroyed	Departures
1981	0	0	-	233,355
1982	0	0	-	223,059
1982	0	0	-	211,432
1984	0	0	-	218,240
1985	0	0	0	233,729
1986	0	0	0	240,387
1987	0	0	0	243,681
1988	0	0	0	243,728
1989	0	0	0	186,464
1990	0	0	0	205,155
1991	0	0	0	240,503
1992	0	0	0	259,353
1993	0	0	0	265,697
1994	0	0	0	283,261
1995	0	0	0	301,992

Notes:
1. Sources: Private communication with the Bureau of Air Safety Investigation and AVSTATS.
2. Accident data for 1994 and 1995 are preliminary.
3. It is assumed that there were as many landings as departures in each year

Capacity Air Transport operations between 1981 and 1995. However this does not mean that the probability of a fatal accident in the High Capacity Air Transport category was, or is, zero. It means that the probability is low, and that the number of aircraft movements during the period was probably not large enough to have resulted in a fatal accident. For the purpose of risk analysis, it is necessary to collect data from a region that has characteristics similar to Australian aviation, but has a larger number of movements. North America or Western Europe are the likely candidates. Data from the US, and its applicability, are discussed in *Section 3.4.6*.

Low Capacity Air Transport

Table 3.6 shows the relevant accident and movement data for the Low Capacity Air Transport operations in Australia from 1981-1995.

TABLE 3.6 LOW CAPACITY AIR TRANSPORT - ACCIDENT AND MOVEMENT DATA 1981 - 1995

Year	Fatal Accidents	Fatalities	Aircraft Destroyed	Number of Departures
1981	0	0	-	196,170
1982	0	0	-	214,060
1982	0	0	-	213,060
1984	0	0	-	206,605
1985	1	1	2	212,309
1986	0	0	0	211,379
1987	0	0	0	212,901
1988	1	3	1	236,673
1989	0	0	0	233,077
1990	0	0	0	245,993
1991	0	0	0	266,248
1992	0	0	0	289,869
1993	1	7	2	305,306
1994	0	0	0	312,667
1995	1	2	1	318,953

Notes:
1. Sources: Private communication with the Bureau of Air Safety Investigations and AVSTATS.
2. Accident data for 1994 and 1995 are preliminary.
3. It is assumed that there were as many landings as departures in each year.

Four fatal accidents occurred for Low Capacity Air Transport operations during 1981-1995. Two of the fatal accidents occurred during final approach, one during initial climb, and one en-route.

Six aircraft were destroyed between 1985 and 1996. Four destroyed aircraft are accounted for in the four fatal accidents discussed above. Two aircraft were destroyed when they crashed but no fatalities occurred within 30 days of the crash. Both crashes occurred soon after take-off. Thus, three aircraft crashed during initial climb and two crashed during final approach. Assuming that there were 300,000 departures by this category of aircraft in the year 1996, the total number of departures over which the six aircraft were destroyed would be 3,145,375. Thus the following crash rates in the vicinity of an airport are calculated:

- Crash rate - take-off/initial climb — 9.54×10^{-7} per take off
- Crash rate - landing/final approach — 6.36×10^{-7} per landing

These calculated rates are based on a small number of accidents, and therefore are only estimates. While it is feasible to collect data for years before 1981 and therefore increase the sample size, such data may not be applicable. A more appropriate basis for increasing confidence in calculated probabilities is to refer to data from other regions for the same period. Data from the US are discussed in *Section 3.4.6*.

General Aviation

Table 3.7 shows the relevant accident and movement data for general aviation operations in Australia from 1981-1995.

TABLE 3.7 GENERAL AVIATION - ACCIDENT AND MOVEMENT DATA 1981 - 1995

Year	Fatal Accidents	Fatalities	Aircraft Destroyed	Number of Departures	Hours Flown (1000's)
1981	18	48	43	2,839,729	1617
1982	26	51	50	2,517,519	1540
1982	24	53	47	2,333,946	1460
1984	19	32	37	2,681,870	1553
1985	17	41	29	2,936,040	1565
1986	19	43	42	2,964,745	1556
1987	17	31	37	2,927,628	1602
1988	33	58	43	3,259,333	1763
1989	27	46	50	3,427,127	1928
1990	30	64	44	3,199,883	1929
1991	21	45	43	2,794,857	1749
1992	25	49	39	2,601,735	1649
1993	22	46	42	2,816,597	1702
1994	25	51	43	2,836,992	1704
1995	22	37	34	3,016,855	1760

Notes:
1. Sources: Private communication with the Bureau of Air Safety Investigations and AVSTATS.
2. Accident data for 1994 and 1995 are preliminary.
3. It is assumed that there were as many landings as departures in each year.

Additional details of general aviation fatal accidents were obtained from the Bureau of Air Safety Investigation. *Table 3.8* shows the flight phase in which these accidents occurred, and *Table 3.9* shows the location of the accident in relation to the airport, for the years 1981-1990. Flight phase and location details of fatal accidents after 1990 are not available.

TABLE 3.8 GENERAL AVIATION FATAL ACCIDENTS 1981 - 1990 AND PHASE OF OPERATION

Phase of Operation	Number of fatal accidents
Ground	2
Take-off	33
Flight	
- Climb	13
- Cruise	41
- Holding/ hovering	4
- Descent	15
- Aerobatics	10
- Agricultural	25
- Low Flying /Other	40
Landing	39
Unknown	8

Source: Compiled from private communications with the Bureau of Air Safety Investigation.

TABLE 3.9 GENERAL AVIATION FATAL ACCIDENTS 1981 - 1990 AND AIRPORT PROXIMITY

Airport Proximity	Number of fatal accidents
At the airport	19
Within 400 m	23
Within 800 m	12
Within 1 km	9
Within 1.5 km	15
Within 3 km	13
Within 5 km	8
Within 6 km	3
Within 8 km	15
Beyond 8 km	107
Unknown	6

Source: Compiled from private communications with the Bureau of Air Safety Investigation.

The objective of this analysis is to determine the historical rate at which aircraft crash outside an airport, but within a 20 kilometre radius.

There were 230 fatal accidents from 1981 to 1990, of which 19 occurred at the airport, and a further 75 occurred while undertaking the types of activities not expected around the Second Sydney Airport, such as agricultural flying, low flying or aerobatics. Therefore, a total of 94 fatal accidents were excluded from the 230 fatal accidents for the calculation of fatal accident rate in the vicinity of an airport such as the Second Sydney Airport.

While it is apparent from *Table 3.9* that 107 fatal accidents occurred at a distance beyond 8 kilometres from an airport, the number that occurred beyond 20 kilometres of an airport is not known. Similarly, although it is apparent from *Table 3.8* than 41 fatal accidents occurred while cruising, the number that occurred beyond 20 kilometres is not known. Therefore the number of general aviation fatal accidents that occurred within a 20 kilometre radius of an airport could not be determined with certainty.

Some or all of the 41 fatal accidents in the cruise phase could have occurred within 20 kilometres of an airport. As a conservative estimate, it was assumed that 30 of the 41 fatal accidents occurred within 20 kilometres of an airport. Therefore a further 11 fatal accidents were excluded from the 230 fatal accidents for the calculation of fatal accident rate in the vicinity of an airport such as the Second Sydney Airport.

Thus, the number of fatal accidents within 20 kilometres of an airport was estimated at 125.

Almost twice (1.84 times) the number of aircraft were destroyed during the same period. Data show that the distribution of location of destroyed aircraft is similar to that of fatal accidents. It was assumed that these aircraft were destroyed because they crashed. Thus, the number of general aviation aircraft crashes within 20 kilometres of an airport is estimated to be 230 (125 x 1.84). The total number of general aviation departures during 1981-1991 was 29,087,820. On that basis, the historical general aviation crash rate is estimated to be 7.9×10^{-6} per departure.

Data also shows that crashes are almost equally distributed between the landing and the take-off phases. Therefore the following rates are calculated:

- Crash rate - take-off/initial climb — 3.95×10^{-6} per take off
- Crash rate - landing/final approach — 3.95×10^{-6} per landing

3.4.6 US CRASH RATES

There are three main categories of operations in the USA:

- Scheduled and Non-Scheduled Services operating under 14 CFR 121;
- Scheduled and Non-Scheduled Services operating under 14 CFR 135; and
- General Aviation (all aircraft not operated under 14 CFR 121 or 14 CFR 135).

The US 14 CFR 121 Scheduled Services correspond to the Australian High Capacity Air Transport, while the US 14 CFR 135 Scheduled Services correspond to the Australian Low Capacity Air Transport.

In the US, the National Transportation Safety Board is the authority responsible for recording and investigating accidents involving US registered civil aircraft. Data from the National Transportation Safety Board, and its applicability are discussed below.

14 CFR 121 Scheduled Services

Applicability to Australia

The scale of air transport activity in the US is many times larger than in Australia. In 1995, there were over eight million departures in the US 14 CFR 121 Scheduled operations. In contrast, there were about 3.6 million departures in the Australian High Capacity Air Transport operations in the fifteen year period from 1981 to 1995. The 'true' rate of a rare event, such as a fatal accident, is more likely to be revealed in the US where the scale of activity is large, than in Australia, where the scale is small. Whether such rates would be applicable to Australia would depend on the similarities between the two regions.

As discussed in *Section 3.4.5*, there were no *fatal* accidents or aircraft destroyed for Australian High Capacity Air Transport operations between 1981 and 1995. However, there were accidents that did not result in any fatalities. *Table 3.10* compares the accident and movement data for the Australian High Capacity Transport and US 14 CFR 121 Scheduled operations.

Over the period 1983 to 1995, the accident rate for the US 14 CFR 121 Scheduled Services was 3.15×10^{-6} per departure. The Australian High Capacity Airline accident rate for the period 1981 to 1995 was higher at 5.85×10^{-6} per departure. The fatal accident rate for the US Scheduled 14 CFR 121 was 5.04×10^{-7} per departure, whereas as discussed before, there has not been any fatal accidents in Australian High Capacity Air Transport. Even if there had been one fatal accident in the Australian High Capacity air Transport operations, the rate would have been 2.8×10^{-7} per departure. While the Australian accident rate is higher, the fatal accident rate is significantly lower. Therefore, the fatal accident rate of the US 14 CFR 121 Scheduled Services would be a conservative estimate of Australian High Capacity Air Transport operations.

TABLE 3.10 US AND AUSTRALIAN ACCIDENT AND MOVEMENT DATA, 1981 - 1985

Year	US 14 CFR 121 Scheduled Services			Aust. High Capacity	
	Accidents	Fatal Accidents	Departures	Accidents	Departures
1981	-	-	-	2	233,355
1982	-	-	-	1	223,059
1983	22	4	5,235,262	1	211,432
1984	13	1	5,666,076	0	218,240
1985	17	4	6,068,893	0	233,729
1986	21	2	6,928,103	1	240,387
1986	32	4	7,293,025	2	243,681
1988	28	3	7,347,575	1	243,728
1989	24	8	7,267,341	3	186,464
1990	22	6	7,928,357	2	205,155
1991	25	4	7,672,367	2	240,503
1992	16	4	7,717,408	2	259,353
1993	22	1	7,935,743	1	265,697
1994	19	4	8,041,799	2	283,261
1995	33	2	8,220,000	1	301,992

Sources: US data from the National Transportation Safety Board, Australian data from the Bureau of Air Safety Investigation and AVSTATS.

Crash Rate

There were 47 fatal accidents in the US 14 CFR 121 Scheduled Services during 1983-1995. Accident synopses of all these fatal accidents were reviewed to judge whether the aircraft crashed or not, and whether the crash was in the 'vicinity' of the airport or en-route. The results are shown on *Table 3.11*.

TABLE 3.11 14 CFR 121 SCHEDULED SERVICES FATAL ACCIDENTS 1983 - 1995 AND LOCATION

Location / Description	Number of fatal accidents
At the airport	10
Near the airport during the take-off phase	10
Near the airport during the landing phase	9
En-route	1
Sabotage	3
No crash	13
Total	47

Source: Compiled from National Transport Safety Board data.

The National Transport Safety Board database does not have a category for 'aircraft destroyed'. However this is not a concern because it is unlikely that a large aircraft could be destroyed without any fatalities, and therefore, all accidents in which an aircraft was destroyed are likely to be covered by the 'fatal accident' category.

Thus, it is judged that 10 aircraft crashed near an airport during the take-off phase, while nine crashed during landing. These accidents occurred over 93,321,949 departures. The following crash rates are calculated:

- Crash rate - take-off/initial climb — 1.07×10^{-7} per departure
- Crash rate - landing/final approach — 9.64×10^{-8} per landing

14 CFR 135 Scheduled Services

The US 14 CFR 135 Scheduled Services correspond to the Australian Low Capacity Air Transport operations. *Table 3.12* shows the fatal accident and movement data for the period 1983-1995.

TABLE 3.12 14 CFR 135 SCHEDULED SERVICES FATAL ACCIDENT AND MOVEMENT DATA, 1983 - 1995

Year	Fatal Accidents	Departures
1983	2	2,328,430
1984	7	2,676,590
1985	7	2,561,463
1986	2	2,798,811
1986	10	2,809,918
1988	2	2,909,005
1989	5	2,818,520
1990	4	3,159,763
1991	8	2,647,876
1992	7	2,911,168
1993	4	3,322,041
1994	3	3,615,888
1995	2	3,506,000

Source: National Transport Safety Board.

Accident synopses for the 63 fatal accidents during 1983 - 1995 were reviewed to determine the location of fatal accidents. The results are shown on *Table 3.13*.

TABLE 3.13 14 CFT 135 SCHEDULED SERVICES FATAL ACCIDENTS, 1983 - 1995, LOCATION

Location/Description	Number of Fatal Accidents
At the airport	3
Near the airport during the take-off phase	14
Near the airport during the landing phase	23
En-route	19
Sabotage	0
No crash	2
No information	2
Total	63

Source: Compiled from National Transport Safety Board accident synopses.

Thus, 14 aircraft crashed near an airport during the take-off phase, while 23 crashed during landing. These accidents occurred over 38,065,473 departures. The following crash rates are calculated:

- Crash rate - take-off/initial climb 3.68×10^{-7} per departure
- Crash rate - landing/final approach 6.04×10^{-7} per landing

The location of en-route fatal accidents could not be determined from accident synopses. Some of these may well have occurred within 20 kilometres of an airport. The actual crash rate could be higher on account of this factor.

The National Transport Safety Board does not classify accidents according to severity of damage to the aircraft, and therefore it is difficult to search for all aircraft destroyed. There could have been some crashes that did not result in any fatalities, as in the Australian Low Capacity Air Transport operations. Therefore, the US 14 CFR 135 Scheduled services crash rate could have been higher on this account.

Taking into account these two factors, the US crash rates appear to be similar to those for the Australian Low Capacity Air Transport operations.

3.4.7 TREND IN ACCIDENT RATES

Figure 3.1 shows the trend in fatal accident rates for the Australian and US operations.

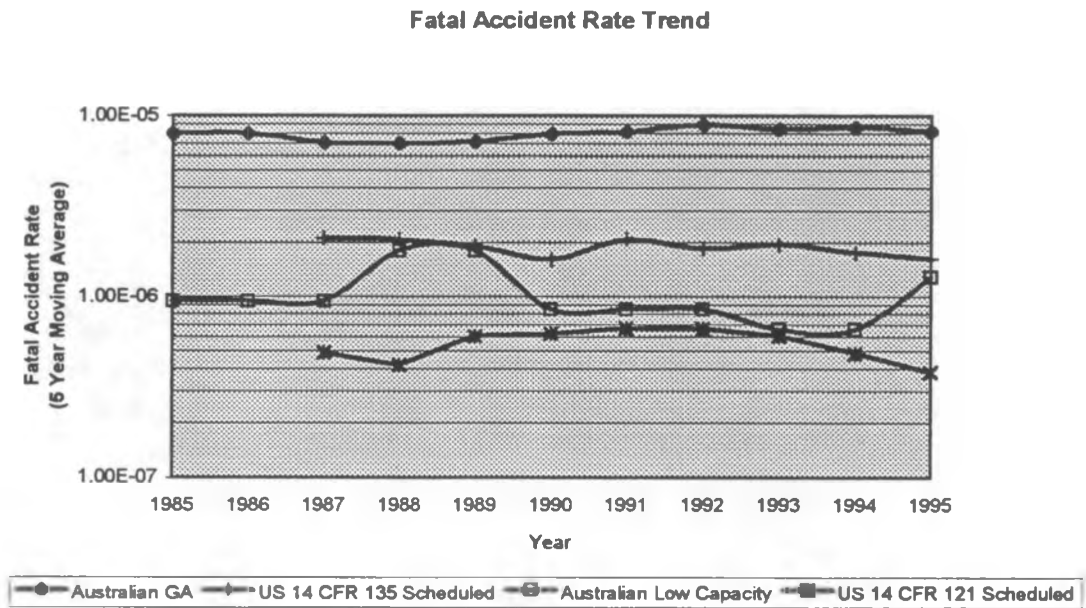


Figure 3.1 Fatal Accident Rate Trends.

There is no major upward or downward trend discernible from the figure. Data do not suggest that the fatal accident rates in the year 2016 would be higher or lower than the current rates.

The crash rates calculated in the previous sections are based on safety performance over the recent past 13 to 15 years, and are considered to be the best estimates, if not somewhat conservative estimates, for the rates in the year 2016.

3.4.8 SUMMARY OF CRASH RATES PREDICTED FOR 2016

Table 3.14 summarises the crash rates used in this risk analysis study. These rates refer to crashes outside the airport, but within a 20 kilometres radius of the airport.

TABLE 3.14 CRASH RATES PREDICTED FOR 2016

Type of Operation	Take-off	Landing
Low Capacity Air Transport	9.54×10^{-7}	6.36×10^{-7}
High Capacity Air Transport	1.07×10^{-7}	9.64×10^{-8}
General Aviation	3.95×10^{-6}	3.95×10^{-6}

Crash rates for Low Capacity Air Transport and general aviation operations are based on actual Australian safety performance during 1981-1995, whereas those for High Capacity Air Transport are based on actual safety performance of the US 14 CFR 121 Scheduled Services.

3.4.9 SUMMARY OF CRASH RATES USED IN PREVIOUS STUDIES

Although some previous studies have differentiated between airline and general aviation movements for the purpose of crash rate analysis, none have sub-divided airline movements into further categories as is done in this study. This difference should be noted when comparing the crash rates used in previous studies and this study.

Manchester Airport Proposed Second Runway

All movements at the Manchester Airport were considered to be either commercial scheduled jet, or general aviation. Commercial jet aircraft crash rates within 20 kilometres of an airport were calculated (Technica, 1994) based on ten departure and seven approach accidents for 8.5×10^{7} scheduled commercial jet movements in Western Europe and North America between 1980 - 1992, as below:

- Crash rate - take-off/initial climb — 1.2×10^{-7} per take off
- Crash rate - landing/final approach — 8.2×10^{-8} per landing

The general aviation aircraft crash rate within 20 kilometres of an airport was 1.0×10^{-6} per movement.

Schipol Airport (Amsterdam)

Crash rates were calculated (Technica, 1990a) for jet and non-jet movements in Western Europe between 1980-1989 as follows:

- Crash rate - take-off/initial climb — 2.2×10^{-7} per take off
- Crash rate - landing/final approach — 5.7×10^{-7} per approach

This rate was used for all aircraft movements at the Schipol Airport.

In an extension of the original study, crash rates were calculated (Technica, 1990b) for world-wide jet movements between 1984-1988 as follows:

- Crash rate - take-off/initial climb — 2.1×10^{-7} per take off
- Crash rate - landing/final approach — 3.7×10^{-7} per approach

This revised rate was used for all aircraft movements at the Schipol Airport.

Sydney (Kingsford Smith) Proposed Third Runway

All movements at the Sydney Airport were considered to be either scheduled airline or general aviation (ACARRE, 1990). The study did not distinguish between arrival and departure movements. Crash rates within 15 kilometres of the airport were 2.55×10^{-7} per landing (85 percent of 3×10^{-7} per landing) for scheduled airlines, and 5.1×10^{-6} per landing for general aviation. Distributing this rate equally between arrival and departure movements, the rates could be considered to be as follows:

- Scheduled airline crash rate — 1.78×10^{-7} per movement
- General aviation crash rate — 2.55×10^{-6} per movement

3.5 CRASH LOCATION PROBABILITY DISTRIBUTION ANALYSIS

3.5.1 INTRODUCTION

This section provides an analysis of the probability of aircraft crashes at different locations in the vicinity of the Second Sydney Airport in the year 2016.

The basic approach to analysis is to review historical data to develop an understanding of how crash locations are related to airport location and flight factors, and then to use these relationships to predict the location of crashes around the Second Sydney Airport options.

3.5.2 HISTORICAL CRASH LOCATION DATA

As noted in *Section 3.4*, very few aircraft within the Australian High or Low Capacity Air Transport operations have crashed. It is judged that the data set used in the calculation of crash frequency is too small to provide a representative distribution of crash location. Therefore it is necessary to use overseas data.

Information on crash location in relation to the airport is generally lacking from a majority of historical accident reports. A small proportion of accident reports contain sufficient information from which the approximate distance to the runway threshold can be determined. An even smaller proportion of accident reports contain crash location information in relation to the runway extended centreline. Details of the aircraft's intended flight path are rarely included.

Previous investigators have represented the crash location data using either the polar coordinates or the Cartesian coordinates, with respect to the runway threshold and the extended runway centreline.

Representation Using Polar Coordinates

Crash location information found in the Civil Aviation Authority's World Airline Accident Summary covering worldwide jet and non-jet crashes during scheduled and non-scheduled operations for the years 1980-1992 has been investigated (Technica, 1994), and the data presented using polar coordinates. The data-set is based on 119 approach and 51 departure crashes, which does not represent *all* crashes, rather only those crashes for which location information is available.

Representation Using Cartesian Coordinates

Worldwide crash data from various sources have been investigated (NLR, 1993), and crash location data, where available, represented using Cartesian coordinates.

3.5.3 INFERENCES FROM HISTORICAL CRASH LOCATION DATA

Historical data show that more aircraft crashed at locations closer to the runway than at larger distances from the runway. This was the case for both departing and approaching aircraft crashes, although this trend was relatively less in the case of approaching aircraft crashes.

Historical data also show that more aircraft crashed on or closer to the extended runway centreline than at distances away on either side of the extended centreline. While this was the case for both approaching and departing aircraft crashes, the departing crashes tended to be relatively more widely dispersed.

3.5.4 MODELLING APPROACH

Several methodologies have been developed in the past for the analysis of the crash probability at locations around an airport. One methodology uses the polar coordinate system. Historical data are used to derive functions for the probability of aircraft crash at different radial distances from the runway threshold and at different angular orientations with respect to the extended runway centreline. A composite function that combines the radial and angular dependence is used to determine the probability distribution of crash at different locations around an airport. This usually results in crash probability being distributed over forward and backward cones relative to the runway direction. This model does not take into account the actual flight paths.

Intuitively, it would appear that the location of crashes would be related to the aircraft's intended flight path to some extent. Information on the aircraft's intended flight path is rarely included in historical accident records. A majority of aircraft that crashed may have intended to travel along the centreline, since most of the crashes are located on or close to the extended runway centreline. However, some aircraft may have intended to follow a curved flight path, which may have contributed to some of the off-centreline crashes. This is more likely to be the case for departing aircraft where curved flight paths are more common.

The approach to modelling in this study is as follows:

- the model assumes that crash location is related to an aircraft's intended flight path. Therefore, the model considers the actual flight paths for each Second Sydney Airport option, instead of using a generic composite distribution. The flight paths are identical to those assumed for noise impact studies;
- approach and departure flight paths are considered separately;
- flight paths are represented as curves originating from or terminating at the runway thresholds;
- annual aircraft movements on each approach and departure flight path are determined by distributing the total annual airport movements according to criteria adopted for noise impact studies. Therefore the total number of aircraft on each flight path are identical to those assumed for noise impact studies;
- total movements on each flight path are further classified according to risk categories;
- the model assumes that the historical radial distance probability distribution for crash location would apply to the curvilinear distance along each flight path; and
- the model assumes that a probability distribution similar to the historical probability distribution for the angle between the crash location and the runway extended centreline would apply to curvilinear flight tracks. In this case, the angle would be between the curved flight path and another curve similar to the flight path but diverging from it at the runway threshold. The distribution around the curved flight path would however be narrower than that around the extended runway centreline in order to avoid a wider distribution of crash locations.

It should be noted that the crash location probability distribution model conserves the total frequency (per year) of crashes in the vicinity of the Second Sydney Airport. Therefore, if particular choice of modelling parameters predicts a higher crash probability at one location, it would by definition predict a lower crash probability at another location.

3.5.5 MODELLING PARAMETERS

Distance Dependence

The radial distance probability distributions discussed in *Section 3.5.3* were assumed to apply to the curvilinear distance along the flight path. Flight paths were modelled for a curvilinear distance of 20 kilometres from the runway threshold. The flight paths were divided into 40 segments of 500 metres each. The probability distribution of crash within each segment is shown on *Table 3.15*.

TABLE 3.15 PROBABILITY DISTRIBUTION FOR SEGMENTS

Segment Number	Probability Distribution (Take-off / Initial Climb)	Probability Distribution (Landing / Final Approach)
1	20.52%	12.81%
2	15.51%	10.49%
3	11.76%	8.63%
4	8.94%	7.13%
5	6.83%	5.92%
6	5.25%	4.96%
7	4.06%	4.18%
8	3.17%	3.55%
9	2.50%	3.05%
10	2.00%	2.65%
11	1.63%	2.33%
12	1.34%	2.06%
13	1.13%	1.86%
14	0.97%	1.69%
15	0.86%	1.55%
16	0.77%	1.44%
17	0.70%	1.36%
18	0.65%	1.29%
19	0.61%	1.23%
20	0.58%	1.19%
21	0.56%	1.15%
22	0.55%	1.12%
23	0.54%	1.10%
24	0.53%	1.08%
25	0.52%	1.06%
26	0.52%	1.05%
27	0.51%	1.04%
28	0.51%	1.03%
29	0.51%	1.03%
30	0.50%	1.02%
31	0.50%	1.02%
32	0.50%	1.01%
33	0.50%	1.01%
34	0.50%	1.01%
35	0.50%	1.01%
36	0.50%	1.01%
37	0.50%	1.00%
38	0.50%	1.00%
39	0.50%	1.00%
40	0.50%	1.00%
Total	**100%**	**100%**

Angle Dependence

It was assumed that a Normal distribution would define the angular dependence of crash location around the curvilinear flight path. The characteristics of a Normal distribution are that 68 percent of all values are within one standard deviations on either side of the mean value, and 95 percent are within two standard deviation on either side of the mean value. It is judged that the standard deviation for crash location angle around the curvilinear flight path would be 1.5 degrees for approaching aircraft, and 4.5 degrees for departing aircraft. Thus 95 percent of crash locations were modelled to be within curvilinear cones of six degrees and 18 degrees for approaching and departing aircraft crashes respectively.

It should be noted that these cones apply to curvilinear flight paths, and that many flight paths are widely curved away from the runway extended centreline. Therefore, the modelling in fact distributes crash location at angles much greater than six degrees or 18 degrees with respect to the runway extended centreline.

The angular dependence of crash location was modelled by defining additional 20 kilometre long curvilinear flight paths diverging at the runway threshold from the central flight path at angles of one and two deviation on either side of the central flight path. These flight paths were divided into 40 segments of 500 metres each. The probability distribution assigned to the flight paths is shown on *Table 3.16*.

TABLE 3.16 PROBABILITY DISTRIBUTIONS FOR FLIGHT PATHS

Flight Path	Probability Distribution
Central	50%
1 standard deviation to the left	20%
1 standard deviation to the right	20%
2 standard deviation to the left	5%
2 standard deviation to the right	5%
Total	**100%**

3.5.6 MODELLING DETAILS

A dedicated computer program *Airport Risk* has been used for modelling the probability of crashes at different locations and for risk summation.

The model distributes the probability of an aircraft crashing in over 200 locations defined by the mid points of 40 segments each of the central, and the four side tracks.

The probability of crashing at any particular location is calculated as follows:

Location Crash Probability = Location Crash Probability (Distance Dependence) x Location Crash Probability (Angle Dependence)

The results of this analysis have been combined with the results of other analyses to determine the individual and societal risks.

3.6 CRASH CONSEQUENCE ANALYSIS

3.6.1 INTRODUCTION

This section provides an analysis of the consequences of aircraft crashes. The results of this analysis are integrated with the results of crash frequency analysis and crash location probability distribution analysis to determine the individual and societal risk levels arising from the operation of the Second Sydney Airport in the year 2016.

3.6.2 OVERVIEW OF CONSEQUENCE ANALYSIS

The consequences of an aircraft crash may include harm to people, property or the environment. Those harmed may include aircrew, passengers of the aircraft, or people on the ground. Harm may include injuries or fatalities. The crash may be within the airport perimeter, or on residential, industrial or other types of facilities outside the airport perimeter. People may be harmed directly in an aircraft crash, or as a result of secondary incidents initiated by an aircraft crash.

Analysis provided in this section considers the following types of consequences:

- the only consequences considered are those to members of the public on the ground, ie., to third parties. Consequences for aircrew and passengers is not the subject of this analysis;
- consequences are defined in terms of fatalities. Although consequences may include injuries and damage to property or the environment, the calculation of consequences in terms of fatalities provides, in most cases, sufficient information for decision making; and
- only direct consequences of aircraft crashes are analysed here. Aircraft crashes on specific installations on the ground may initiate secondary incidents. For example, an aircraft crash on a chemical plant may initiate a toxic gas release and people not directly harmed in the crash may be harmed by the secondary incident.

People on the ground may be fatally injured if they are within the area affected by the impact of aircraft parts or collapsing building parts, or the area affected by heat radiation from aircraft fuel fire.

The basic approach to consequence analysis is to estimate the size of impact damage area and the heat radiation damage area within which fatalities may occur. The number of fatalities on the ground is estimated from the size of the effected area and population density at that location.

3.6.3 FACTORS INFLUENCING THE SIZE OF IMPACT DAMAGE AREA

The size of an area affected by the impact damage depends upon a number of factors, the most relevant of which include:

- the size of the aircraft;
- the angle of crash; and
- the strength of buildings impacted upon.

A larger aircraft would obviously have a larger impact damage area, than a smaller aircraft.

Shallow angle crashes generally result in larger impact damage areas than steep angle crashes. Steep angle crashes result in a smaller concentrated impact damage area, although debris may scatter over a large area.

If impacted buildings are strong, the impact damage area would be smaller. For example, the impact damage area would be smaller for a crash onto an apartment block as compared with the impact damage area for a crash onto detached houses.

3.6.4 FACTORS INFLUENCING THE SIZE OF HEAT RADIATION AFFECTED AREA

The two main factors that influence the size of the area affected by heat radiation are:

- the fuel load; and
- the angle of crash.

Higher fuel loads would obviously contribute more to a fire and therefore increase the area affected by heat radiation. Fuel load depends mainly on the size of the aircraft. However, for the same aircraft, the fuel load during approach is typically only 10 percent - 50 percent of that during take-off. Therefore the area affected by heat radiation for crashes during landing is generally smaller than that for crashes during take-off. For large aircraft, the fuel load during take-off could vary significantly, depending upon the distance to its destination (stage length).

For crashes at steep angles, the resulting fire would generally be centred around the central impact point. In the case of shallow crashes, two separate fires could develop, one on either side of the central impact area.

3.6.5 SCENARIOS CONSIDERED

Considering both the impact and heat radiation effects, the main factors that could influence the crash effect area are summarised below:

- aircraft size;
- angle of crash;
- strength of buildings impacted;
- crash mode (landing or take-off);
- distance to destination for large aircraft.

Different combinations of the above factors could result in different consequence scenarios. In this study, all aircraft are categorised as either small, medium or large aircraft. The number of seats is used as the basis for size categorisation as shown on *Table 3.17*.

TABLE 3.17 AIRCRAFT SIZE CATEGORIES

Number of seats	Size Category
< 70	Small
71-180	Medium
>180	Large

An analysis of selected United Kingdom Civil Aviation Authority crash data and the judgement of aviation experts concluded that two impact angles, shallow (7 degrees) and steep (45 degrees) sufficiently represent aircraft crash angles. Both the Schipol and Manchester Airport studies assumed that for departures, crash angles were 'shallow' if the crash occurred in the first 500 metres, and 'steep' thereafter, whereas for approaches, 60 percent of crash angles were 'shallow' and 40 percent were 'steep'. The same is assumed in this study.

In regards to the strength of buildings, it is assumed that all buildings are single detached houses. As noted before, the impact area would be smaller if the crash is on a more robust building such as an apartment block, and therefore, this assumption is conservative.

Landing and take-off crashes are considered separately to account for different fuel loads. Crashes during take-off involving large aircraft are further divided into two categories according to the distance to destination, again to account for the differences in fuel loads. Those with destination stage lengths 5, 6 or 7 are considered to have a higher fuel load.

3.6.6 REPRESENTATIVE AIRCRAFT

Details of aircraft selected to represent the small, medium and large aircraft sizes are shown in *Table 3.18*.

TABLE 3.18 REPRESENTATIVE AIRCRAFT DETAILS

Description	Small	Medium	Large
Aircraft	Fokker F28	Boeing 737-300 / 400	Boeing 747-400
Max. Passengers	60	124/143	420
Wing Span (m)	23.6	28.9	64.44
Length (m)	21.9	33.4/36.5	70.66
Height (m)	8.5	11.13	19.41
Max. Take-off weight (kg)	20,800	56,473/62,820	394,600
Max Fuel Capacity (litres)	5,136	20,104	216,850
Estimated Fuel on landing (tonnes)	0.65	2.2	10.8
Estimated Fuel on take-off (tonnes)	2-4	4-14	28.8
Estimated Fuel on landing: stage lengths 5, 6, 7 (tonnes)	n/a	n/a	155

3.6.7 ESTIMATED EFFECT AREAS

The combined impact and heat radiation effect areas used in the investigation of third party risks at Manchester Airport are shown on *Table 3.19*. The areas shown on the table are scaled such that the probability of fatality within the area is 100 percent. Scaled areas are the mathematical equivalent of a larger effect area over which the probability of fatality is less than 100 percent. For example, a 1,000 square metres effect over which the probability of fatality is 50 percent is scaled to 500 square metres.

TABLE 3.19 SCALED EFFECT AREAS (SQUARE METRES)

Aircraft Size	Take-off		Landing	
	Steep Angle	Shallow Angle	Steep Angle	Shallow Angle
Small	2,100	3,700	2,000	2,600
Medium	6,600	7,800	5,900	6,900
Large	16,700	28,100	16,500	25,800
Large- Increased Fuel Load	21,000	48,400	16,500	25,800

The NLR study (NLR, 1993) reviewed worldwide historical accident data to determine the relationship between the consequences and various causal factors such as those outlined previously. The study found that the relationships between the effect area and the causal factors is not clear enough to be suitable for developing a statistical model. It recommends a simple approach for the estimation of effect area based on just the maximum take-off weight of the aircraft. For crashes in build-up areas, the effect area equals 200 square metres per ton. These numbers hold for aircraft of considerable size (typically larger that 20 ton maximum take-off weight. The average probability of fatality within the effect area is 30 percent. *Table 3.20* shows the scaled effect area using the NLR equation for the three representative aircraft.

TABLE 3.20 SCALED EFFECT AREAS - NLR METHODOLOGY

Size Category	Representative Aircraft	Maximum Take-off Weight (ton)	Scaled Effect Area (m^2)
Small	Fokker F-28	21	1,200
Medium	Boeing 737-300/400	57	3,420
Large	Boeing 747-400	395	23,700

In comparison with the effect areas used in the Manchester investigation, consequence areas calculated using the NLR methodology are smaller for the small and medium size aircraft, but in broad agreement for the large aircraft category. In this study, the effect areas shown on *Table 3.19* are used.

3.6.8 ESTIMATED FATALITIES ON THE GROUND

If an aircraft crashes at a particular location, the number of fatalities on the ground would depend both on the size of the effect area and the population density at that location.

Population densities for each 500 metre square area in the vicinity of each Second Sydney Airport option in the year 2016 were predicted as part of the Draft EIS process. These projections formed an input to the risk analysis Computer Program Airport Risk, which uses the population density at each location for societal risk calculation. Population densities (people per square kilometre) in the study area ranged from 12 to 11,040 for the three Badgerys Creek options, from zero to 12,616 for Holsworthy Option A, and from zero to 19,988 for Holsworthy Option B.

Table 3.21 shows the estimated number of fatalities on the ground calculated for various types of crashes in an area with a population density of 4,000 people per square kilometre.

TABLE 3.21 ESTIMATED NUMBER OF FATALITIES ON THE GROUND (POPULATION DENSITY 4,000 PEOPLE PER SQUARE KILOMETRE)

Aircraft Size	Take-off		Landing	
	Steep Angle	Shallow Angle	Steep Angle	Shallow Angle
Small	8	15	8	10
Medium	26	31	24	28
Large	67	112	66	103
Large- Increased Fuel Load	84	194	66	103

3.6.9 RISK SUMMATION

The results of crash rate analysis, crash location probability distribution analysis, and crash consequence analysis have been integrated together to provide three types of results:

- Crash Frequency Distribution (number of crashes per square kilometre per year) at each location;
- Individual Fatality Risk (probability of fatality per year) at each location; and
- Societal Risk (per year).

These three risk results represent the cumulative effect of all flights over a period of one year. This section explains how the three results are calculated. The results for each Second Sydney Airport option are reported in *Section 3.7*.

3.6.10 RISK SUMMATION

A dedicated computer program *Airport Risk* was used for calculating the three types of results. Essentially, the program models each take-off and landing movement along each track for each aircraft risk category over a period of one year. The number of aircraft movements per year along each track for each aircraft risk category is determined separately, and this forms an input to the model. A study area approximately 45 x 45 kilometres centred around each airport option was defined, and divided into grid squares of 500 x 500 m dimensions.

For each grid square:

Crash Frequency per year = Number of movements per year x Crash Rate per movement x Location Crash Probability

Individual Fatality Risk per year	=	Number of movements per year x crash rate movement x Location Crash Probability x Proportion of grid square within the Scaled Effect Area
Societal Risk	=	Number of movements per year x Crash Rate per movement x Location Crash Probability x Proportion of grid square within the Scaled Effect Area x Population of grid square

Crash Frequency and Individual Risk at each grid square has been added up over all movements along all tracks. Societal risk has been summed up over all grid squares in the study area.

Contours showing the location of nominated levels of crash frequency (per year per square kilometre) have been developed from the results of Crash Frequency modelling.

Similarly, contours showing the location of nominated levels of Individual Fatality Risk (per year) have been developed from the results of Individual Risk modelling.

F-N curves have been developed from the results of Societal Risk modelling, and show the frequency per year (F) of crashes that result in N or more fatal injuries on the ground.

3.7 RISK RESULTS AND ASSESSMENT

All risk results in this section refer to third parties outside the airport boundary. The results are best estimates and it is acknowledged that they would be subject to upper and lower confidence limits. However since all results would be subject to the same confidence limits, they are still useful for the purpose of comparing the airport options.

Risks from aircraft not intending to depart or approach the Second Sydney Airport have not been included in this analysis. This 'background' risk in the study area would be expected to be low.

3.7.1 PREDICTED CRASH FREQUENCIES

Contours which show the probability of an aircraft crash per square kilometre per year in the areas surrounding the various airport options have been produced. These probability contours, which are shown as *Figures 3.2 to 3.6* for the various airport options, are based upon a worst case scenario,

Predicted Maximum Frequency
of Aircraft Crashes per Square Kilometre

$1x10^{-3}$ (1 crash per thousand years)

$1x10^{-4}$ (1 crash per 10 thousand years)

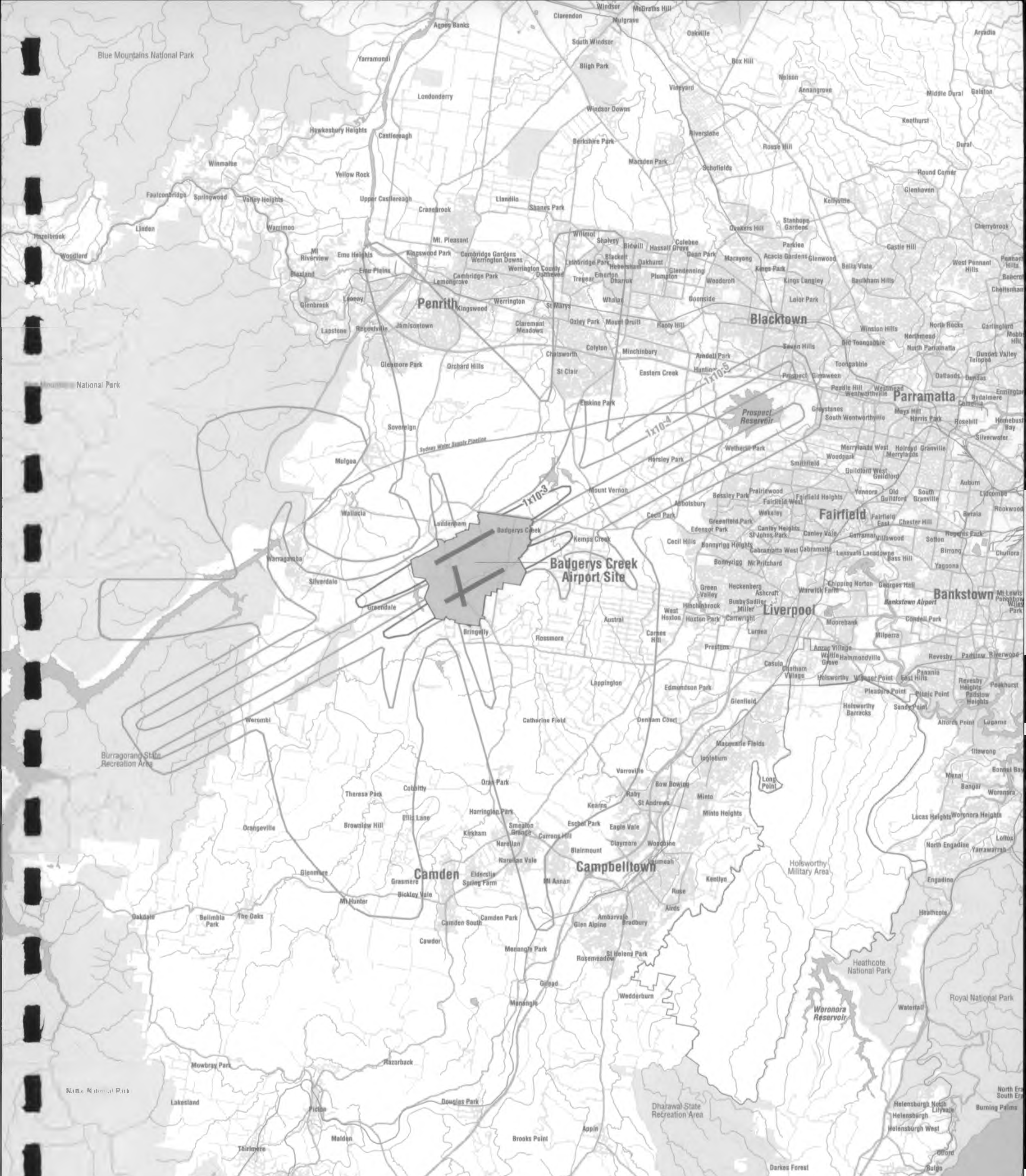
$1x10^{-5}$ (1 crash per 100 thousand years)

Urban Areas (indicated by local roads)

Figure 3.2

Predicted Maximum Frequency of Aircraft Crashes for Badgerys Creek Option A

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 1. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.



Predicted Maximum Frequency of Aircraft Crashes per Square Kilometre

$1x10^{-3}$ (1 crash per thousand years)

$1x10^{-4}$ (1 crash per 10 thousand years)

$1x10^{-5}$ (1 crash per 100 thousand years)

Urban Area (indicated by local roads)

Figure 3.3

Predicted Maximum Frequency of Aircraft Crashes for Badgerys Creek Option B

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 3. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.

0Km 10Km

Predicted Maximum Frequency
of Aircraft Crashes per Square Kilometre

$1x10^{-3}$ (1 crash per thousand years)

$1x10^{-4}$ (1 crash per 10 thousand years)

$1x10^{-5}$ (1 crash per 100 thousand years)

Urban Areas (indicated by local roads)

Figure 3.4

Predicted Maximum Frequency of Aircraft Crashes for Badgerys Creek Option C

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 2. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.

Predicted Maximum Frequency
of Aircraft Crashes per Square Kilometre

$1x10^{-3}$	(1 crash per thousand years)
$1x10^{-4}$	(1 crash per 10 thousand years)
$1x10^{-5}$	(1 crash per 100 thousand years)
	Urban Areas (indicated by local roads)

TN
MN
N
0Km 10Km

Figure 3.5
Predicted Maximum Frequency of Aircraft Crashes for Holsworthy Option A

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 2. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.

Predicted Maximum Frequency
of Aircraft Crashes per Square Kilometre

$1x10^{-3}$ (1 crash per thousand years)
$1x10^{-4}$ (1 crash per 10 thousand years)
$1x10^{-5}$ (1 crash per 100 thousand years)
Urban Area (indicated by local roads)

Figure 3.6
Predicted Maximum Frequency of Aircraft Crashes for Holsworthy Option B

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 2. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.

0Km 10Km

Air Traffic Forecast 3, in the year 2016, and the mode of operation with the highest fatality rate, for each option.

3.7.2 INDIVIDUAL RISK

Badgerys Creek Option A

Figure 3.7 shows the location of contours representing individual fatality risk of 1×10^{-5}, 1×10^{-6} and 1×10^{-7} per year for the mode of operations which has the highest fatality rate (Airport Operation 1). Both modes have been investigated, however the contours are similar. For simplicity, only the worst case (highest fatality rate) is shown in *Figure 3.7*.

The 1×10^{-5} per year individual fatality risk contours enclose areas along runway extended centrelines only. Individuals within these contours are exposed to an individual fatality risk of 1×10^{-5} per year or more. Some scattered farmlands with low population densities are enclosed within these contours. No residential areas with high population densities are enclosed within these contours.

Individuals within the 1×10^{-6} per year individual risk contours are exposed to an individual fatality risk of 1×10^{-6} per year or more. In Airport Operation 1 (preferred landings from the south west and take-offs to the north east) the 1×10^{-6} per year individual risk contours enclose parts of Silverdale towards the west. In Airport Operation 2 (preferred landings from the north east and take-offs to the south west) the contours do not extend as far as Silverdale. Instead they enclose parts of Prospect and Girraween to the North East.

Fatality risks to individuals outside the 1×10^{-6} per year individual risk contours are less than 1×10^{-6} per year.

Badgerys Creek Option B

Figure 3.8 shows the location of contours representing individual fatality risk of 1×10^{-5}, 1×10^{-6} and 1×10^{-7} per year for the modes of operation which has the highest fatality rate (Airport Operation 3). All three modes have been investigated, however only the worst case (highest fatality rate) is shown for simplicity on *Figure 3.8*.

In general, the 1×10^{-5} per year individual risk contours enclose areas along runway extended centrelines only. Individuals within these contours are exposed to an individual fatality risk of 1×10^{-5} per year or more. Some scattered farmlands with low population densities are enclosed within these contours. No residential areas with high population densities are enclosed within these contours.

Individuals within the 1 x 10^{-6} per year individual risk contours are exposed to an individual fatality risk of 1 x 10^{-6} per year or more. In Airport Operation 1 (preferred landings from the South West and take-offs to the North East) the 1 x 10^{-6} per year individual risk contours enclose parts of Silverdale towards the West. In Airport Operation 2 (preferred landings from the North East and take-offs to the South West), the contours do not extend up to Silverdale, instead they enclose parts of Prospect to the North East. In Airport Operation 3 (share the noise scenario) the contours do not extend as far as Prospect to the North East or Silverdale to the West, but parts of Luddenham are enclosed within these contours.

Risk to individuals outside the 1 x 10^{-6} per year individual risk contours are less than 1 x 10^{-6} per year.

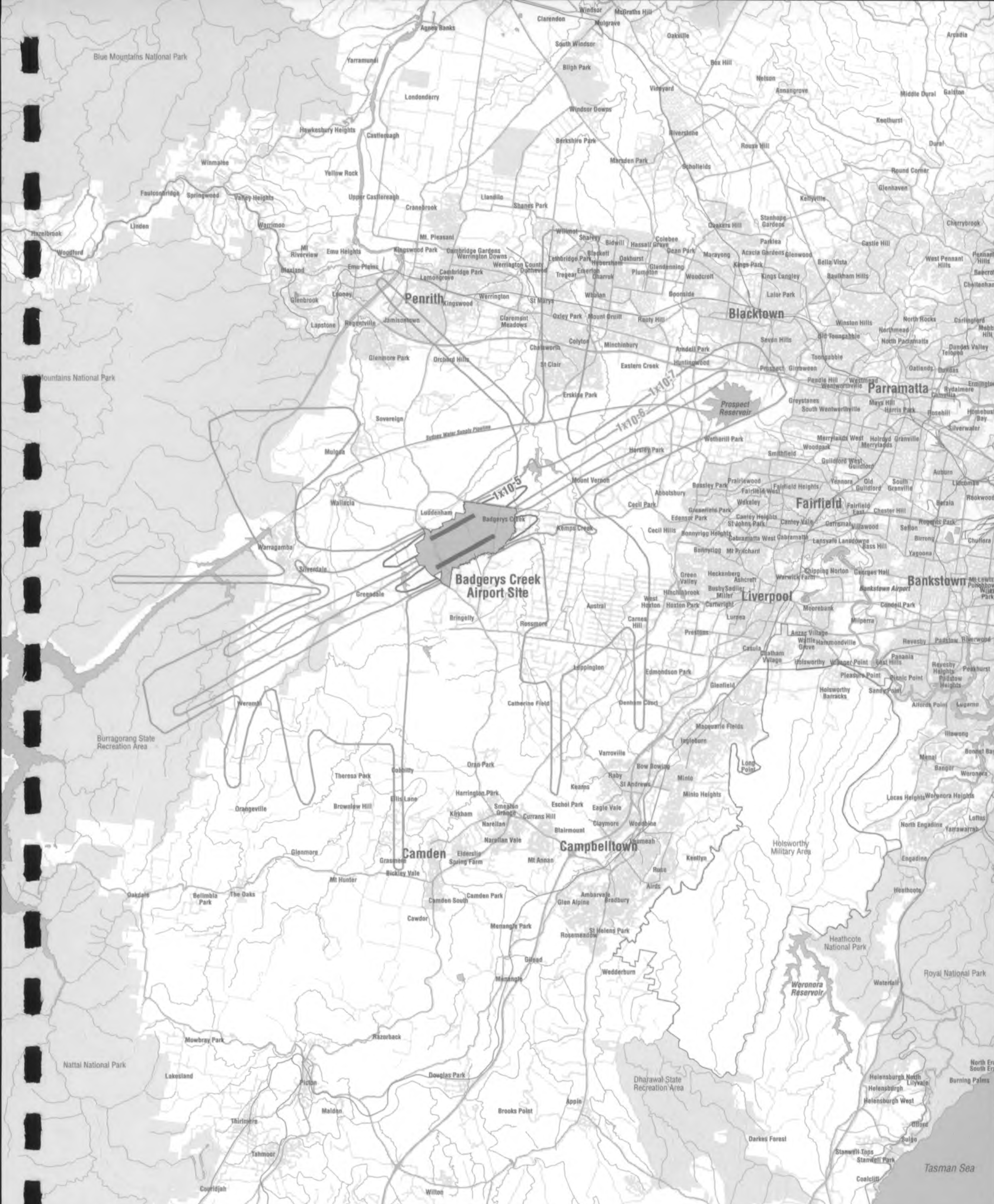
Badgerys Creek Option C

Figure 3.9 shows the location of contours representing individual fatality risk of 1 x 10^{-5}, 1 x 10^{-6} and 1 x 10^{-7} per year for the mode of operations which has the highest fatality rate (Airport Operation 2). All three modes have been investigated but only one mode (the worst case) is shown for simplicity on *Figure 3.9*.

As for Badgerys Creek Option B the 1 x 10^{-5} per year individual risk contours enclose areas along runway extended centrelines only. Individuals within these contours are exposed to an individual fatality risk of 1 x 10^{-5} per year or more. Some scattered farmlands with low population densities are enclosed within these contours. No residential areas with high population densities are enclosed within these contours in any of the three operating modes investigated.

Individuals within the 1 x 10^{-6} per year individual risk contours are exposed to an individual fatality risk of 1 x 10^{-6} per year or more. In Airport Operation 1 (preferred landings from the south and take-offs to the north) the 1 x 10^{-6} per year individual risk contours enclose parts of Camden towards the south. In Airport Operation 2 (preferred landings from the north and take-offs to the south), the contours do not extend far to the south. Instead they enclose parts of Werrington, Werrington County, St Claire, and St Marys to the north. In Airport Operation 3 (share the noise scenario) the 1 x 10^{-6} contours enclose parts of Camden to the south and Werrington, Werrington County, St Claire and St Marys to the north.

Risk to individuals outside the 1 x 10^{-6} per year individual risk contours are less than 1 x 10^{-6} per year.



Risk of Fatality per year due to aircraft crash

$1x10^{-5}$	(10 chances in 1million of a fatality per year due to aircraft crash)	
$1x10^{-6}$	(1 chance in 1 million of a fatality per year due to aircraft crash)	
$1x10^{-7}$	(0.1 chances in 1 million of a fatality per year due to aircraft crash)	
	Urban Areas (indicated by local roads)	

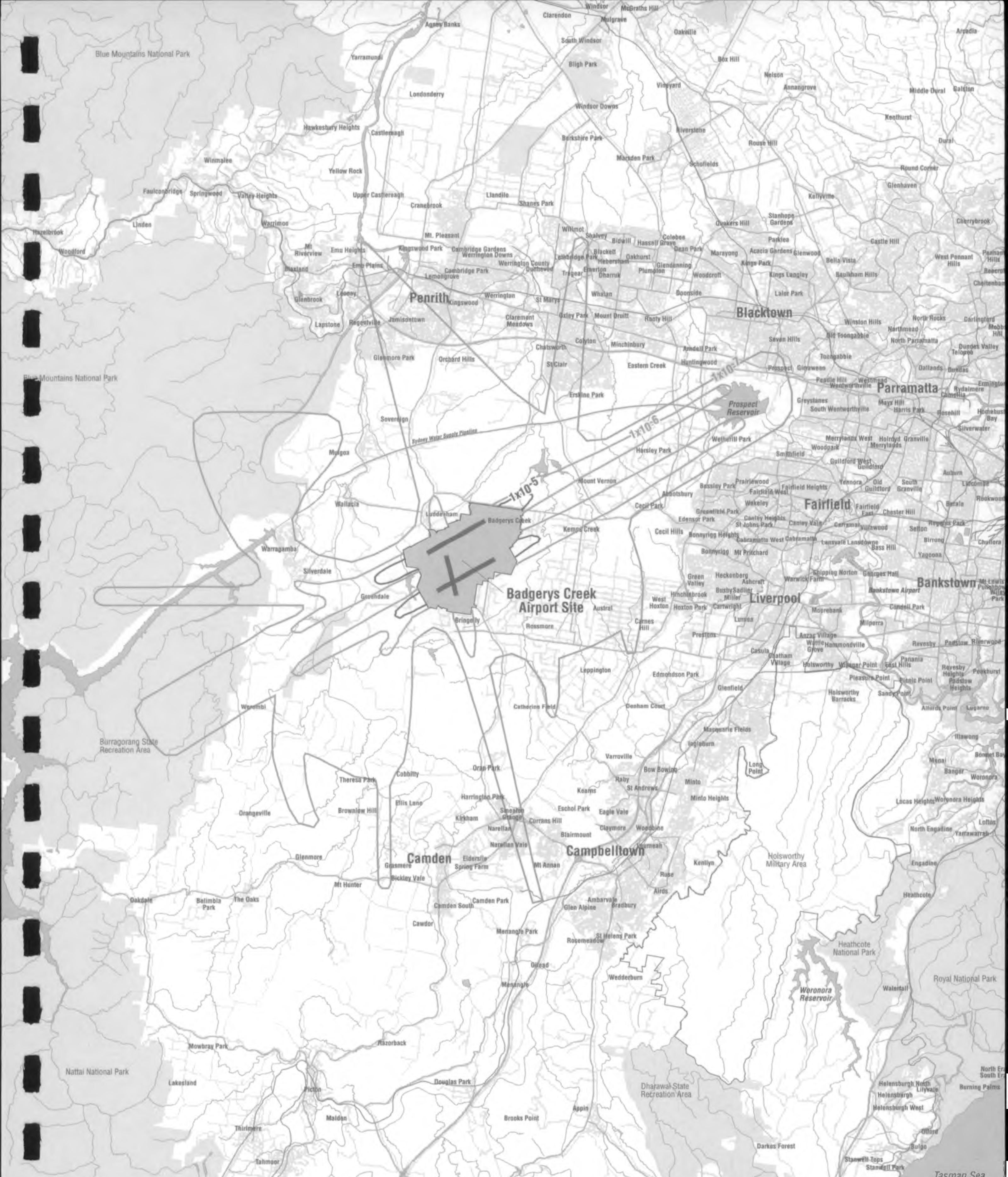
Figure 3.7

Individual Fatality Risk Contours for Badgerys Creek Option A

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 1. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.

TN
MN
N

0Km 10Km



Risk of Fatality per year due to aircraft crash

$1x10^{-5}$	(10 chances in 1million of a fatality per year due to aircraft crash)	
$1x10^{-6}$	(1 chance in 1 million of a fatality per year due to aircraft crash)	
$1x10^{-7}$	(0.1 chances in 1 million of a fatality per year due to aircraft crash)	
	Urban Areas (indicated by local roads)	

Figure 3.8

Individual Fatality Risk Contours for Badgerys Creek Option B

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 3. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.

Risk of Fatality per year due to aircraft crash

1x10-5	(10 chances in 1million of a fatality per year due to aircraft crash)	
1x10-6	(1 chance in 1 million of a fatality per year due to aircraft crash)	
1x10-7	(0.1 chances in 1 million of a fatality per year due to aircraft crash)	
	Urban Areas (indicated by local roads)	

Figure 3.9

Individual Fatality Risk Contours for Badgerys Creek Option C

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 2. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.

TN MN N

0Km 10Km

Holsworthy Option A

Figure 3.10 shows the location of contours representing individual fatality risk of 1 x 10^{-5}, 1 x 10^{-6} and 1 x 10^{-7} per year for the mode of operation with the highest fatality rate (Airport Operation 2). All three modes of operations have been investigated, however only the worst case (highest fatality rate) is shown on *Figure 3.10*.

The 1 x 10^{-5} per year individual risk contours enclose areas along runway extended centrelines only. There are no populated areas within these contours, therefore no individual is exposed to an individual fatality risk of 1 x 10^{-5} per year or more.

Individuals within the 1 x 10^{-6} per year individual risk contours are exposed to an individual fatality risk of 1 x 10^{-6} per year or more. In Airport Operation 1 (preferred landings from the south and take-offs to the north) the 1 x 10^{-6} per year individual risk contours enclose parts of Macquarie Fields towards the west, and parts of Casula, Liverpool, and Cabramatta west towards the north. In Airport Operation 2 (preferred landings from the north and take-offs to the South), the contours extend further north than in Airport Operation 1, to enclose parts of Lurnea, Cartwright, Ashcroft, Mt Pritchard, Greenfield Park and Canley Heights as well. Similarly, the contours in Airport Operation 3 (share the noise scenario) extend further north than in Airport Operation 1, although not as much as in Airport Operation 2.

Risk to individuals outside the 1 x 10^{-6} per year individual risk contours are less than 1 x 10^{-6} per year.

Holsworthy Option B

Figure 3.11 shows the location of contours representing individual fatality risk of 1 x 10^{-5}, 1 x 10^{-6} and 1 x 10^{-7} per year for the mode of operation with the highest fatality rate (Airport Operation 2). All three modes have been investigated, however only the worst case (highest fatality rate) is shown on *Figure 3.11*.

The 1 x 10^{-5} per year individual risk contours enclose areas along runway extended centrelines only. There are no populated areas within these contours, therefore no individual is exposed to an individual fatality risk of 1 x 10^{-5} per year or more.

Individuals within the 1 x 10^{-6} per year individual risk contours are exposed to an individual fatality risk of 1 x 10^{-6} per year or more. In Airport Operation 1 (preferred landings from the south east and take-offs to the North West) the 1 x 10^{-6} per year individual risk contours enclose parts of St Helens Park and Glen Alpine towards the north west, and Helensburg north to the south east. In Airport Operation 2 (preferred landings from the north west and take-offs to the south east), the contours extend further north west than in Airport Operation 1, and also enclose parts of Narellan Vale, Spring Farm, Elderslie and Narellan. The contours in Airport Operation 3 (share the noise scenario) do not extend as far north west as Airport Operation 2, and enclose approximately the same areas as Airport Operation 1.

Risk to individuals outside the 1 x 10^{-6} per year individual risk contours are less than x 10^{-6} per year.

Number of People Within Contours

Table 3.22 summarises the number of people exposed to a level of individual fatality risk of greater than one in a million for the five airport options. These figures were generated by a Geographic Information System (GIS) Procedure which counted the populations enclosed within and between the 1 x 10^{-5} and 1 x 10^{-6} individual fatality risk contours. The populations counted were projected populations which were derived from existing statistical data and planning scenarios outlined in *Technical Paper No. 2*. This assumes the mode of operation that has the highest fatality rate.

TABLE 3.22 NUMBER OF PEOPLE EXPOSED TO A LEVEL OF INDIVIDUAL FATALITY RISK GREATER THAN ONE IN A MILLION

Airport Option	Greater than 1 in a million chance of fatality per year
Badgerys Creek A	2,500
Badgerys Creek B	2,500
Badgerys Creek C	9,000
Holsworthy A	60,000
Holsworthy B	21,000

3.7.3 SOCIETAL RISK

Fatality Rate

One of the measures of societal risk is the fatality rate. It is the 'expected' number of fatalities on the ground per year. Risk from a single incident is the incident frequency, multiplied by the number of fatalities on the ground in that incident. Fatality rate is the aggregate risk from all incidents. *Table 3.23* shows the fatality rates for the five airport options in the modes of operations investigated per 100 years of operation.

Risk of Fatality per year due to aircraft crash

(10 chances in 1million of a fatality per year due to aircraft crash)

(1 chance in 1 million of a fatality per year due to aircraft crash)

1x10⁻⁷ (0.1 chances in 1 million of a fatality per year due to aircraft crash)

Urban Areas (indicated by local roads)

Figure 3.10

Individual Fatality Risk Contours for Holsworthy Option A

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 2. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.

TN MN N

0Km 10Km

Risk of Fatality per year due to aircraft crash

$1x10^{-5}$	(10 chances in 1million of a fatality per year due to aircraft crash)	
$1x10^{-6}$	(1 chance in 1 million of a fatality per year due to aircraft crash)	
$1x10^{-7}$	(0.1 chances in 1 million of a fatality per year due to aircraft crash)	
	Urban Areas (indicated by local roads)	

Figure 3.11

Individual Fatality Risk Contours for Holsworthy Option B

Note: Based on Air Traffic Forecast 3 in 2016 and Airport Operation 2. This type of operation would have the highest overall risk of fatality. Other airport operations have different risk profiles.

TN MN N

0Km 10Km

TABLE 3.23 FATALITY RATE (PERSONS PER 100 YEARS)

Airport Option	Airport Operation 1	Airport Operation 2	Airport Operation 3
Badgerys Creek A	2.5	1.8	n/a
Badgerys Creek B	2	1.5	2.2
Badgerys Creek C	4	5	4.6
Holsworthy A	7.1	12.9	9
Holsworthy B	5	6.4	5.5

Incident Severity

Figure 3.12 shows the relationship between frequency, F, and potential number of fatalities on the ground, N, from aircraft crashes in the vicinity of the five airport options, in the mode of operation that has the highest fatality rate.

The F-N curves for the Badgerys Creek options indicate that the frequency of one or more fatalities is between 6.85×10^{-3} per year (ie., about 1 in 146 chance per year) and 2.07×10^{-2} (ie., about 1 in 48 chance per year). The frequency reduces by more than 94 percent for incidents resulting in 10 or more fatalities, and by more than 99.9 percent for incidents resulting in 100 or more fatalities.

For the Holsworthy options, the frequency of one or more fatalities is between 6.87×10^{-3} per year (ie., about 1 in 145 chance per year) and 1.02×10^{-2} per year (that is, about 1 in 98 chance per year). The frequency reduces by more than 65 percent for incidents resulting in 10 or more fatalities, and by more than 99.8 percent for incidents resulting in 100 or more fatalities.

Table 3.24 shows the frequency, F, of incidents resulting in specified number N, or more fatalities on the ground for the five airport options, in the mode of operation that has the highest fatality rate. This corresponds with the curves shown on *Figure 3.12*.

TABLE 3.24 FREQUENCY OF INCIDENTS

No of Fatalities, or more	Frequency of Incidents ($\times 10^{-4}$ per year) Badgerys Creek A	Badgerys Creek B	Badgerys Creek C	Holsworthy A	Holsworthy B
1	83	68	207	102	69
10	2.8	3.2	4.8	35	16
50	0.44	0.40	0.73	6.2	2.4
100	0.028	0.045	0.03	1.6	0.68

3.8 RISK MITIGATION

3.8.1 INTRODUCTION

The risk of an aircraft crash on a developed area could be mitigated by adopting appropriate measures during the planning, design, and operational stages of the project. Some of the options for risk mitigation are outlined below. In addition, normal risk mitigating measures, such as safety standards, and regulations are outlined.

3.8.2 SELECTION OF OPTION

The main decision to be made at the planning stage is the selection of an airport option. This risk assessment provides sufficient information to compare the risk impacts of the five airport options. A risk mitigation measure would therefore be to give preference to options with relatively low risk impact. An approximate ranking of options on the basis of fatality rates, from lowest to highest is as follows:

1. Badgerys Creek Option B (lowest minimum fatality rate).
2. Badgerys Creek Option A.
3. Badgerys Creek Option C.
4. Holsworthy Option B.
5. Holsworthy Option A (highest maximum fatality rate).

3.8.3 SCALE OF DEVELOPMENT

For an identical fleet mix, the risk of an aircraft crash varies in direct proportion to the annual number of aircraft movements at the airport. Therefore, a reduction in total annual traffic movements would result in a similar reduction in risk. The full quantitative risk analysis in this study is based on Air Traffic Forecast 3, which gives the worst-case risk impact. Risk in Air Traffic Forecast 1 would be relatively lower. Therefore, a possible risk mitigation option would be to restrict the scale of the airport to Air Traffic Forecast 1.

3.8.4 SAFETY STANDARDS AND REGULATIONS

The International Civil Aviation Organisation has set certain minimum standards for the world aviation industry. There are International Standards, Recommended Practices and Procedures covering the following technical fields of aviation: licensing of personnel, rules of the air, aeronautical meteorology, aeronautical charts, units of measurements, operation of aircraft, nationality and registration marks, airworthiness, aeronautical

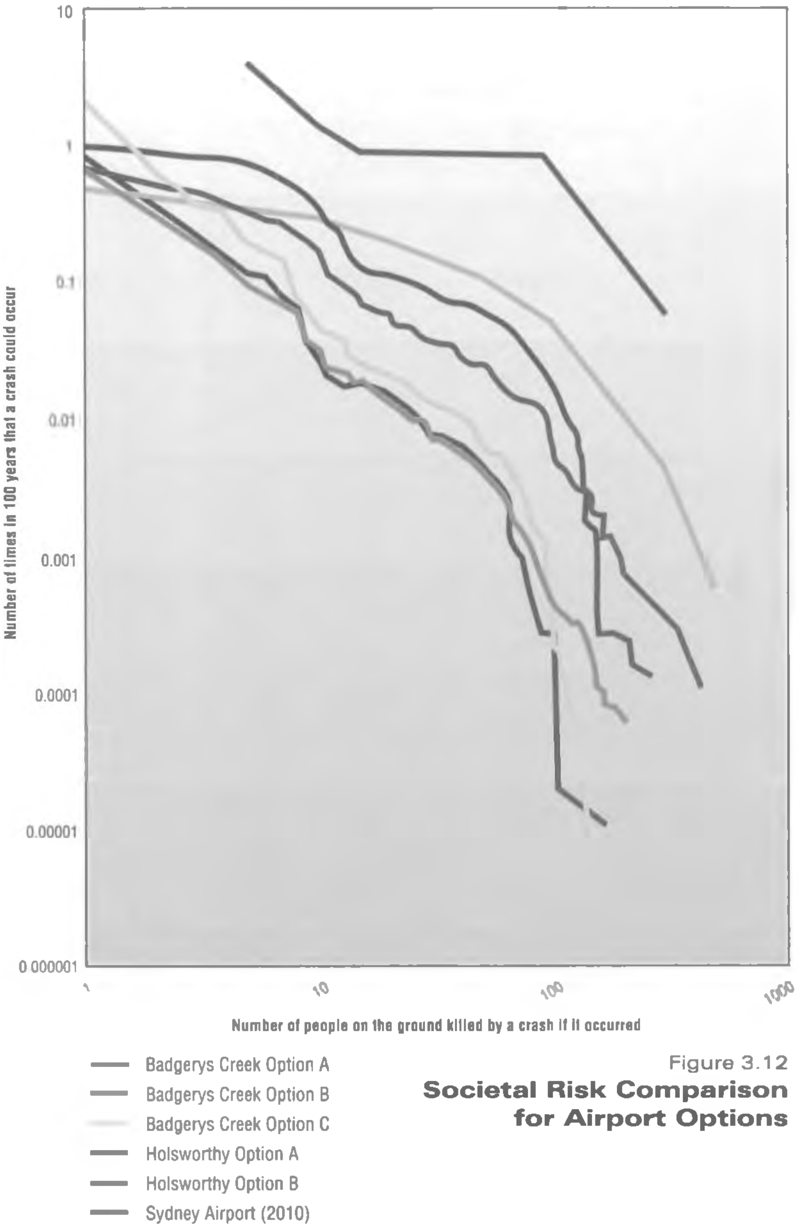


Figure 3.12

Societal Risk Comparison for Airport Options

telecommunications, air traffic services, search and rescue, aircraft accident investigation, aerodromes, aeronautical information services, aircraft noise and engine emission, security and the safe transport of dangerous goods.

The Civil Aviation Safety Authority is responsible for regulating the safety of civil aviation in Australia. One of its stated principles is the adoption of international standards and practices as a starting point for legislation and process development, and modification only where unique Australian context warrants. The Authority is currently rewriting all the civil aviation safety regulations in Australia, under its Regulatory Framework Program. The draft criteria for the development of new regulations include a focus on safety, and adoption of a 'systems' approach. The Authority is also undertaking a review of its role under its Regulatory Role Program.

3.8.5 SAFETY MANAGEMENT SYSTEM

A safety management system is a comprehensive, integrated and formalised approach to safety management through all levels of an organisation. It explicitly demonstrates how safety is managed in an organisation. It covers a wide range of topics, including:

- safety policies and objectives;
- organisation reporting structures, roles and responsibilities for safety;
- management of risk through identification of hazards, and assessment and management of risk;
- methods of employee participation in safety;
- employee selection, competency, training and induction;
- integration of support services organisations in safety management;
- safe operational procedures designed to ensure safety in normal and abnormal circumstances;
- systems for maintenance, modification and inspection;
- systems for managing change to ensure safety;
- emergency response procedures;
- accident reporting, investigation, corrective and follow-up action; and
- safety monitoring and auditing.

Safety management systems should be developed and implemented by all organisations operating aircraft or other providing air traffic and other support services.

3.8.6 MODES OF OPERATION AND FLIGHT PATHS

Operational measures could be adopted to further mitigate the risk of an aircraft crash at specific locations. Quantitative risk analysis shows that areas exposed to individual fatality risk levels greater than 1×10^{-6} per year are different under different mode of operations at each airport option. One of the risk mitigating measures would therefore be to select the mode of operation that minimises the total residential area enclosed within the 1×10^{-6} per year individual risk contours. Individual as well as societal risk could be mitigated further by more detailed planning of flight paths to minimise concentrated movements over densely populated areas in close proximity of the airport. Complex flight paths to avoid populated areas at longer distances from the airport would however not be very effective in reducing the risk.

3.8.7 LAND USE SAFETY PLANNING

For development proposals in the vicinity of the selected airport option, there would be a need to consider the compatibility of each development proposal with the risk level at the proposed location.

Individual risk contours developed as part of this study show the risk levels at different locations around each airport option. Individual fatality risk criteria for various land uses have been suggested by the new South Wales Department of Urban Affairs and Planning (1990). The compatibility of a development proposal at a particular location should be assessed by comparing the risk levels at the location with the acceptable risk criteria for that type of land use.

There would generally be no constraint to any type of development outside the 1×10^{-7} per year individual risk contours.

In the region between the 1×10^{-7} per year and 1×10^{-6} per year individual risk contours, there would generally be no constraint to any type of development except for sensitive developments, such as schools, hospitals, child-care facilities and old age homes. If sensitive developments are to be located in this region, then they should be located as far away as possible from the 1×10^{-6} per year contours, and as close as possible to the 1×10^{-7} per year contours, ie., where risk levels are below 0.5×10^{-6} per year. In order to mitigate societal risks, population density in this region should also not increase significantly. Therefore consideration should be given to not locating high density residential, hotel or motel developments within this region.

Sensitive, residential, hotel and motel developments should not be located in the region between 1 x 10^{-6} per year and 1 x 10^{-5} per year individual risk contours. Commercial developments including retail centres, offices and entertainment centres could be located away from the 1 x 10^{-5} per year contour and closer to the 1 x 10^{-6} per year contour, ie., where risk levels are below 5 x 10^{-6} per year. There should be no constraints to sporting complex and industrial developments in this region.

Only industrial land use is compatible in the region within the 1 x 10^{-5} per year individual risk contours.

4 AIRCRAFT CRASHES INTO LUCAS HEIGHTS SCIENCE AND TECHNOLOGY CENTRE

4.1 METHODOLOGY

4.1.1 AIMS

The sites for the two Holsworthy options are located near the Lucas Heights Science and Technology Centre, where the Australian Nuclear Science and Technology Organisation operates HIFAR (the High Flux Australian Reactor) and other nuclear facilities. For the Holsworthy options, the aim of this part of the study is to discuss the safety and risk implications of flight paths over the Lucas Heights Science and Technology Centre, including implications for existing airspace restrictions.

4.1.2 SCOPE OF WORK

Existing Environment

A brief description of existing hazards and risks to communities in the vicinity of the Lucas Heights Science and Technology Centre is provided, and existing land use and airspace constraints are identified. The consequence and frequency of aircraft crashes on the HIFAR from existing air traffic is analysed and assessed.

The Nuclear Safety Bureau has drafted its policy for off-site health risk from reactor accidents and the siting of nuclear facilities. The criteria for assessment of off-site health risk suggested in the policy are outlined.

Impact Assessment

Airport Options

The two Holsworthy options are located at different sites and therefore the risk implications of the two options are different. Specific safety and risk assessments have been undertaken for each of the two Holsworthy options.

Air Traffic Scenarios Considered

Section 3.1.2 describes the three possible air traffic forecast scenarios considered in the EIS process. Preliminary analysis of all three forecasts, for the year 2016, is outlined in *Section 3.3*. This analysis shows that Air Traffic Forecast 3 would present a relatively higher risk impact than the other two forecasts. Therefore, detailed quantitative risk assessments were undertaken for Air Traffic Forecast 3, in the year 2016 only, which represent the worst case impacts.

Airport Modes of Operation Considered

The likely pattern of runway usage at the airport, in terms of operating modes and preferred runways, has not been decided at this stage. For year 2016, the risk associated with three possible modes are investigated. These operating modes are as described in *Section 3.1.2*.

Risk Assessment

The proposed air traffic operations at the two Holsworthy options are described, and hazards and risks to the Lucas Heights Science and Technology Centre from aircraft crashes are analysed and assessed. Both the likelihood of aircraft crashes on HIFAR, and the off-site health consequences of such an accident, are analysed. The public health risks are assessed against the Nuclear Safety Bureau's risk criteria for nuclear facilities.

Environmental Management

Measures that could mitigate the hazard and risk of an aircraft crash on the nuclear facility are outlined.

4.1.3 INFORMATION SOURCES

Existing Environment

Information on potential sources of hazards at the Lucas Heights Science and technology Centre was provided by the Australian Science and Technology Organisation and the Nuclear Safety Bureau.

Off-site health consequences of accidents at HIFAR and the acceptability of its siting have been assessed by the Nuclear Safety Bureau (NSB, 1995).

Data on annual air traffic movements in the vicinity of the Lucas Heights Science and Technology Centre was provided by Airservices Australia (Airservices, 1996).

Impact Assessment

Information on air traffic forecasts and air traffic corridors for the Second Sydney Airport Holsworthy options was provided by Second Sydney Airport Planners (1997d).

Information on public heath consequences of a large aircraft crash at the facilities was provided by the Australian Nuclear Science and Technology Organisation (1997).

4.1.4 CONSULTATIONS

Discussions were held with Airservices Australia regarding proposed flight paths, air traffic operations and airspace restrictions over the Lucas Heights Science and Technology Centre.

The proposed air traffic operations at the two Holsworthy options were discussed with the Australian Nuclear Science and Technology Organisation and the Nuclear Safety Bureau.

Nuclear Safety Bureau was consulted for guidance on criteria for the likelihood of aircraft crash on HIFAR, and the off-site health consequences of such an accident.

4.2 EXISTING ENVIRONMENT

4.2.1 DESCRIPTION OF FACILITIES

There are a number of facilities at the Lucas Heights Science and Technology Centre with the potential for off-site consequences. These include the HIFAR research reactor, fuel storage areas and radio-pharmaceutical production activities. Of these facilities, the major off-site effect from an aircraft crash would come from a crash into the research reactor. Because of the physical separation of the buildings, there are few circumstances where simultaneous release might occur. Even if a crash occurred which simultaneously affected several adjoining facilities, the consequences would not be more than a factor of two greater than those calculated in the following sections.

4.2.2 EXISTING SAFEGUARDS

The defence against health risks to the public from accidents at a nuclear reactor are dependent upon the design and engineering systems adopted, and the location of the reactor. The defence-in-depth approach adopted by the Australian Nuclear Science and Technology Organisation provides multiple layers of barriers such that as the protection provided by each safety feature is challenged in an accident, there will be a further safety feature to provide protection to the public. An exclusion zone of 1.6 kilometre, centred around the HIFAR reactor has been defined within which permanent residential development is not permitted. This exclusion zone provides a defence against risks to the public when all engineered safety features have been degraded.

4.2.3 CONSEQUENCES OF A LARGE AIRCRAFT CRASH

The Australian Nuclear Science and Technology Organisation (1997) has estimated the consequences of a large aircraft crash on HIFAR and other facilities on site. The analysis has estimated the consequences for a statistical sample of weather conditions derived from meteorological data collected at Lucas Heights during 1994 and 1995.

The analysis indicates that off-site evacuation, administration of stable iodine or sheltering would not be considered necessary following a large aircraft crash on HIFAR in 99 percent of weather conditions. Countermeasures would only have to be taken if the crash occurred during particularly calm and stable weather conditions.

In such an event, the main countermeasure which could be required would be sheltering. Some intervention to prevent consumption of food produced on land near the site could also be required. An increase in the incidence of cancer could also occur within 25 kilometres of the Lucas Heights Science and Technology Centre.

The consequences of a crash on other facilities on site have also been evaluated. Results indicate that the consequences are less severe than the consequences of a crash on the Reactor Containment Building.

4.2.4 LIKELIHOOD OF A LARGE AIRCRAFT CRASH

Historical data show that a majority of accidents occurred during final approach, landing, takeoff and initial climb phases of a flight. Aircraft are closer to an airport during these flight phases, and for this reason a majority of aircraft crashes occurred on or closer to airports than at larger distance from airports.

Sydney Airport is 19 kilometres north-east of Lucas Heights. Aircraft to and from the Sydney Airport are not expected to be in the final approach or initial climb phases at such distances. Therefore accidents associated with these flight phases would not contribute significantly to the frequency of aircraft crash at the Lucas Heights facilities.

Aircraft operating from the Bankstown Airport, which is 13 kilometre north of Lucas Heights are mainly light General Aviation Aircraft. Therefore operations at Bankstown Airport would not be expected to contribute significantly to the frequency of large aircraft crashes at Lucas Heights.

Although aircraft are restricted from flying within one nautical mile of HIFAR below an altitude of 2,000 feet, Lucas Heights lies under one of the main flight paths into and out of Sydney Airport. Radar tracks indicate that about 2,500 jets flew through a 10 kilometre x 10 kilometre box centred on the reactor in the month of November, 1996 (Airservices Australia, 1996). There were no non-jet aircraft overflights in the area. On that basis, it is estimated that about 30,000 flights use this 14 kilometre wide flight path each year. For the purpose of analysis, 95 percent of these flights have been assumed to be Air Transport operations, with General Aviation making up less than 5 percent of the total traffic. This flight path would be the most dominant contributor to the total frequency of aircraft crashes at Lucas Heights.

The frequency of aircraft crash on HIFAR due to the existing flight path is calculated using the relationship below (NRC, 1981):

Crash Frequency per year on HIFAR = Number of movements per year x En-route Crash Rate per kilometre x Effective area of the plant in square kilometre x Width of the flight path in kilometre.

Table 4.1 shows the relevant accident and operation data for Air Transport during the years 1985 to 1995.

TABLE 4.1 AIR TRANSPORT - ACCIDENT AND OPERATION DATA 1985 - 1995

Year	Fatal Accidents	Fatalities	Aircraft Destroyed	Hours Flown (1,000's)
1985	1	1	2	496
1986	0	0	0	521
1987	0	0	0	558
1988	1	3	1	605
1989	0	0	0	556
1990	0	0	0	617
1991	0	0	0	696
1992	0	0	0	751
1993	1	7	2	791
1994	0	0	0	867
1995	1	2	1	686

Notes:
1. Source: Private communication with BASI.
2. Accident data for 1994 and 1995 are preliminary.

None of the fatal accidents or aircraft destroyed involved aircraft with more than 38 seats. Two fatal accidents occurred during final approach, one during initial climb, and one en-route. Six aircraft were destroyed between 1985 and 1995. Four destroyed aircraft are accounted for in the four fatal accidents discussed above. Two aircraft were destroyed when they crashed but no fatalities occurred within 30 days of the crash. Both crashes occurred soon after take-off. Thus, one aircraft crashed en-route over a total of 7,159,900 hours of operations. This gives an en-route crash rate of 0.014 per 100,000 hours.

Assuming an average speed of 480 kilometre per hour, the overall en-route crash rate for Air Transport aircraft in Australia is calculated as 2.92×10^{-10} per kilometre travelled.

Table 3.7 (in the Quantitative Risk Assessment Section) shows the relevant accident and operation data for General Aviation operations in Australia from 1981-1995.

Additional details of General Aviation fatal accidents were obtained from the Bureau of Air Safety Investigation. *Table 3.8* shows the flight phase in which these accidents occurred, and *Table 3.9* shows the location of the accident in relation to the airport, for the years 1981-1990. Flight phase and location details of fatal accidents after 1990 are not available.

The objective of this analysis is to determine the historical en-route crash rate for General Aviation aircraft.

There were 148 in-flight fatal accidents during the years 1981 to 1990, of which 75 occurred while undertaking the types of activities not expected around Lucas Heights, such as agricultural flying, low flying or aerobatics. Therefore, these 75 fatal accidents have been excluded from the 148 fatal accidents for the calculation of en-route fatal accident rate.

According to *Table 3.7*, almost twice the number of aircraft were destroyed during the same period. Data show that the distribution of location of destroyed aircraft is similar to that of fatal accidents. It has been assumed that these aircraft were destroyed because they crashed. Thus, the number of General Aviation aircraft that crashed en-route has been estimated to be 135 (=(148-75) x 1.84). General Aviation operations occurred during 1981-1991 for a total of 18,265,800 hours. On that basis, the historical General Aviation en-route crash rate is estimated to be 0.739 per 100,000 hours.

Assuming an average speed of 240 kilometres per hour, the en-route crash rate for General Aviation aircraft in the vicinity of Lucas Heights has been calculated to be 3.08×10^{-8} per kilometre travelled.

The effective target area presented by the reactor containment building is its roof area plus the shadow area. The reactor containment building is approximately 21 metres in diameter (d) and 21 metres high (h). The roof area is approximately 360 square metres. The shadow area is calculated using the relationship $(h \times d) / \tan(\theta)$, where θ is crash angle of the aircraft. For low angle crashes, the shadow area is relatively large. However, shallow angle crashes are associated with final approach and landing phases, rather than the en-route phase. For this analysis, a crash angle of 30 degrees has been assumed. This is a conservative assumption for en-route crashes. On this basis, the effective target area for the reactor containment building has been calculated to be 1.15×10^{-3} square kilometre.

The crash frequency on the Reactor Containment Building of Air Transport aircraft using the airway has been calculated using the relationship outlined previously:

$30{,}000 \times (0.95 \times 2.92 \times 10^{-10}) \times 1.15 \times 10^{-3} / 14.14 = 6.77 \times 10^{-10}$ per year.

The existing crash frequency of large aircraft would be less than 6.77×10^{-10} per year, since the Air Transport category includes aircraft of all sizes, including those with less than 38 seats.

The existing crash frequency on the Reactor Containment Building of General Aviation aircraft using the flight path has been calculated to be:

$30{,}000 \times (0.05 \times 3.08 \times 10^{-8}) \times 1.15 \times 10^{-3} / 14.14 = 3.76 \times 10^{-9}$ per year.

The total existing crash frequency on the Reactor Containment Building of all aircraft using the flight path has been calculated to be 4.44×10^{-9} per year.

4.2.5 EXISTING AIRSPACE AND LAND USE CONSTRAINTS

The airspace to a radius of one nautical mile centred around the HIFAR and below a height of 2000 feet above sea level is a permanent restricted flying zone. An exclusion zone of 1.6 kilometre, centred around the HIFAR reactor has been defined within which permanent residential development is not permitted.

4.3 IMPACTS OF HOLSWORTHY OPTION A

4.3.1 PROPOSED FLIGHT PATHS

The parallel runways for Holsworthy Option A are located west of the Lucas Heights Science and Technology Centre, and are orientated in a near north-south (158 degrees/338 degrees) direction. This location and orientation of the parallel runways avoids the need for flight paths over the Lucas Heights Science and Technology Centre. The cross wind runway is located south of the Lucas Heights Science and Technology Centre and oriented in an east-west direction (088 degrees/268 degrees). The location and orientation of he cross wind runway also avoids the need for flight paths over the Lucas Heights Science and Technology Centre.

Arrival and departure flight tracks have not been finalised at this stage, however, a set of arrival and departure tracks were defined for each airport option in discussion with Airservices Australia to enable noise impact studies to be undertaken.

None of the arrival or departure tracks pass over or within one nautical mile of HIFAR, and therefore, the removal of existing airspace restrictions over the Lucas Heights Science and Technology Centre is not proposed.

4.3.2 HAZARDS AND RISKS IDENTIFIED

Both the airport, as well as the nuclear facilities at Lucas Heights, could be sources of risks to one another. The interaction between the two facilities could be a source of risk to the surrounding communities. Therefore the following types of risks are considered relevant for consideration:

- risk to people at the airport from accidents at the nuclear facilities at Lucas Heights;
- risk to surrounding communities, including people at the airport, from an aircraft crash on the nuclear facilities at Lucas Heights.

These risks are discussed in the following sections.

4.3.3 RISK ASSESSMENT

Accidents at the Lucas Heights Science and Technology Centre

Accidents at the Lucas Heights Science and Technology Centre could be initiated either due to internal or external initiating events. The frequency of internal and external initiating events, except aircraft crashes, is not expected to increase as a result of construction and operation of an airport at the site of Holsworthy Option A.

No part of the airport at Holsworthy Option A is located within the 1.6 kilometre radius exclusion zone centred around HIFAR. The terminal and apron area, where people would be concentrated, are not located within 2.5 kilometres of HIFAR.

The low frequency of accidents at HIFAR indicates that risks to people at the airport from accidents at HIFAR would be low.

Aircraft Crashes at the Lucas Heights Science and Technology Centre

Potential consequences of a large aircraft crash on HIFAR are discussed in *Section 4.2.3*. Calculations undertaken by the Australian Nuclear Science and Technology Organisation (1997) indicate that following a large aircraft crash on HIFAR, off-site evacuation, sheltering or administering stable iodine would not be considered necessary in 99 percent of weather conditions.

The likely incidence of an aircraft from Holsworthy Option A crashing into the Reactor Containment Building is discussed below.

For aircraft departing from parallel runways 34L and 34R, the location of HIFAR is almost 90 degrees with respect to runway centrelines. Similarly, for aircraft departing on the cross runway 27, the location of HIFAR is almost 90 degrees with respect to runway centreline. Thus, the probability of a crash at such angles is very low.

Figure 3.5 shows contours for the frequency of aircraft crash per square kilometre per year for Airport Operation 2, the mode with the highest fatality rate. No part of the Lucas Heights Science and Technology Centre is enclosed within the 1×10^{-6} crash per square kilometre per year contour in any of the three operating modes investigated.

These contours have been developed by taking into account the annual number of aircraft movements and the actual arrival and departure flight paths. The assumptions and basis for the development of these contours is explained in *Sections 3.4* and *3.5*. This frequency refers to all aircraft, including small regional airlines and General Aviation aircraft.

Although these contours indicate that the frequency of aircraft crash at the Lucas Heights Science and Technology Centre would be less than 1×10^{-6} per square kilometre per year, for the calculation of crash frequency on the reactor containment building below, it is conservatively assumed that the crash frequency at the Lucas Heights Science and Technology Centre would be 1×10^{-6} per square kilometres per year.

In *Section 4.2.4*, the effective target area presented by the reactor containment building to an aircraft crashing at a 30 degree angle was calculated as 1.15×10^{-3} square kilometres. In the vicinity of an airport, a significant proportion of crashes could be at shallow angles. For calculations below, it is assumed that an aircraft would crash at a shallow angle of 7 degrees on the reactor containment building. Buildings present a larger target area when the crash angle is shallow, and therefore, the assumption of a shallow angle would predict a larger target area, and therefore a higher probability of crash on the Reactor Containment Building.

At seven degree crash angles, the effective target area presented by the reactor containment building is estimated to be 4.07×10^{-3} square kilometres.

The frequency of aircraft crashes on the reactor containment building, calculated by multiplying the crash frequency per square kilometre per year by the effective target area, is estimated to be 4.07×10^{-9} per year. This crash frequency includes aircraft of all sizes. Analysis of data contained in Section 3.3 indicates that Air Transport operations, that is, all operations other than General Aviation, would account for about 44 per cent of the total frequency of aircraft crashes in the vicinity of the Second Sydney Airport, for Air Traffic Forecast 3. Therefore the crash frequency on the Reactor Containment Building of Air Transport aircraft operating from Holsworthy Option A is calculated to be 1.77×10^{-9} per year.

The crash frequency on the Reactor Containment Building of large aircraft operating from Holsworthy Option A would be less than 1.77×10^{-9} per year, since Air Transport includes aircraft of all sizes, including those with less than 38 seats.

In *Section 4.2.4*, the crash frequency on the Reactor Containment Building of large aircraft using the existing flight path to and from Sydney Airport was calculated to be less than 6.77×10^{-10} per year. This flight path would not be likely to operate when operations at Holsworthy Option A commence. However, even if this flight path were to remain as it is now, the total crash frequency on the Reactor Containment Building of large aircraft, which is calculated by adding the crash frequency of aircraft using the flight path to the Sydney Airport and operating from Holsworthy Option A, would be less than 2.45×10^{-9} per year.

The effective radiation dose to a member of the public at the exclusion zone boundary following a large aircraft crash on HIFAR is estimated to be less that 8.13 millisievert for 99 percent of weather conditions. Doses at further distances would be lower. Such an exposure would occur only in a certain combination of circumstances, the frequency per year of which can be estimated by multiplying the following:

- frequency per year of a large aircraft crash on HIFAR;
- probability of core damage following a crash; and
- probability of stable weather conditions with low wind speed at the time of the crash. These conditions do not promote horizontal atmospheric dispersion of radiation, and are very unlikely.

The last two conditional probabilities are less than one, and the frequency of large aircraft crash would be less than 2.45×10^{-9} per year. Therefore the frequency of a member of the public receiving a radiation dose of 8.13 millisievert would be less than 2.45×10^{-9} per year. This frequency is much lower than the basic dose objective set by the Nuclear Safety Bureau for exposure to a higher maximum effective dose of 50 millisievert.

4.3.4 SOCIAL AND ECONOMIC CONSEQUENCES

It should be noted that both Nuclear Safety Bureau's policy as well as this risk assessment address only the health effects of accidents. Based on experience of past accidents that have occurred at nuclear reactors, the social and economic consequences of such accidents overshadow the effects on public health. Estimates by the Nuclear Safety Bureau (1990) indicate that an accident at HIFAR involving release of radioactive materials to the environment is likely to result in more serious consequences than those associated with heath effects alone. The social and economic consequences have not been considered here, however they would almost certainly be the most significant impact of an accident at HIFAR.

4.4 IMPACTS OF HOLSWORTHY OPTION B

4.4.1 PROPOSED FLIGHT PATHS

The site for Holsworthy Option B is located about 10 kilometres south-west of the Lucas Heights Science and Technology Centre. The location and orientation of the parallel runways (105 degrees/285 degrees) avoids the need for flight paths over the Lucas Heights Science and Technology Centre. Similarly, the location and orientation of the cross wind runway (164 degrees/344 degrees) also avoids the need for flight paths over the Lucas Heights Science and Technology Centre.

Arrival and departure flight tracks have not been finalised at this stage, however, a set of arrival and departure tracks were defined for each airport option in discussion with Airservices Australia to enable noise impact studies to be undertaken.

None of the arrival or departure tracks pass over or within one nautical mile of HIFAR, and therefore, the removal of existing airspace restrictions over the Lucas Heights Science and Technology Centre is not proposed.

4.4.2 HAZARDS AND RISKS IDENTIFIED

Both the airport, as well as the nuclear facilities at Lucas Heights, could be sources of risks to one another. The interaction between the two facilities could be a source of risk to the surrounding communities. Therefore the following types of risks are considered relevant for consideration:

- risk to people at the airport from accidents at the nuclear facilities at Lucas Heights;
- risk to surrounding communities, including people at the airport, from an aircraft crash on the nuclear facilities at Lucas Heights.

These risks are discussed in the following sections.

4.4.3 RISK ASSESSMENT

Accidents at the Lucas Heights Science and Technology Centre

Accidents at the Lucas Heights Science and Technology Centre could be initiated either due to internal or external initiating events. The frequency of internal and external initiating events, except aircraft crashes, is not expected to increase as a result of construction and operation of an airport at the site of Holsworthy Option B.

No part of the airport at Holsworthy Option B is located within 10 kilometres of the HIFAR.

The low frequency of accidents at HIFAR indicates that risks to people at the airport from accidents at HIFAR would be low.

Aircraft Crashes at the Lucas Heights Science and Technology Centre

Potential consequences of a large aircraft crash on HIFAR are discussed provided in *Section 4.2.3*. Calculations undertaken by the Australian Nuclear Science and Technology Organisation (1997) indicate that following a large aircraft crash on HIFAR, off-site evacuation, sheltering or administering stable iodine would not be considered necessary in 99 percent of weather conditions.

The likely incidence of an aircraft from Holsworthy Option B crashing into the Reactor Containment Building is discussed below.

For aircraft departing from parallel runways 29L and 29R, the location of HIFAR is almost 90 degrees with respect to runway centrelines. Similarly, for aircraft departing on the cross runway 27, the location of HIFAR is about 45 degrees with respect to runway centreline. Thus, the probability of a crash at such high angles is low.

Figure 3.6 shows contours for the frequency of aircraft crash per square kilometre per year for Airport Operation 2, the mode with the highest fatality rate. No part of the Lucas Heights Science and Technology Centre is enclosed within the 1×10^{-6} crash per square kilometre per year contour in any of the three operating modes investigated.

These contours have been developed taking into account the annual number of aircraft movements and the actual arrival and departure flight paths. The assumptions and basis for the development of these contours is explained in *Sections 3.4 and 3.5*. This frequency refers to all aircraft, including small regional airlines and General Aviation aircraft.

Although these contours indicate that the frequency of aircraft crash at the Lucas Heights Science and Technology Centre would be less than 1 x 10^{-6} per square kilometre per year, for the calculation of crash frequency on the reactor containment building below, it is conservatively assumed that the crash frequency at the Lucas Heights Science and Technology Centre would be 1 x 10^{-6} per square kilometre per year.

In *Section 4.2.4*, the effective target area presented by the reactor containment building to an aircraft crashing at a 30 degree angle was calculated as 1.15 x 10^{-3} square kilometres. In the vicinity of an airport, a significant proportion of crashes could be at shallow angles. For calculations below, it is assumed that an aircraft would crash at a shallow angle of seven degrees on the reactor containment building. Buildings present a larger target area when the crash angle is shallow, and therefore, the assumption of a shallow angle would predict a larger target area, and therefore a higher probability of crash on the reactor containment building.

At seven degree crash angles, the effective target area presented by the reactor containment building is estimated to be 4.07 x 10^{-3} square kilometres.

The frequency of aircraft crashes on the reactor containment building, calculated by multiplying the crash frequency per square kilometre per year by the effective target area, is estimated to be 4.07 x 10^{-9} per year. This crash frequency includes aircraft of all sizes. Analysis of data contained in *Section 3.3* indicates that Air Transport operations, ie., all operations other than General Aviation, would account for about 44 per cent of the total frequency of aircraft crashes in the vicinity of the Second Sydney Airport for Air Traffic Forecast 3. Therefore the crash frequency on the Reactor Containment Building of Air Transport aircraft operating from Holsworthy Option B is calculated to be 1.77 x 10^{-9} per year.

The crash frequency on the reactor containment building of large aircraft operating from Holsworthy Option B would be less than 1.77 x 10^{-9} per year, since Air Transport includes aircraft of all sizes, including those with less than 38 seats.

In *Section 4.2.4*, the crash frequency on the Reactor Containment Building of large aircraft using the existing flight path to and from Sydney Airport was calculated to be less than 6.77 x 10^{-10} per year. It is likely that this airway. This flight path would not be likely to operate when operations at Holsworthy Option B commence. However, even if this flight path were to remain as it is now, the total crash frequency on the Reactor Containment Building of large aircraft, which is calculated by adding the crash frequency of aircraft using the flightpath to Sydney Airport and operating from Holsworthy Option B, would be less than 2.45 x 10^{-9} per year.

The effective radiation dose to a member of the public at the exclusion zone boundary following a large aircraft crash on HIFAR is estimated to be less that 8.13 millisievert for 99 percent of weather conditions. Doses at further distances would be lower. Such an exposure would occur only in a certain combination of circumstances, the frequency per year of which can be estimated by multiplying the following:

- frequency per year of a large aircraft crash on HIFAR;
- probability of core damage following a crash; and
- probability of stable weather conditions with low wind speed at the time of the crash. These conditions do not promote horizontal atmospheric dispersion of radiation, and are very unlikely.

The last two conditional probabilities are less than one, and the frequency of large aircraft crash would be less than 2.45×10^{-9} per year. Therefore the frequency of a member of the public receiving a radiation dose of 8.13 millisievert would be less than 2.45×10^{-9} per year. This frequency is much lower than the basic dose objective set by the Nuclear Safety Bureau for exposure to a higher maximum effective dose of 50 millisievert.

4.4.4 SOCIAL AND ECONOMIC CONSEQUENCES

It should be noted that both Nuclear Safety Bureau's policy as well as this risk assessment address only the health effects of accidents. Based on experience of past accidents that have occurred at nuclear reactors, the social and economic consequences of such accidents overshadow the effects on public health. Estimates by the Nuclear Safety Bureau (1990) indicate that an accident at HIFAR involving release of radioactive materials to the environment is likely to result in more serious consequences than those associated with heath effects alone. The social and economic consequences have not been considered here, however they would almost certainly be the most significant impact of an accident at HIFAR.

4.5 RISK MITIGATION

4.5.1 INTRODUCTION

The management of risk of an aircraft crash at the Lucas Heights Science and Technology Centre encompasses the planning, design, and operational stages of the project. General measures that reduce the overall frequency of aircraft crashes would also reduce the frequency of aircraft crashes on the Lucas Heights Science and Technology Centre. Particular measures that could reduce the frequency of aircraft crashes at the Lucas Heights Science and Technology Centre are outlined below.

4.5.2 SELECTION OF OPTION

The runways at the two Holsworthy options are oriented in directions that obviate the need for establishing flight paths over the Lucas Heights Science and Technology Centre. With these runway orientations and the assumed flight paths, the risk of an aircraft crash at the Lucas Heights Science and Technology Centre, and the consequential risk to public health, has been assessed to be within the Nuclear Safety Bureau's draft criteria. Notwithstanding the low assessed public health risk, there could be significant social and economic consequences of such an accident. Such risks could largely be avoided by selecting one of the Badgerys Creek options.

This opportunity to avoid risks is available only at the planning stage. Good risk management practice suggests avoiding all avoidable risks. On this basis, the selection of one of the Badgerys Creek options would be preferable over one of the Holsworthy options.

Holsworthy Option A is located within a few kilometres of the Lucas Heights Science and Technology Centre, whereas Option B is more than ten kilometres away. Although the quantitative risk assessment does not indicate significant differences in the hazard and risk implications of the two Holsworthy options, an examination of risk contours indicates that contours are much closer to the Lucas Heights Science and Technology Centre in the case of Holsworthy Option A, when compared with corresponding contours of Holsworthy Option B. Qualitatively, the risks would be higher in the case of Holsworthy Option A. Therefore, among the two Holsworthy options, the selection of Option B would result in lower hazard and risk impacts.

4.5.3 AIRSPACE RESTRICTIONS

Aircraft operating from the two Holsworthy options would not need to enter the currently restricted airspace above the Lucas Heights Science and Technology Centre. The current airspace restrictions would therefore remain during the operational phase of the Holsworthy options. This is largely a prevention measure, ie., it would minimise the likelihood of a crash into the Lucas Heights Science and Technology Centre.

Special instructions would be developed and published so that arriving and departing aircraft are aware of the location and significance of the Lucas Height Science and Technology Centre.

Airspace restrictions would be enforced by the air traffic control. The restricted zone would be marked on air traffic control radar screens, as is marked now on the radar screens at the Sydney Airport. All aircraft movements in the vicinity of the airport would be monitored by air traffic control, and appropriate instructions would be given to any aircraft heading into the restricted airspace.

Procedures should be developed for abnormal operations, such as missed approaches and aborted take-offs, so that aircraft avoid entering the restricted airspace during such abnormal circumstances.

The effectiveness of air traffic control in implementing the airspace restriction should be monitored continually and audited periodically as part of its safety management system.

4.5.4 PILOT AVOIDANCE

In some crashes, pilots tend to have a degree of control and manage to direct their crashing aircraft away from buildings. All pilots should be made aware of the location and significance of the Lucas Heights Science and Technology Centre, and in particular the location of the reactor containment building, so that they avoid that building if they can.

4.5.5 COMMUNICATION

For Holsworthy Option A, a dedicated telephone line or other suitable means of communication between the Lucas Heights Science and Technology Centre and air traffic control at the airport is proposed.

4.5.6 INTEGRATED EMERGENCY PLANS

Emergency plans for the Lucas Heights Science and Technology Centre would have to be expanded to take into account the presence of the Second Sydney Airport if one of the two Holsworthy options is selected. Similarly, emergency plans for the airport would have to take into account the proximity to Lucas Heights Science and Technology Centre.

5 CRASHES INTO WATER SUPPLY INFRASTRUCTURE

5.1 METHODOLOGY

5.1.1 AIMS

The aim of this part of the study is to identify and assess the risks associated with aircraft crashing into major water supply infrastructure.

5.1.2 SCOPE OF WORK

The five airport options are located at different sites, which indicates that the risk impacts on particular facilities could be different for each option. Therefore specific assessments have been undertaken for each of the five airport options. The assessments are based on Air Traffic Forecast 3 in the year 2016, which represent the worst case impacts. For each airport option, three possible modes of operations are investigated.

Contours representing the frequency of aircraft crashes in the vicinity of each airport option in each mode of operation are examined to identify major water supply infrastructure that are exposed to different levels of aircraft crash frequency. The consequences of aircraft crashes on these major infrastructure are described, and the risk levels are compared with the risk from other external hazards.

5.1.3 INFORMATION SOURCES

Sydney Water assisted in the identification of its major assets that are located within areas exposed to relatively higher frequency of aircraft crashes. Additional information was obtained from previous environmental impact statements for Sydney Water's proposed infrastructure upgrades. Sydney Water also provided preliminary estimates of the consequences of an aircraft crash into a number of its assets.

5.2 EXISTING ENVIRONMENT

5.2.1 INTRODUCTION

Sydney's water supply infrastructure includes major dams and storage reservoirs, major above-ground pipelines and canals, water filtration plants, water pumping stations and service reservoirs.

Major water supply infrastructure assets that are located within approximately 20 kilometres of the sites for the three Badgerys Creek options are Warragamba Dam and reservoir, Prospect Reservoir and dam, Warragamba Pipelines, Upper Canal, Prospect Water Filtration Plant, and Orchard Hills Water Filtration Plant. A water filtration plant is proposed at South Creek in the future. The Warragamba Dam, Warragamba Pipelines and the Prospect Water Filtration plant are part of Sydney's largest water supply system, accounting for almost 80 per cent of the region's drinking water supply. The Orchard Hills Water Treatment Plant supplies water to a population of about 192,000 in Penrith, Emu Plains and lower Blue Mountains.

Major water supply infrastructure assets that are located within approximately 20 kilometres of the sites for the two Holsworthy options are Woronora Dam and reservoir, Cataract Dam and reservoir, Cordeaux Dam and reservoir, Woronora Pipelines, Upper Canal, Woronora Water Filtration Plant and Macarthur Water Filtration Plant. The northernmost Illawarra towns around Helensburg are supplied from Woronora Dam. Much of the Sutherland Shire is also supplied from Woronora Dam, although most parts of the Shire can also be supplied from Prospect. Cataract Dam, Cordeaux Dam and the Upper Canal are part of the system that supplies the Camden and Campbelltown areas.

5.2.2 RISK ASSESSMENT CRITERIA

Infrastructure facilities are generally designed and operated to achieve certain levels of reliability and safety. Although a high level of reliability and safety can be achieved, the state of absolute reliability and safety is neither achievable nor economically viable. There will always be some risk that water supply would be interrupted due to internal initiating events, such as equipment failure, or due to external initiating events, such as extreme weather conditions and earthquakes. In the case of dams, there is also some risk to downstream public and property from dam failures due to extreme floods or earthquakes.

Operations at the Second Sydney Airport options could potentially increase the risk of an aircraft crash on some of the water supply infrastructure. As a consequence, the risk of water supply interruption could potentially increase. The risk to people and property downstream of dams could also potentially increase.

Both qualitative and quantitative criteria are adopted in assessing the acceptably or tolerability of this increase in risk from the Second Sydney Airport options. Some of the qualitative criteria are:

- all avoidable risks should be avoided; and

- irrespective of the numerical value of the risk, the risk should be reduced wherever practicable.

Quantitatively, the increase in risk is compared with some existing catastrophic risks. This would allow judgement to be made regarding the tolerability of risk from the Second Sydney Airport options.

Risk of dam failure from floods is assessed in terms of Imminent Failure Flood (IFF) and Probable Maximum Flood (PMF). The IFF is the flood which just threatens dam failure, and depends on the design of the dam. The PMF is a credible but extremely rare event, which depends on the characteristics of the catchment. For many older dams, the IFF is small in comparison with the PMF, ie., dams could fail during the PMF (or in fact during all floods larger than the IFF).. While it is not possible theoretically to calculate the frequency of the PMF, a notional value of 1×10^{-6} per year is a reasonable assumption (Pearce, 1994).

In the case of Warragamba Dam, upgrades have been proposed to mitigate the effects of flooding in the Hawkesbury-Nepean Valley (ERM Mitchell McCotter, 1995a), and to protect the dam wall during the Probable Maximum Flood (PMF) (ERM Mitchell McCotter, 1996).

The risk of Prospect dam wall failure due to an earthquake was estimated to be 1×10^{-5} per year (ERM Mitchell McCotter, 1995b). It was estimated that dam failure could cause the loss of nearly 1,440 lives. This risk was considered to be unacceptable, and remedial work was proposed to improve dam safety.

Failure rates of transmission pipelines could differ significantly, depending on operating conditions, age and maintenance regimes. For oil and gas transmission pipelines, rupture frequencies used in most risk assessments fall within the range 1×10^{-4} to 1×10^{-5} per kilometre.

5.3 IMPACT ASSESSMENT

5.3.1 INTRODUCTION

The frequency of aircraft crashes in the vicinity of each airport option was analysed as part of aircraft crash quantitative risk assessment. Figures showing the location of contours representing 1×10^{-3}, 1×10^{-4}, and 1×10^{-5} crashes per square kilometre per year were developed for each airport option in three modes of operations. Risks to major water supply assets that are located within the three contours are discussed below. Risks to assets located outside the 1×10^{-5} crash frequency per square kilometre per year are not considered because of three main reasons.

Firstly, the frequency of aircraft crashes on assets located within the 1×10^{-5} contours is already low in comparison with the frequency of other external events. Consider an area of 1 kilometre square located between the 1×10^{-4} and 1×10^{-5} contours. It can be assumed that the frequency of an aircraft crash over this area would be 5×10^{-5} per year. The frequency of an aircraft directly impacting on a particular asset located within this 1 square kilometre area would depend on how large a targe area it provides to a crashing aircraft.

Mathematically this frequency is approximately equal to the frequency of aircraft crash per square kilometre per year multiplied by the area in square kilometres of the most vulnerable part of the asset. For example, if the most vulnerable part of an asset measures 100 metres x 100 metres, and the asset is located between the 1×10^{-4} and 1×10^{-5} contours, the frequency of aircraft crash on that part would be $5 \times 10^{-5} \times 10{,}000 \times 10^{-6}$ per year, or 5×10^{-7} per year.

Such an event is less likely than other very rare external events, such as the PMF with a frequency of 1×10^{-6} per year. The frequency of aircraft crashes on assets outside the 1×10^{-5} contours is even lower.

Secondly, the contours representing 1×10^{-6} and 1×10^{-7} crashes per square kilometre per year, although not shown on the figures, are generally located just beyond the 1×10^{-5} contours, indicating that the frequency of aircraft crashes reduces rapidly beyond the 1×10^{-5} contours.

Thirdly, the contours refer to crashes of aircraft of all sizes. Analysis of data contained in *Section 3.3* indicates that small aircraft are more than four times more likely to crash around the Second Sydney Airport than larger aircraft. The frequency of large aircraft crashes, which have the greater potential for damage, would be only a small proportion of the total frequency represented by the contours.

5.3.2 BADGERYS CREEK OPTIONS A AND B

Proposed Flight Paths

Flight paths have not been finalised at this stage, however a set of approach and departure tracks were defined for each airport option in discussions with Airservices Australia to enable noise impact studies to be undertaken.

The parallel runways for the Badgerys Creek Options A and B are in direct line with the Prospect Complex. Two approach and two departure tracks from the parallel runways pass over the Prospect complex. Three departure tracks and two arrival tracks are positioned over the Warragamba Dam.

Identification of Assets within Contours

Figures 3.2 and *3.3* show the location of crash frequency contours for Badgerys Creek Options A and B in the modes of operations with the highest fatality rates. Contours for other modes of operation (not shown) are similar to this. No major water supply facilities are located within the 1×10^{-3} contours, for any of the modes of operation.

In all the operating modes investigated, the 1×10^{-4} contours enclose the Warragamba Dam, parts of the Warragamba pipelines, and parts of the Prospect Complex.

Some additional length of the Warragamba pipelines, and parts of the Orchard Hills Water Filtration Plant are enclosed within the 1×10^{-5} contours in all the operating modes investigated, although the exposure is comparatively less in Airport Operations 2 (landings from the north east and take-offs to the south west).

Risk Analysis and Assessment

Prospect Dam

The length of the Prospect Dam wall is approximately 2,500 metres. Assuming a width of about 100 metres, the effective target area presented by the dam wall to a crashing aircraft is estimated to be about 0.25 square kilometres. The dam wall is located near the 1×10^{-4} crashes per square kilometre per year contours, for the three possible modes of operation investigated. Therefore the frequency of an aircraft crash on the dam wall is estimated to be 2.5×10^{-5} per year.

In 1995, the risk of dam wall failure due to earthquakes was estimated to be 1×10^{-5} per year. Remedial work was proposed to reduce the risk from earthquakes. The status of this upgrade and the consequential reduction in risk has not been investigated in this study. The likelihood of dam failure following an aircraft crash has also not been investigated. However, this preliminary analysis indicates that the increase in risk due to aircraft overflights would be significant in comparison with existing risk.

Warragamba Dam

Warragamba Dam is about 300 metres long and about 200 metres high. The 'roof' area of the dam is minimal. The dam wall is located near the 1×10^{-4} crashes per square kilometre per year contour for all three possible modes of operation investigated. Since both approach and departure tracks are positioned above the dam, it is estimated that crashes during approach and departure contribute equally to the total frequency. It has been assumed that for departures, crash angles are 'shallow' if the crash occurred in the first 500 metres, and 'steep' thereafter. For approaches, 60 percent of crash angles have been assumed to be 'shallow' and 40 percent 'steep'. Therefore, at Warragamba Dam, it is estimated that 70 percent of crashes would be at a steep angle and 30 percent at a shallow angle.

The target area presented by the dam to an aircraft crashing at a 'shallow' 7 degree angle, and a 'steep' 45 degree angle has been estimated, using the relationship $(h \times l)/\tan(\theta)$, to be approximately 0.49 and 0.06 square kilometres respectively. Therefore the frequency weighted target area of the dam has been calculated to be 0.19 square kilometres, and the frequency of an aircraft crash on the dam wall is estimated to be about 1.9×10^{-5} per year. The likelihood of dam failure following an aircraft crash has not been investigated in this study.

A potential problem is the failure of one of the gates resulting from a crash directly on the gates. Under this scenario, a significant flood wave would be released and almost half the present stored capacity of the dam would be lost. The impact of the wave of water to downstream public and property has not been investigated. Although the gates could potentially be repaired within a few months, it would take several years to build up the water levels.

The gates are confined to the top 30 metres of the dam wall along a length of about 90 metres. The frequency weighted target area presented by this vulnerable area to a crashing aircraft is estimated to be about 8.5×10^{-3} square kilometres. The frequency of aircraft crashes on the gate area is estimated to be 8.5×10^{-7} per year, which is similar to the frequency of the Predicted Maximum Flood (1×10^{-6}).

Risks to Warragamba Dam could be mitigated by minimising flights above the dam.

Warragamba Pipelines

Water stored in Lake Burragorang (formed by Warragamba Dam) is gravity fed to the Prospect Complex through the parallel 3,000 millimetre diameter and 2,100 millimetre diameter above-ground Warragamba Pipelines. These pipelines would be damaged if an aircraft crashed directly onto them, or skidded into them. The distance to which a crashing aircraft could skid depends on a the size of the aircraft and the angle of crash. For the purpose of analysis, it has been assumed that the pipelines would be damaged if an aircraft crashed within 100 metres of the pipelines. Therefore a one kilometre section of the pipeline would present a target area of 0.1 square kilometre.

Among the operating modes investigated, in the worst case, a total length of about 5 kilometre of the pipeline is enclosed within the 1×10^{-4} crashes per square kilometre per year contours. The average crash frequency within the

1×10^{-4} contour is assumed to be 5×10^{-4} crashes per square kilometre per year. Therefore, for this section of the pipeline, the frequency of aircraft crash is estimated to be 5×10^{-5} per kilometre per year.

An additional 5 kilometre section of the pipeline is enclosed within the 1×10^{-5} contours. For this section, the frequency of aircraft crash is estimated to be 5×10^{-6} per kilometre per year.

If water supply to Prospect Water Filtration Plant was interrupted, this could affect 2.9 million people. Minimal services could be provided using the Upper Canal, however some areas may not receive any supply. If short lengths of the pipelines, approximately 10 metres are damaged, this could potentially be repaired within two or three weeks. Damage to longer lengths would take approximately two to three months.

5.3.3 BADGERYS CREEK OPTION C

Proposed Flight Paths

Flight paths have not been finalised at this stage, however a set of approach and departure tracks were defined for each airport option in discussions with Airservices Australia to enable noise impact studies to be undertaken.

The main approach and departure paths from the parallel runways cross the Warragamba Pipelines. Approach flight paths to one end of the cross runway are positioned above the Warragamba Dam. Some departure tracks are positioned in the vicinity of the Warragamba Dam and the Prospect Reservoir.

Identification of Assets Within the Contours

Figure 3.4 shows the location of crash frequency contours for Badgerys Creek Option C in one of the three modes of operations investigated. About one kilometre section of the Warragamba Pipelines is located within the 1×10^{-3} contours in Airport Operation 2 (preferred landings from the north and take-offs to the south).

Some additional length of the Warragamba pipelines is enclosed within the 1×10^{-4} contours in all modes of operation investigated.

Some additional length of the Warragamba Pipelines, and part of the Orchard Hills Water Filtration Plant are enclosed within the 1×10^{-5} contours in all modes of operations investigated.

The Warragamba Dam is at the boundary of the 1×10^{-5} contours in Airport Operation 3 (share the noise scenario) and Airport Operation 1.

Risk Analysis and Assessment

Warragamba Dam

The predicted frequency of aircraft crashes at the Warragamba Dam is one order of magnitude lower in the case of Badgerys Creek Option C than for Options A or B. In the pervious section, the frequency weighted target area of the dam was estimated to be 0.19 square kilometre. Therefore, in the case of Badgerys Creek Option C, the frequency of an aircraft crash on the dam is estimated to be about 1.9×10^{-6} per year. The likelihood of dam failure following an aircraft crash has not been investigated in this study.

Also in the previous section, the target area presented by the dam valve area was estimated to be about 8.5×10^{-3} kilometre. The frequency of aircraft crashes on the gate area is therefore estimated to be 8.5×10^{-8} per year. This is considered low.

Warragamba Pipelines

In the previous section, the target area presented by a one kilometre section of the pipeline was estimated to be 0.1 square kilometre.

Among the operating modes investigated, in the worst case (Airport Operation 2) a total length of about one kilometre of the pipeline is enclosed within the 1×10^{-3} crashes per square kilometre per year contours. The average crash frequency within the 1×10^{-3} contour is assumed to be 5×10^{-3} crashes per square kilometre per year. Therefore, for this section of the pipeline, the frequency of aircraft crash is estimated to be 5×10^{-4} per kilometre per year.

In other modes of operations, approximately four kilometres of the pipeline is enclosed within the 1×10^{-4} contours. Over this section, the frequency of aircraft crashes is estimated to be 5×10^{-5} per kilometre per year.

In addition, about one to two kilometre of the pipeline is enclosed within the 1×10^{-5} contours. Over this section, the frequency of aircraft crashes is estimated to be 5×10^{-6} per kilometre per year.

5.3.4 HOLSWORTHY OPTION A

Proposed Flight Paths

The parallel runways for Holsworthy Option A are in direct line with the Woronora Dam. Flight paths have not been finalised at this stage, however a set of approach and departure tracks were defined for each airport option in discussions with Airservices Australia to enable noise impact studies to be undertaken. Almost all approach and departure tracks from one of the parallel runways pass over the dam area.

Identification of Assets Within Contours

Figure 3.5 shows the location of crash frequency contours for Holsworthy Option A in one of the three modes of operations investigated.

The Woronora Dam is located near the 1 x 10^{-4} contours for all modes of operations investigated.

Risk Analysis and Assessment

The location of contours indicates that the frequency of aircraft crash in the Woronora Dam area would be approximately 1 x 10^{-4} crashes per square kilometre per year.

5.3.5 HOLSWORTHY OPTION B

Proposed Flight Paths

Flight paths have not been finalised at this stage, however a set of approach and departure tracks were defined for each airport option in discussions with Airservices Australia to enable noise impact studies to be undertaken. One departure flight path is positioned over the Cataract Dam area.

Identification of Assets Within the Contours

Figure 3.6 shows the location of crash frequency contours for Holsworthy Option B in one of the three modes of operations investigated.

Cataract Dam is located near the 1 x 10^{-5} contours in Airport Operation 1 (preferred landings from the south east and take-offs to the north west) and beyond the 1 x 10^{-5} contours for other modes of operation investigated.

Risk Analysis and Assessment

The location of contours indicates that the frequency of aircraft crash in the Cataract Dam area would be approximately 1 x 10^{-5} crashes per square kilometre per year.

5.4 RISK MITIGATION

Badgerys Creek Options A and B

The likelihood of Warragamba Dam failure following an aircraft crash should be investigated. If the likelihood is high, options to reduce the frequency of aircraft crash at the dam should be investigated, including re-positioning flight tracks and minimising aircraft movements on tacks in the vicinity of the dam. If the likelihood of dam failure following an aircraft crash is determined to be low, and flight paths above the dam cannot be avoided, then the hazard to the dam gates from an aircraft crash, and options to reduce the consequences should be investigated.

The likelihood of Prospect dam wall failure following an aircraft crash should be investigated. If the likelihood is high, options to reduce the consequences of an aircraft crash should be investigated. The frequency of aircraft crashes at the Prospect Complex could also be reduced by reducing the number of movements. Options to reduce the impact of an aircraft crash on the Warragamba Pipelines and the Prospect Complex should also be investigated.

Badgerys Creek Option C

Options to reduce the impact of an aircraft crash on the Warragamba Pipelines should be investigated. The frequency of aircraft crashes on the pipelines could be reduced by reducing the number of aircraft movements.

The likelihood of Warragamba Dam failure following an aircraft crash should be investigated. If the likelihood is high, options to reduce the frequency of aircraft crash at the dam should be investigated, including re-positioning flight tracks and minimising aircraft movements on tacks in the vicinity of the dam.

Holsworthy Option A

The frequency and the consequences of aircraft crashes on the Woronora Dam should be further investigated, and risk mitigation measures implemented if risks are considered high.

Holsworthy Option B

The frequency and the consequences of aircraft crashes on the Cataract Dam should be further investigated, and risk mitigation measures implemented if risks are considered high.

Appendix B

Bird and Bat Strike Hazards Report

Assessment of Potential Bird and Bat Strike Hazards

Department of Transport and Regional Development

Prepared by:
Peter M. Davidson Pty Ltd

Edited by:
PPK Environment and Infrastructure

9 Blaxland Road
Rhodes NSW 2138
PO Box 248
Concord West NSW 2138
Australia

Telephone (61 2) 9743 0333
Facsimile: (61 2) 9736 1568

25 August, 1997
58H233A PR_1451

CONTENTS

Page Number

PART A: INTRODUCTION

1 INTRODUCTION 1-1

2 BACKGROUND 2-1

3 STUDY METHODOLOGY 3-1

3.1 AIMS AND SCOPE 3-1
3.2 APPROACH 3-1
3.3 BIRD HAZARD RISK FACTORS 3-2

PART B: EXISTING ENVIRONMENT

4 EXISTING ENVIRONMENT 4-1

4.1 BADGERYS CREEK 4-1
4.2 HOLSWORTHY 4-1
4.3 EFFECT OF HABITATS AND LAND USE 4-2

4.3.1 BIRD ACTIVITY 4-2
4.3.2 BAT ACTIVITY 4-3

4.4 BIRD AND BAT POPULATIONS AND MOVEMENTS 4-4
4.5 HAZARDOUS SPECIES 4-4

4.5.1 SPECIES 4-4
4.5.2 POPULATIONS AND MOVEMENTS 4-6

PART C: ASSESSMENT OF IMPACTS

5 OPERATIONAL IMPACTS 5-1

5.1 BIRD HAZARD ASSESSMENT 5-1
5.2 BADGERYS CREEK 5-1
5.3 HOLSWORTHY OPTION A 5-2

5.4 Holsworthy Option B 5-4

Part D: Environmental Management

6 Environmental Management 6-1

Part E: Summary of Impacts

7 Summary of Environmental Impacts 7-1

7.1 Badgerys Creek 7-1
7.2 Holsworthy 7-1

References R-1

Appendices

Appendix 1 Species Lists
Appendix 2 Hazardous Bird and Bats Species
Appendix 3 Civil Aviation Regulation 96

PART A: INTRODUCTION

1 INTRODUCTION

Peter M Davidson Pty Ltd was commissioned by PPK Environment and Infrastructure to investigate potential hazards associated with bird and bat strike, for the Second Sydney Airport EIS.

The study covers potential airport sites at Badgerys Creek, west of Sydney, and within the Holsworthy Military Area south west of Sydney.

2 BACKGROUND

Birds can be a significant hazard to aircraft: collisions with individual birds, especially if large, can result in damage to aircraft structures including windscreens, wings, tail, aerials, lights and engines. Collisions with flocks of birds can result in simultaneous damage to a number of systems, including engines. Damage to structures and systems can cause control and visibility difficulties, sometimes resulting in loss of the aircraft, especially if the bird strike occurs during critical phases of flight such as take-off and landing.

Ingestion of a bird or birds into a turbo-prop or turbo-fan engine can cause damage to fan blades and other engine components. In some birdstrikes, pieces of broken fan blades have been flung out of the front of the engine or have penetrated the engine cowl, then damaged other parts of the aircraft. In 1975, the whole fan from the right-hand engine of a DC10 which was taking off at New York's Kennedy International Airport detached from the engine and preceded the aircraft down the runway after a number of gulls were ingested. The aircraft was destroyed by fire after coming to rest in a ditch beside the runway. Amazingly none of the 142 people on board (all airline personnel on a re-positioning flight) were critically injured.

Flying through a flock of birds can result in simultaneous ingestion of a number of birds into more than one engine. In Australia there have been a number of birdstrikes in which all engines on a passenger jet aircraft have been damaged. Fortunately in all of these incidents the aircraft has been able to land safely. This has not been the case overseas.

Birdstrike data collated by then Australian Civil Aviation Authority's Bird Hazard Investigation Unit shows that world-wide to January 1992 there were at least 22 fatal civil aircraft accidents known to be caused by birds, resulting in the deaths of 182 people. At least one of those accidents (Atlanta, 27 February 1973) was directly caused by birds attracted to a garbage dump near the airport from which the aircraft was taking off. In that accident the aircraft crashed into an apartment building after ingesting Brown-headed Cowbirds into an engine. Brown -headed Cowbirds are slightly larger than the Common Starling *Sturnus vulgaris* and weigh about 100 grams.

World-wide in 1988, in civil passenger aircraft accidents related to engine failure, birdstrikes caused about one-fifth of the aircraft hull losses and fatalities (Source: Civil Aviation Authority, 1989).

Two Australian examples of birdstrikes which caused substantial damage to passenger jet aircraft are outlined below.

At Sydney in 1969 a Boeing 707 ran through a flock of Silver Gulls *Larus novaehollandiae* at V_1 (above which speed the pilot is unable to abort takeoff without over-running the end of the runway). The pilot aborted the aircraft's takeoff but the aircraft overran the end of the runway, almost continued into Alexandra Canal and was damaged severely after its undercarriage collapsed. One passenger suffered serious injuries. (Source: Bureau of Air Safety Investigation).

A four-engined BAe146 struck a flock of Galahs *Cacatua roseicapilla* as it took off at Adelaide in February 1992. The pilot saw that the aircraft was likely to hit the birds and rotated the aircraft early, causing the aircraft to drag its tail on the runway. The aircraft became airborne then ingested birds into all four engines, three of which lost power. The aircraft managed to land without injury to passengers or crew. (Source: Bureau of Air Safety Investigation 1992).

Between 1981 and 1991 birds were ingested into the engines of Australian civil aircraft on 209 occasions. Forty-one percent of those engine ingestions resulted in damage (derived from Bureau of Air Safety Investigation data).

In 1992, ninety-six countries (which did not include Australia as it no longer provides its birdstrike records to the International Civil Aviation Organisation) reported 5,605 birdstrikes to civil aircraft. Almost 6 percent of those strikes caused aircraft damage: 136 caused substantial damage and a further 181 caused minor damage. (Source: International Civil Aviation Organisation).

Bats, especially fruit bats or "flying foxes" (which may weigh up to about 1.3 kilograms), can also cause significant damage to aircraft.

Unless they occur in very large numbers, small birds or bats are unlikely to cause damage to aircraft. For instance, swallows and martins (average weight approximately 10 grams) even in flocks of thousands, are unlikely to cause significant damage to modern civil jet airliners. Other problems, however, such as obscured vision, could result from a birdstrike with a large flock of such birds. Such flocks are rare at Australian airports and swallows and martins are therefore not considered to present a significant hazard.

The damage which may be caused to an aircraft is linearly proportional to the bird's mass (weight). In theory it is also proportional to the square of the velocity of impact. That is, if the velocity doubles, the energy of impact increases fourfold and the resultant damage may be expected to increase similarly.

With this relationship between velocity and damage in mind and the knowledge that aircraft fly much faster during cruise than take-off and landing, some authors (for example van Tets et al, 1977) have concluded that a high-flying hawk presents a much greater hazard than a low-flying flock of gulls.

This conclusion is unsound, however, as it does not take account of three important factors:

- significant power is required to attain or maintain safe flying speeds during take-off and landing. Loss of power during take-off and landing is more likely to result in loss of an aircraft than during cruise;
- a single bird can only damage one engine (or any other part of an aircraft), whereas a flock of birds could damage all engines, resulting in total loss of power; and

- in the case of ingestion of a bird into a turbo-fan engine, the velocity of impact is related to the speed of rotation of the engines fan blades (tip speed may be as high as 700 kilometres per hour), not just the aircraft's flying speed. Engine power and thus fan blade speed is much higher during take-off and landing, than cruise.

Most birds fly at relatively low heights above the ground and thus about 80 percent of all birdstrikes occur below 70 metres. Civil passenger aircraft flying so low must be taking-off or landing at an airport. Most birdstrikes therefore occur on or near airports.

Bird hazards to aircraft can be minimised through improving aircraft design and construction, changing operating procedures and reducing bird activity on or near airports. Reducing bird activity can be achieved through careful airport site selection, design, construction, operation and maintenance; appropriate habitat management and land use planning on and near airports; and effective airport bird management procedures.

3 STUDY METHODOLOGY

3.1 AIMS AND SCOPE

The aim of this study is to provide an assessment of bird and bat hazards which may be associated with airport development and aircraft operations at the potential airport sites at Badgerys Creek and Holsworthy.

In order to achieve this, existing data on the populations and movements of potentially hazardous bird and bat species has been reviewed. Information has been obtained from the Flora and Fauna Consultant on this project, Biosis Research, and from other sources. Action which may be taken to mitigate potential hazards has been investigated and is presented in this report.

Common and scientific names of Australian birds follow Christidis and Boles, 1994. The common scientific names of bats follow Strahan, 1983.

3.2 APPROACH

The approach taken has been to utilise information obtained by the Flora and Fauna Study, as much as possible and to supplement this with specific site inspections and literature research. The Study relies on existing species lists, anecdotal reports and fieldwork undertaken by the Flora and Fauna Subconsultants to establish presence or absence of endangered species.

This approach, combined with knowledge of the habitats at and in the vicinity of the sites, provides a reasonable basis for assessing and predicting bird and bat hazards to aircraft.

Bird and bat hazards may be split into those that are associated with the habitats provided at the airport itself and those associated with surrounding land use and habitats.

Open grasslands, drainage systems, landscaping, sealed surfaces and buildings at an airport can provide food, shelter and sometimes breeding opportunities for particular species of birds. Land uses and habitats outside an airport, such as sewage treatment plants, garbage dumps, forests and wetlands, may attract birds which become a hazard to aircraft if they fly onto the airport or through aircraft flight paths.

This assessment of potential bird and bat strike hazards for the Badgerys Creek and Holsworthy sites takes account of habitat and land use, both on and off the airport sites.

In undertaking the impact assessment work, it has been assumed that land use in the vicinity of an airport at Badgerys Creek would change from semi-rural to urban and light industrial; that land use to the north and west an airport at Holsworthy Option A would become increasingly urbanised and industrialised and that land use in the vicinity of an airport at Holsworthy Option B would remain largely unchanged.

It has also been assumed that apart from the possible effects of different runway orientation, the types of aircraft, number of aircraft movements, mix of operations and operational procedures would be similar for all of the five options.

3.3 BIRD HAZARD RISK FACTORS

It is not possible to reliably quantify bird hazard risk or establish a valid measure which may be used to compare risk between different locations.

For locations where birdstrike reports and reliable aircraft movement data are available the *birdstrike rate* (number of birdstrikes per 10,000 specified aircraft movements [for example rate per thousand aircraft]) may be calculated. Because of large variations in the quality of birdstrike reports and reporting and other factors such as bird species and behaviour and aircraft types, comparing birdstrike rates between different locations is not necessarily valid.

In theory, if there were reliable and comparable data on all bird populations and movements and on the relationships between species and damage for different aircraft types and components at airports for which birdstrike rates could be calculated, it may be possible to construct a bird hazard risk index. Such an index could, in theory, then be used to forecast the bird hazard which might be encountered at a proposed airport site at which no birdstrike data are available. In practice, even if such data were currently available such calculations would be extremely difficult. Furthermore, any such hazard index would be susceptible to criticism on the relative weight given to the different elements on which the index was based.

There are no data on which birdstrike rates could be calculated for the sites of the Badgerys Creek and Holsworthy Airport options, let alone any valid quantifiable bird hazard index.

Bird hazard may be subjectively classified as 'low', 'moderate' and 'significant'. In each case, the reliability of the subjective bird hazard classification will depend on the classifier's depth of knowledge and experience of bird hazards to aircraft.

Hypothetically, the following factors can be used to broadly classify bird hazard risk at a particular location:

Table 3.1 Bird Hazard

Factors	Low	Moderate	Significant
Bird[1] Population	small	moderate	large
Size	small	medium	medium/large
Flocks	none/small	seasonal/medium	regular/large
Movements[2]	rare/seasonal	occasional/seasonal	frequent, may be seasonal

Notes: 1. Species which are likely to be a hazard to aircraft
2. Likely to conflict with aircraft flight paths.

PART B: EXISTING ENVIRONMENT

4 EXISTING ENVIRONMENT

4.1 BADGERYS CREEK

The proposed area encompassing Options A, B and C and surrounding land consists predominantly of undulating cleared pastures, with scattered eucalypts and other native trees, some patches of native woodland and relatively narrow strips of riparian woodland (characterised by *Casuarina* sp.) along major creeks.

Parkland use around Badgerys Creek consists of mostly small rural holdings with numerous farm dams and a variety of domestic stock. There are also a number of horse stables and commercial poultry farms.

A major non-putrescible landfill exists to the north-east of the airport options, on the northern side of Elizabeth Drive. The operator, Pacific Waste Management Pty Ltd., has been unsuccessful in seeking to dispose of putrescible wastes at this site *(10189 of 1994, Land and Environment Court of New South Wales - Talbot J, 24 February 1995)*. However, other sites in the vicinity of the airport options could be considered suitable for disposal of wastes by landfill, and thereby attract birds to the area.

4.2 HOLSWORTHY

The majority of the Holsworthy Military Area is covered with relatively undisturbed native eucalypt forest. Dry eucalypt woodland and heath predominates on the sandstone ridges, while the deeper gullies support a more diverse "gully forest" (AXIS/Australian Museum Business Services, 1995).

Extensive areas of similar habitat surround both Holsworthy sites, but there appears to be no significant difference in habitat between the two potential airport sites.

Dry weather and off-road vehicle tracks have been formed along many of the ridges, however there are no significant cleared areas within the sites.

The forest habitats at Holsworthy are structurally more uniform than the habitats at Badgerys Creek. However Badgerys Creek also has more diverse and extensive aquatic habitats than Holsworthy.

A major putrescible landfill exists to the north-east of Holsworthy Option A site, at New Illawarra Road, Lucas Heights. A small landfill is located to the west of Holsworthy Option A at St Helens Park, South Campbelltown. Few other sites in the vicinity of Holsworthy Option A are likely to be considered suitable for disposal of wastes by landfill.

Holsworthy Option B is relatively remote from existing landfill sites. For this reason, it is unlikely that any future landfill sites will be located close to Holsworthy Option B.

Lake Woronora, a large water storage dam, lies approximately 3 kilometres south of the Holsworthy Option A site and a similar distance east of Holsworthy Option B.

4.3 EFFECT OF HABITATS AND LAND USE

4.3.1 BIRD ACTIVITY

To survive, birds require food and shelter and also suitable places to breed successfully. Different habitats provide these requirements to varying degrees, depending on the needs of each species. Ducks which feed on aquatic insects or their larvae will not be found in a forest, conversely honeyeaters which feed on flowering eucalypts for nectar or insects will not be found on open grasslands, tidal mudflats or open water.

Although there are trees and some woodland at Badgerys Creek, in the main, the open grassland habitats at Badgerys Creek are markedly different to the woodland and forest at Holsworthy. The species of birds which occur at Badgerys Creek and Holsworthy reflect these habitat differences.

Most forest birds are small and, apart from cockatoos, the larger forest birds (such as Powerful Owl *Ninox strenua* and Wedge-tailed Eagle *Aquila audax*) do not occur in flocks. By contrast, many of the birds which frequent open grassland/woodland and open water/swamp habitat are large and often occur in flocks.

The different structure and physical characteristics of the Badgerys Creek habitats (open grassland/woodland and open water/swamp) and the Holsworthy habitats (predominantly forest) affects the type and pattern of bird movements.

In open country, such as at Badgerys Creek, bird movements are likely to be:

- flights to and from specific feeding areas such as farm dams, yards, paddocks;
- local movements of woodland birds onto nearby grassland;
- movement along vegetation corridors;
- soaring flight by large birds of prey, some waterbirds and grassland birds, to thousands of metres above ground level as individuals or in flocks; and
- nocturnal movements (mostly of waterfowl and other waterbirds), often in flocks.

In forest habitat, such as at Holsworthy, bird movements are likely to be:

- within the forest canopy, or just above it;
- generally dispersed because most birds feed locally;
- flocks attracted to food trees; and
- soaring flight, usually individual or pairs of large birds of prey, never in flocks.

Birds such as Pelican *Pelecanus conspicillatus*, cormorants, ibis and eagles soar to great heights on spiralling upward currents of air known as thermals. Thermals form over flat open areas such as grassland, but not over forests. Soaring flight is therefore uncommon over forested areas.

Migratory flights by honeyeaters and other songbirds may occur seasonally over either type of habitat, however most will follow vegetation corridors at low level (tree top height, or just above) and will occur during the day. A small number of songbirds (such as Silvereye *Zosterops lateralis*) migrate at night.

4.3.2 BAT ACTIVITY

The movements of insectivorous micro bats (Microchiroptera) are likely to be dispersed, except close to roosts. Feeding flights may be focused by vegetation along roads and tracks and by areas of water. Roosts are likely to be relatively small and may occur in lofts and roof spaces of buildings, in tree hollows scattered through forest, or rock crevices and overhangs along gullies. Evening dispersal of thousands of bats from large roosts or breeding sites may follow concentrated flight paths. No large micro bat roosts or breeding sites are known to occur within the Badgerys Creek and Holsworthy areas.

At dusk flying foxes (fruit bats, Megachiroptera) leave their communal daytime camps to feed during the night on the nectar and fruits of flowering trees and shrubs. When leaving the camp, concentrated mobs of fruit bats may fly along a particular flight path until they arrive in their chosen feeding area, where they disperse. These flights may continue for an hour or so after dusk and involve thousands of fruit bats, if the camp is large. The bats rarely fly at heights greater than about 50 metres above the ground, usually flying just above the trees and other obstructions. In the hours before dawn, the fruit bats return to their camp individually and in small groups.

In open grassland/woodland habitat, such as at Badgerys Creek, feeding activity by fruit bats will be focused in gardens and orchards and along vegetation corridors. In forest habitat, such as at Holsworthy, fruit bats will disperse in accordance with the distribution of the suitable flowering and fruiting trees and shrubs. The greater the amount of suitable food available, the larger the number of fruit bats likely to forage in the area.

4.4 BIRD AND BAT POPULATIONS AND MOVEMENTS

Species

The first step in deriving a list of species which may be expected to pose a hazard to aircraft using any of the airport sites has been to determine all the bird and bat species which are either known to occur or are likely to occur at or in the vicinity of the Badgerys Creek and Holsworthy Airport options.

Probable bird species have been based on a number of species lists (see *Appendix 1*); observations by P. Davidson (1980's, 1992, 1996); by D. Engel, Mark Chidel and Renata Bali of Biosis Research (1996) and anecdotal observations provided by local residents.

Probable bat species have been based on the findings of the AXIS/Australian Museum Business Services Study (1995), observations by Mark Chidel of Biosis Research, anecdotal observations provided by local residents and consultation with Dr Chris Tidemann (Australian National University) and Sydney-based amateur bat researchers, including S. Cullis and J. Spence.

Populations

No systematic quantitative data are available which will enable the total population of any bird or bat species at or in the vicinity of the airport options to be accurately estimated. Therefore assessment of populations has been based on qualitative information on the relative abundance of different species in different habitats, together with records of the number of individuals of a species observed at a specific site, when available.

Studies of the Grey-headed Fruit Bat camp at Cabramatta Creek have provided an indication of that species' population in the south-western Sydney region (Tidemann and Spence, 1995).

Movements

There has not been any systematic scientific research into the movements of any bird or bat species at or in the vicinity of the airport options. Determination of probable movement patterns of hazardous species has been based on anecdotal information and observations, and on the observed distribution of suitable habitat.

4.5 HAZARDOUS SPECIES

This study addresses only those species of bird and bat known to occur, or which are likely to occur, at or in the vicinity of the Badgerys Creek and Holsworthy airport options and which are likely to be a hazard to aircraft.

4.5.1 SPECIES

The analysis has identified 40 possibly hazardous bird or bat species, of which 18 are considered likely to be the most hazardous, on the basis of size, behaviour and probable abundance at one or more site. These species are listed at *Appendix 2*, which also lists probable relative abundance at each site and provides a brief outline of each species.

Other species could be struck by aircraft, but are not regarded as posing a significant hazard because they are either too uncommon, too small, or do not exhibit hazardous behaviour such as flocking.

Bird and bat species which are assessed as being likely to pose the greatest hazard to aircraft at the Badgerys Creek and or Holsworthy sites are listed in *Table 4.1*.

Table 4.1 Bird and Bat Species which Pose Greatest Hazard to Aircraft

Common Name	Scientific Name
Bird Species	
Black Swan	*Cygnus atratus*
Australian Wood Duck	*Chenonetta jubata*
Pacific Black Duck	*Anas superciliosa*
Grey Teal	*Anas gracilis*
Australian Pelican	*Pelecanus conspicillatus*
White-faced Heron	*Egretta noveahollandiae*
Australian White Ibis	*Threskiornis molluca*
Straw-necked Ibis	*Threskiornis spinicollis*
Whistling Kite	*Haliastur sphenurus*
Swamp Harrier	*Circus approximans*
Wedge-tailed Eagle	*Aquila audax*
Masked Lapwing	*Vanellus miles*
Silver Gull	*Larus novaehollandiae*
Yellow-tailed Black Cockatoo	*Calyptorhynchus funereus*
Galah	*Cacatua roseicapilla*
Sulphur-crested Cockatoo	*Cacatua galerita*
Common Starling	*Sturnus vulgaris*
Bat Species	
Grey-headed Fruit Bat	*Pteropus poliocephalus*

Some of these species, such as the Black Swan, Australian Pelican and Wedge-tailed Eagle have been included because of their large size, even though the likely populations of these species at or near any of the airport sites is expected to be low. Silver Gull numbers and activity can increase rapidly in response to increased availability of foodstuffs, which may be associated with changes in land use. The Silver Gull has therefore been included even though Silver Gulls are uncommon in the areas studied or do not occur at present.

4.5.2 POPULATIONS AND MOVEMENTS

Waterbirds

Both Holsworthy sites are entirely forested with little, if any open water habitat. Black Swan, Australian Wood Duck, Pacific Black Duck, Grey Teal and Australian Pelican either do not presently occur at Holsworthy or are uncommon.

Most of the open water habitats at Badgerys Creek are relatively small individual farm dams. Thus the number of waterbirds at any one location is likely to be small. Many of the dams are unsuitable for swan and pelican. Swan and pelican numbers are likely to be in tens rather than hundreds Wood duck are likely to occur in hundreds rather than thousands. Black duck and grey teal numbers generally likely to be less than wood duck.

Except when disturbed, waterfowl usually move between feeding areas after dark. In Australia between 1985 and 1992 waterfowl comprised the majority identifications of feathers and other remains retrieved from civil aircraft after birdstrikes at night (Rowell, 1996).

Ducks, especially Wood Duck and Pacific Black Duck, may frequent short grass and sealed surfaces to feed, especially during periods of wet weather with local flooding.

Cormorants occur on dams at and near Badgerys Creek. Their numbers would be expected to be relatively low, however flocks of tens of cormorants may move across the Badgerys Creek airport option occasionally when moving between larger bodies of water in the region. Some of those movements could utilise thermal updrafts and occur at a significant height above ground. It is not expected that movements of cormorants would conflict with aircraft flight paths sufficiently often to pose a significant hazard to aircraft at either Badgerys Creek or Holsworthy.

Swamp and Grassland Birds

Swamp and grassland birds have been grouped together because a number of species frequent both swamps (or their margins) and grassland. These habitats are virtually absent from both Holsworthy Option A and Option B. However, some dams in the Badgerys Creek area have swampy margins and grassland covers the majority of the site.

Six species of herons and egrets may occur, however only the White-faced Heron is likely to frequent any of the proposed sites at Badgerys Creek and Holsworthy in sufficient numbers to cause a significant hazards to aircraft. This species could be expected to feed on grassland areas and in unlined drains at any of the airport sites. It is likely to occur in greater numbers or with greater frequency at Badgerys Creek than Holsworthy.

The White Ibis is a swamp margin species which has adapted to scavenging food in and around urban areas, particularly at garbage dumps and in parks. Consequently its population has increased significantly and is still increasing.

Small numbers of White Ibis occur at and near the Badgerys Creek site, but few, if any, at Holsworthy.

About 70 White Ibis were observed (P. Davidson) at the Lucas Heights waste disposal site on 10 January 1997, however up to about 200 may occur there at times (P. Lamont, 1996). White Ibis probably roost along the Georges River to the north-east of Lucas Heights and it is unlikely that they would conflict with aircraft flight paths for Holsworthy Option A.

Straw-necked Ibis prefer grasslands, but may occur at the edges of swamps and at garbage dumps. They often feed in large flocks, which may move between feeding areas by soaring on thermals. This species could occur at both Badgerys Creek and Holsworthy, but is more likely to occur in significant numbers at Badgerys Creek.

Masked Lapwings (often also referred to as Spur-winged Plover) occur in open short grasslands, estuaries, swamp margins and the edges of dams, usually in pairs or small family parties, but large flocks may form following the breeding season. Masked Lapwings would frequent airport grassed areas at both Badgerys Creek and Holsworthy, but are more likely to occur in significant numbers at Badgerys Creek.

Birds of Prey

Six species of diurnal birds of prey (eagles and hawks) are likely to occur at least one of the proposed airport sites sufficiently frequently to pose some hazard to aircraft. The Wedge-tailed Eagle may be a significant hazard because of its large size. While it is usually likely to occur only singly or in pairs, it may also occur in small family groups.

Whistling Kite and Swamp Harrier would be likely to occur more frequently than Wedge-tailed Eagle and are more likely to be struck by aircraft. It is extremely unlikely that an aircraft would collide with more than one, however they are large and may cause significant damage. Wedge-tailed Eagle, Whistling Kite and Swamp Harrier are likely to occur more frequently at Badgerys Creek than at Holsworthy.

Cockatoos and Parrots

Flocks of about 100 Yellow-tailed Black Cockatoos have been observed at Holsworthy and small groups at Badgerys Creek. A flock of these cockatoos would be a significant hazard to aircraft. Yellow-tailed Black Cockatoos do not feed on grasslands, but in trees and tall shrubs. They would only be a hazard to aircraft when flying across an active runway, or through aircraft flight paths. Such movements could occur when these birds move between feeding areas in surrounding forest. This is more likely to occur at Holsworthy than at Badgerys Creek. It is anticipated, however, that even at Holsworthy movement of Yellow-tailed Black Cockatoos across runway areas would be infrequent and may only occur at dawn and dusk.

Small flocks of Galahs and Sulphur-crested Cockatoos may occur at an airport at any of the proposed sites, but Galahs are more common at Badgerys Creek than at Holsworthy. Sulphur-crested Cockatoos can also occur in flocks on grassland, and in forest areas.

Urban and Garbage Dump Birds

A number of birds which occur at airports are commonly associated with urban development, including garbage dumps and other waste disposal facilities.

The White Ibis, which in its natural habitat frequents swamp margins, has been discussed above.

The Silver Gull is renown for its ability to thrive in and around urban areas. The population of this species has increased by a number of orders of magnitude since Captain Cook sailed up the east coast of Australia 230 years ago. Much of this increase has occurred in the last 50 years, as a result of the large amounts of garbage dumped at waste sites in the Sydney region. However, Silver Gulls are not common in the Badgerys Creek area and are rare in Holsworthy.

The presence of large numbers of gulls at a garbage dump in the vicinity of an airport usually results in a significant hazard to aircraft from flocks of gulls flying through aircraft flight paths or visiting the airport itself to feed or shelter.

Silver Gulls rarely occur at the Lucas Heights waste disposal site, in spite of the presence of large amounts of exposed putrescible wastes. This is remarkable, however gulls usually follow estuaries and water courses when flying between their overnight roost and feeding areas such as a garbage dump. Therefore most gulls feeding in western Sydney fly from Botany Bay along the Georges River, or along the Parramatta River from Homebush Bay and the harbour.

The elevated forested sandstone plateau on which the Lucas Heights waste site is located is not habitat preferred by gulls. Even so, it is possible that large numbers of Silver Gulls would visit the Lucas Heights site if it was the only significant source of waste foodstuffs in western Sydney. Silver Gulls would be likely to visit putrescible waste sites in the Badgerys Creek area, especially if there were no such sites closer to the coast.

Rock Dove ("Feral", "Domestic" or "Homing" Pigeon), Australian Raven, Common Starling and Common Myna also feed at putrescible waste sites, often in large numbers. Four to five hundred ravens have been observed at the Lucas Heights site at times (P. Lamont, 1996). All of these species also occur at airports.

Rock Dove, Starling and Myna are likely to occur in greater numbers at Badgerys Creek than at Holsworthy.

Fruit Bats

Fruit bats have been observed at Badgerys Creek, feeding in trees (Silky Oak *Grevillea robusta*) in gardens. Much larger numbers of fruit bats are likely at and near the Holsworthy airport options, which is the most extensive source of eucalyptus flowers, on which they predominantly feed. Fruit bats also feed on fruit in orchards at Darkes Forest, south of Holsworthy Military Area.

Bodies of fruit bats have been observed on the perimeter fence in the southern and south-eastern sections of the Holsworthy Military Area.

A fruit bat breeding colony is located at Cabramatta Creek, near Warwick Farm racecourse. Between 5,000 and 10,000 Grey-headed Fruit Bats occupy the site from September to March each year. This site is also used by smaller numbers of Little Red Fruit Bat as they migrate up and down the east coast (Tidemann, 1995). The number of Grey-headed Fruit Bats occupying this site has increased since 1993, with a maximum of about 28,000 being estimated in 1995 (Cullis, 1996). At the same time, the number of Grey-headed Fruit Bats in the Gordon colony declined.

There are other semi-permanent fruit bat camps at Brownlow Hill (near Camden), at Mt Kembla and at Jamberoo (Cullis, 1997a; Spence, 1997; Tidemann, 1997). Other small temporary day-time camps may occur in the Holsworthy area, but none are currently known.

A study of Grey-headed Fruit Bats fitted with radio transmitters at seven colonies between Grafton and Ulladulla between September 1987 and may 1989 concluded that bats flew up to about 17 kilometres from the Gordon colony to feed at night. The longest feeding range was 25 kilometres from Lismore to Nimbin Rocks. The study also showed that fruit bats move between colonies, the longest inter-colony movement being 750 kilometres. (Spencer et al, 1991).

More recent work on fruit bat feeding dispersal distances indicates that about 40 percent of fruit bats may fly more than 15 kilometres when dispersing from a camp to feed, about 25 percent more than 20 kilometres and that only about 5 percent disperse further than 35 kilometres (Tidemann, 1997).

The Cabramatta Creek fruit bat colony is about 20 kilometres east of Badgerys Creek, about 16 kilometres north of Holsworthy Option A and about 26 kilometres north of Holsworthy Option B. The southern end of Holsworthy Option B is about 32 kilometres from the Cabramatta Creek colony.

There is no data on the number of fruit bats which may feed in the Holsworthy area. If all 28,000 Grey-headed Fruit Bats from the Cabramatta Creek colony dispersed evenly to the south and south-east into the Holsworthy/Port Hacking area in the pattern outlined above, approximately 1,750 fruit bats could exist in the area of Holsworthy Option A. However, the actual number could be much less than this: the Cabramatta Creek colony usually has 5,000 - 10,000 fruit bats during the summer months and it is unlikely that all would disperse to the Holsworthy area. Fruit bats feeding in the Holsworthy area may also come from the Brownlow Hill and Mt Kembla camps.

In any case, it is clear that a significant number of fruit bats feed in the Holsworthy area at times, especially during summer. In addition to feeding movements, there may at times be migrations of fruit bats in the Holsworthy area. Only further research, perhaps using radio tracking, would permit a reasonable estimate of their total numbers, density, distribution and pattern of movements.

PART C: ASSESSMENT OF IMPACTS

5 OPERATIONAL IMPACTS

5.1 BIRD HAZARD ASSESSMENT

A variety of types of data can be useful in assessing probable bird and bat hazards to aircraft. These data include birdstrike reports, birdstrike rate per number of aircraft movements, flock densities and quantitative data on bird (and bat) populations and movements.

Unfortunately little, if any, of these data is available for the proposed Badgerys Creek and Holsworthy sites.

In assessing the bird hazard for a particular site a number of questions need to asked:

- What are the elements of the predicted bird hazard, taking into account species behaviour, populations, movements on the airport, locally and regionally?
- Is any aspect of that hazard likely to be significant?
- What elements of the bird hazard can be managed?

A particular bird hazard is considered to be 'manageable' if it is likely that environmental management or bird harassment techniques may be applied effectively.

5.2 BADGERYS CREEK

A summary of hazardous bird and bat activity at Badgerys Creek is as follows:

- no significant movements of birds or bats are expected;
- birds are likely to seek food and shelter at an airport, but they would probably be in "normal" numbers for airport grassland habitat;
- large flocks are expected to be uncommon. It is possible that flocks of ducks (especially Wood Duck), lapwings, ibis, and other grassland birds could inhabit the area, depending on season and conditions;
- some local waterbird and grassland bird movements are anticipated. Some of these will potentially involve flocks of soaring waterbirds and Ibis. These are probably not frequent, regular or sustained;
- some rural/urban bird problems could occur, particularly with rock dove (domestic pigeons); and

- small to moderate numbers of fruit bats could be expected to feed in the surrounding area at night. Their movements will probably be dispersed.

Important site characteristics are outlined below:

- surrounding land use is semi-rural with grassland, dams;
- airport drainage will consist of open unlined drains and detention basins. Soil drainage characteristics will be important in determining how long surface water is retained; and
- there appears to be no significant difference between runway options. there are no known defined regular significant bird or bat movements which may conflict with one runway orientation in comparison with another.

Hazard management issues are as follows:

- it may be difficult to effectively use some standard bird harassment techniques such as firing cracker shells, due to proximity of existing housing. This would be required especially near the airport perimeter, during night and early morning;
- the number of waterbirds at the site will be affected significantly by drainage (in particular detention basin) design and maintenance; and
- there is a potential problem with potential future waste disposal facilities in vicinity of the airport options.

Overall conclusions are that:

- the bird hazard is moderate, typical for site in open grassland/semi-rural setting;
- no special bird or bat hazards or significant hazardous bird or bat movements are anticipated; and
- there is no significant difference between the three Badgerys Creek options.

5.3 HOLSWORTHY OPTION A

A summary of hazardous bird and bat activity at Holsworthy Option A is as follows:

- lapwings, ibis and other grassland birds are likely to be present in small to moderate numbers. The are likely to be more manageable than at Badgerys Creek due to lack of suitable habitat surrounding the Holsworthy options;
- flocks of Yellow-tailed Black Cockatoos may cross runways, however this would probably occur infrequently. It may be manageable by harassing the birds with cracker shells; and

- fruit bats are likely to be a significant hazard to aircraft, especially during summer months. These movements are likely to be dispersed, but research into this aspect is required.

Important site characteristics are outlined below:

- the surrounding land is forested, with urban areas to north, north-east and north-west;
- airport drainage will consist of open unlined drains and detention basins. Soil drainage characteristics will be important in determining how long surface water is retained; and
- there appears to be no known defined regular significant bird or bat movements which may conflict with the proposed runway orientation.

Bird hazard management issues are as follows:

- Yellow-tailed black Cockatoos are probably manageable, but this will not be known without a study of cockatoo movements and perhaps clearing of the site;
- fruit bats would probably be difficult to manage;
- the number of waterbirds at the site will be affected significantly by drainage (in particular detention basin) design and maintenance; and
- there is a potential problem with existing and future waste disposal facilities in vicinity of Holsworthy Option A.

Overall conclusions are that:

- hazards from birds are moderate and probably less than at Badgerys Creek. The presence of Yellow-tailed Black Cockatoos is likely to be infrequent and manageable; and
- hazards posed by fruit bats are likely to be significant and difficult to manage.

The fruit bat hazard at Holsworthy Option A would probably be difficult to manager because:

- destruction of fruit bat camps at Cabramatta Creek and elsewhere would be difficult and unacceptable;
- destruction of all fruit bat food sources in the Holsworthy area would be difficult and unacceptable;
- fruit bats are difficult to detect at night;
- the fruit bats would probably be dispersed over large areas of the surrounding native forest;

- shooting and cracker shells have very limited effect on fruit bats in flight; and
- there are no other techniques which would prevent fruit bats from flying over or past the airport sites.

Removal of trees (food sources) from areas near the end of the runways for Obstacle Limitation Surface Clearing could possibly reduce the risk of bat strike.

5.4 HOLSWORTHY OPTION B

A summary of hazardous bird and bat activity at Holsworthy Option B is as follows:

- lapwings, ibis and other grassland birds are likely to occur in small to moderate numbers, perhaps fewer than at Holsworthy Option A. This problem is likely to be more manageable than at Badgerys Creek and Holsworthy due to lack of suitable habitat nearby;
- flocks of Yellow-tailed Black Cockatoos may cross runways, probably infrequently. This is probably manageable by harassing the birds with cracker shells, if necessary; and
- fruit bats are likely to be a significant hazard to aircraft, especially during summer months. Their movements are likely to be dispersed, but research into this aspect is required. This potential hazard is very difficult, if not impossible to manage.

Important site characteristics; runway orientation factors:

- the surrounding land is forested;
- airport drainage will consist of open unlined drains and detention basins. Soil drainage characteristics will be important in determining how long surface water is retained; and
- there appears to be no known defined regular significant bird or bat movements which may conflict with the proposed runway orientation.

Bird hazard management issues are as follows:

- Yellow-tailed black Cockatoos are probably manageable, but this will not be known without a study of cockatoo movements;
- fruit bats are probably an unmanageable problem;
- the number of waterbirds at the site will be affected significantly by drainage (in particular detention basin) design and maintenance; and
- there is a potential problem with existing and future waste disposal facilities in vicinity of Holsworthy Option B.

Overall conclusions are that:

- hazards from birds are moderate. The presence of Yellow-tailed Black Cockatoos is likely to be infrequent and manageable. The extent of hazards from birds is probably less than at Badgerys Creek and possibly less than Holsworthy Option A; and
- hazards posed by fruit bats are likely to be significant and difficult to manage.

The fruit bat hazard at the Holsworthy Option B would probably be difficult to manage for the same reasons as for Holsworthy Option A.

Removal of trees (food sources) from areas near the end of the runways for Obstacle Limitations Surface Clearing could potentially reduce the risk of bat strike.

PART D: ENVIRONMENTAL MANAGEMENT

6 ENVIRONMENTAL MANAGEMENT

Bird hazards at Badgerys Creek are likely to be moderate because although there are no significant movements of birds or bats known at present there is some potential for moderate activity of flocks of medium to large birds. The Badgerys Creek sites are likely to have few if any birds and, given current knowledge of bird activity, are not likely to have significant movements of birds or bats in the future.

The fruit bat hazard at the Holsworthy sites is likely to be significant because of the number of bats likely to be in potential conflict with aircraft, at least seasonally.

Bird Hazard Reduction

Bird hazards to aircraft can be minimised through improving aircraft design and construction, changing operating procedures and reducing bird activity on or near airports. Reducing bird activity can be achieved through careful airport site selection, design, construction, operation and maintenance; appropriate habitat management and land use planning on and near airports; and effective airport bird management procedures.

The bird hazard reduction techniques which may be available and effective at a particular airport are too numerous to detail.

An airport bird hazard management strategy and plan will need to be developed to apply environmental management principles as the basis of bird hazard management.

It is important that Commonwealth, State and Local government agencies should recognise the importance of sound land use planning and control in the vicinity of an airport as an effective means of minimising bird hazards to aircraft.

In particular, there should be land use controls on:

- pigeon lofts, and
- developments and facilities which may cause waste foodstuffs to attract birds.

The Civil Aviation Safety Authority has a vital role to play in the control of waste foodstuffs in the vicinity of airports, through Civil Aviation Regulation 96 (*Appendix 3*).

Appropriate and effective State and Local government legislation and planning controls should be used in preference to Civil Aviation Regulation 96 as the means for controlling waste foodstuffs in the vicinity of an airport. The judgement in the planning appeal by Pacific Waste Management Pty Ltd relating to its landfill site at Elizabeth Drive should be considered in this light,(10189 of 1994, Land and Environment Court of New South Wales - Talbot J, 24 February 1995).

If State and Local government planning controls are not effective in controlling waste foodstuffs, the Civil Aviation Safety Authority should make it clear that Civil Aviation Regulation 96 will be applied to any existing waste disposal sites in the vicinity of the airport site at the commencement of aircraft operations, if it is considered that waste foodstuffs may attract birds such as to pose a hazard or potential hazard to aircraft.

In summary, the following measures would be likely to assist in understanding and minimising potential bird and bat hazards to aircraft:

- detailed attention to airport design, operation and maintenance. In particular design and operation of drainage facilities, but including buildings, landscaping and waste disposal;
- conduct research into likely effect on bird populations of drainage detention design options, to provide sound basis for selecting appropriate design;
- develop and implement a site specific airport bird hazard management strategy and plan, including procedures for monitoring and assessing bird activity on and near the site;
- monitor land use planning in the vicinity of the site, especially waste disposal facilities. Negotiate changes to, or oppose as appropriate, all land use applications which may result in hazardous bird or bat activity;
- the airport operator should request the Civil Aviation Safety Authority to have Civil Aviation Regulation 96 applied as appropriate. This regulation enables waste foodstuffs in the vicinity of an airport to be controlled so as to reduce potential bird strike hazards; and
- regular independent review of bird hazard management procedures.

PART E: SUMMARY OF IMPACTS

7 SUMMARY OF ENVIRONMENTAL IMPACTS

7.1 BADGERYS CREEK

- A "normal" level of bird and bat hazard may be expected for the Badgerys Creek Options A, B and C.
- The bird hazard at this site should be manageable, using conventional techniques.

7.2 HOLSWORTHY

- There is little difference expected in bird and bat hazard between Holsworthy Option A and B. At both sites the bird hazard is expected to be moderate, and it is probably less than at Badgerys Creek.
- However fruit bats are likely to pose a significant hazard at night, especially during summer months at both sites. The fruit bat hazard is expected to be difficult to manage.

Monitoring of local and regional bird movements and land uses in the vicinity is important for both Badgerys Creek and Holsworthy.

Removal of trees (food sources) at the end of the runways as part of Obstacle Limitation Surface Clearing could potentially assist in reducing the risk of bat strike.

REFERENCES

AXIS Environmental/Australian Museum Business Service Consulting (1995), Appendix A, Report for the Department of Defence.

Fairfield City Council, 1995. Report on the Current State of the Flying Fox Colony at Cabramatta Creek Habitat. Environmental Control Branch,. August 1995.

Bureau of Air Safety Investigation 1992. Abbreviated Investigation Report (ICAO Style): British Aerospace BAe146 VH-NJQ, Adelaide Airport, South Australia. Department of Transport and Communications Report B/924/1007. 3 February 1992.

Christidis, L., & W.E. Boles. 1994. *The Taxonomy and Species of Birds of Australia and its Territories.* Royal Australasian Ornithologists Union Monograph No.2. RAOU, Melbourne.

Cullis, Sharyn. 1996. Cabramatta Creek Flying Foxes. Unpublished note dated 25 November 1996.

Cullis, Sharyn. 1997. Cabramatta Creek Flying Foxes. Unpublished note dated 30 January 1997.

Cullis, Sharyn. 1997a Personal communication January 1997.

Engel, David. Personal communication January 1997.

Higgins, P.J. and S.J.J.F Davies, (eds.). 1996. *Handbook of Australian, New Zealand & Antarctic Birds, Volume 3.* Oxford University Press. Melbourne.

Lamont P. Personal Communication, 1996.

Marchant, S. and P.J. Higgins, (eds.). 1990. *Handbook of Australian, New Zealand & Antarctic Birds, Volume 1.* Oxford University Press. Melbourne.

Marchant, S. and P.J. Higgins, (eds.). 1993. *Handbook of Australian, New Zealand & Antarctic Birds, Volume 2.* Oxford University Press. Melbourne.

Rowell, Alison. Personal communication 1996.

Schodde, R. and I.J. Mason. 1980. *Nocturnal Birds of Australia.* Lansdowne. Melbourne.

Spencer, H.J., C. Palmer and K. Parry-Jones. 1991. Movements of Fruit-bats in Eastern Australia, Determined by Using Radio-tracking. Wildl. Res. 18:463-8.

Strahan, R. (ed). 1983. *Complete book of Australian Mammals.* Angus & Robertson, Sydney.

Tidemann, C.R., and J.A. Spence. 1995. Flying-fox Camp on Cabramatta Creek. Research Report. School of Resource and Environmental Management, Australian National University. March 1995.

Van Tets, G.F., W.J.M. Vestgens, A.H. D'Andria and R. Barker. 1977. *Guide to the Recognition and Reduction of Aerodrome Bird Hazards*. Australian Government Publishing Service. Canberra.

Appendix 1

Species Lists

1. Badgerys Creek

1.1 *Flora and Fauna Assessment - Lot 2 Elizabeth Drive (Pacific Waste Management): Appendix C: List of Bird Species for the Study Area at Badgerys Creek.*

Notes whether recorded in or near the study area in December 1992; whether recorded on the Badgerys Creek airport site (1985). Does not give abundance.

1.2 *Location Bird List - Annangrove, Cumberland Bird Observers (to 29 November 1996)*

138 species, 46 visits. Records number of times species observed and gives % of times observed/total no. of observations (visits). Does not give abundance.

1.3 *Faunal Area External Report: 2 December 1996. Badgerys Creek. NSW National Parks and Wildlife Service.*

Species list only, with dates, observers. Does not give abundance.

1.4 *(Appendix F): Frequency of Occurrence and Status of Avifauna Located at the Proposed Airport Site at Badgerys Creek. (p586)*

Species list. Does not give abundance.

2. Holsworthy

2.1 *Holsworthy Military Area Land Capability Appraisal: Table 3: Bird Species Recorded from the Study Area. (Dames & Moore).*

Species list only. Does not give abundance.

2.2 *Holsworthy Training Area Environmental Audit: Main Report. Department of Defence.*

Species presence or absence by habitat. . Does not give abundance.

2.3 *Faunal Area External Report: 13 November 1996. Holsworthy Military Area. NSW National Parks and Wildlife Service.*

Species list only, with dates, observers. Does not give abundance.

2.4 *Bird Atlas records (10 minute blocks: 34°03'S 150°45'E; 34°03'S 150°55'E; 34°13'S 150°45'E; 34°13'S 150°55'E).*

2.5 *Voyager Point - Threatened Species Assessment: Table 3.2: Bird Species. ERM Mitchell McCotter.*

Species list only. 12 Species only. Does not give abundance.

2.6 *Birds Recorded at Wattle Grove: Table 2.1. ERM Mitchell McCotter, October 1996.*

Species list only. 12 Species only. Does not give abundance.

2.7 *Avifauna of the Wedderburn Plateau and Adjoining Lands: Appendix 2.*

Species list & sources, land unit association. Does not give abundance.

Appendix 2

Hazardous Bird and Bats Species

Table 1: Hazardous Bird Species

Species Common Name	Av Wt (g)	Badgerys Creek (Present)	Badgerys Creek (Post Development)	Holsworthy (Present)	Holsworthy (Post Development)
Black Swan	6000	U	U	-	U
Australian Wood Duck	800	C	C	-	U
Mallard	1700	C	C	-	U
Pacific Black Duck	1000	C	C	-	U
Grey Teal	500	C	C	-	U
Hardhead	900	U	U	-	U
Darter	1760	U	U	-	U
Little Pied Cormorant	800	U	U	-	U
Pied Cormorant	2100	U	U	-	U
Little Black Cormorant	1100	U	U	-	U
Great Cormorant	2400	U	U	-	U
Australian Pelican	5800	U	U	-	U
White-faced Heron	610	C	C	-	U
Little Egret	350	U	U	-	U
Great Egret	1000	U	U	-	U
Intermediate Egret	400	U	U	-	U
Cattle Egret	340	U	U	-	U
Australian White Ibis	1800	C	C	-	U
Straw-necked Ibis	1300	C	C	-	U
Whistling Kite	750	U	U	U	U
White-bellied Sea-Eagle	3000	U	U	-	U
Swamp Harrier	750	U	U	-	U
Wedge-tailed Eagle	3500	U	U	U	U
Brown Falcon	550	C	C	-	U
Nankeen Kestrel	170	C	C	-	U
Masked Lapwing	350	C	C	-	U
Silver Gull	320	U	U?	-	U?
Rock Dove	300	C	C	-	U
Glossy Black Cockatoo	430	-	-	U	U
Yellow-tailed Black Cockatoo	750	U	-	U	U
Galah	325	U	U	-	U
Little Corella	355	U	U	-	U
Sulphur-crested Cockatoo	785	C	C	U	U
Barn Owl	400	C	C	-	U
Australian Magpie	330	C	C	U	C
Australian Raven	590	C	C	U	C
Common Starling	70	C	C	U	U
Common Myna	100	C	C	-	U

Table 2: Hazardous Bat Species

Species Common Name	Av Wt (g)	Badgerys Creek (Present)	Badgerys Creek (Post Development)	Holsworthy (Present)	Holsworthy (Post Development)
Grey-headed Flying Fox	*700*	C	U	C	C
Little Red Flying Fox	360	U	U	U	U

Notes:

1. Species considered likely to be the most hazardous, on the basis of size, behaviour and probable abundance at one or more site have been highlighted in *italic* text.

2. Average weights are given as an indication of size. In some species there may be a wide range of weights and or an average weight difference between males and females, although the range of male and female weights may overlap. Weights have been derived from Higgins and Davies (1996), Marchant and Higgins (1990), Marchant and Higgins (1993), Rowell (personal communication), Schodde and Mason (1980), Spencer and others (1991) and Strahan (1983).

3. C = common U = unknown

Brief comments on each hazardous species:

Black Swan

- Likely to occur only in small numbers but may occur in flocks. Large size makes this species hazardous.
- Most movements at night, therefore little information on movements.
- Occurs on larger dams in vicinity Badgerys Creek from time to time.
- May be attracted to drainage detention basins, especially at Badgerys Creek.

Australian Wood Duck

- Often occurs in flocks.
- Occurs in moderate numbers at dams surrounded by grassland, especially pasture.
- Most movements at night, therefore little information on movements.
- May be attracted to drainage detention basins, especially at Badgerys Creek.

Mallard

- Likely to be in small numbers.
- Introduced duck which hybridises with Pacific Black Duck.
- Small numbers may occur on farm dams.

- Most movements at night, therefore little information on movements.

Pacific Black Duck

- Often in large flocks.
- Occurs in moderate numbers at dams, may not be as common as Wood Duck at Badgerys Creek.
- Most movements at night, therefore no information on movements.
- May be attracted to drainage detention basins.

Grey Teal

- Likely to occur in moderate numbers at dams. May occur in flocks.
- Most movements at night, therefore no information on movements.
- May be attracted to drainage detention basins, especially at Badgerys Creek.

Hardhead

- Likely to be in small numbers, but may occur in flocks.
- Most movements at night, therefore no information on movements.
- May be attracted to drainage detention basins, especially at Badgerys Creek.

Darter

- Likely to occur singly or in small numbers. May soar on thermals with cormorants and pelicans.
- Moves during day, but no information on movements.
- May be attracted to drainage detention basins.

Little Pied Cormorant

- Likely to occur singly or in small numbers. May soar on thermals with darter, other cormorants and pelicans.
- Moves during day, but no information on movements at these sites.
- May be attracted to drainage detention basins.

Pied Cormorant

- Likely to occur singly or in small numbers. May soar on thermals with darter, other cormorants and pelicans.

- Moves during day, but no information on movements at these sites.
- May be attracted to drainage detention basins.

Little Black Cormorant

- Likely to occur singly or in small numbers. May soar on thermals with darter, other cormorants and pelicans.
- Moves during day, but no information on movements at these sites.
- May be attracted to drainage detention basins.

Great Cormorant

- Likely to occur singly or in small numbers. May soar on thermals with darter, other cormorants and pelicans.
- Moves during day, but no information on movements at these sites.
- May be attracted to drainage detention basins.

Australian Pelican

- Occurs in moderate numbers, often in small flocks or groups. Soars on thermals.
- Moves during day, but no information on movements at these sites.
- May be attracted to drainage detention basins.

White-faced Heron

- Occurs in moderate numbers, often singly, however may also occur in small flocks or groups.
- Moves during day, but no information on movements at these sites.
- Attracted to dams and grasslands.
- May be attracted to drainage detention basins.

Little Egret

- Occurs in small numbers, often singly.
- Moves during day, but no information on movements at these sites.
- Attracted to swampy margins of dams.
- May be attracted to drainage detention basins

Great Egret

- Unlikely to occur in flocks.
- Singly or in small numbers around swampy margins of dams.
- Moves during day, but no information on movements at these sites.
- Detention basin design and maintenance important.

Intermediate Egret

- Singly or in small numbers around swampy margins of dams.
- Moves during day, but no information on movements at these sites.
- Detention basin design and maintenance important.

Cattle Egret

- May occur in flocks, but more usually in small numbers around swampy margins of dams and in pasture.
- Moves during day, but no information on movements at these sites.
- Detention basin design and maintenance important.

Australian White Ibis

- Flocks may soar on thermals. Often flies between roost and feeding areas in flocks.
- May occur singly or in small numbers around swampy margins of dams, but also may occur in large flocks.
- Population increasing in Sydney area. Large numbers often feed at garbage dumps.

Straw-necked Ibis

- Flocks may soar on thermals. Often flies between roost and feeding areas in flocks.
- May occur singly or in small numbers on pastures and grassland, but also may occur in large flocks (4-500).
- May feed at garbage dumps, but less commonly than white ibis.

Whistling Kite

- Soars on thermals.
- Singly, in pairs or small groups.

- Hunts over wetter grasslands and swamps.

White-bellied Sea-Eagle

- May soar to great heights when hunting, but not as high or for as long as wedge-tailed eagle.
- Individually or in pairs.
- Usually in vicinity of larger water storage dams and rivers, rather than over grassland.
- Reportedly observed at least as often as Wedge-tailed Eagle in Badgerys Creek area and more often in Holsworthy area.

Swamp Harrier

- Usually individually, but may occur in small groups.
- Margins of dams and swamps; wetter grasslands.

Wedge-tailed Eagle

- Often soars to great heights when hunting and patrolling breeding territory.
- Usually individually or in pairs, but may occur in small groups.
- Open pastures and timbered hills.

Nankeen Kestrel

- Singly or in pairs.
- Hunts over open grassland by hovering at heights up to about 30m above ground, depending on wind and terrain. Common at many airports.

Masked Lapwing

- Singly, in pairs, or in flocks.
- Breeds territorially in grasslands. Also margins of swamps, drains and rivers.
- Common at Australian airports.

Silver Gull

- Often in flocks, may soar on thermals.
- Few in Badgerys Creek area and rare in Holsworthy.

- Attracted to areas of water and public open space. Feeds at garbage dumps and public recreation areas. Will also feed in and over pastures. Avoids forested areas.

- Population in the Sydney region has increased one hundred fold or more over the last 40 years.

Rock Dove

- Often in flocks.

- High flock density.

- Open grassland near urban areas; buildings. Flocks of feral pigeons fed by people in urban areas, also feeds on weed seeds in disturbed grassland.

- Flocks of racing or homing pigeons may be released for exercise or for racing.

Glossy Black Cockatoo

- Small flocks.

- Restricted to forested areas, especially with she-oak.

- Likely to occur at Holsworthy in small numbers.

Yellow-tailed Black Cockatoo

- May occur in flocks up to about a hundred: 100 recorded by NSW Field Ornithologists Club, 20 May 1987; 120 recorded by P. Zammit, 13 June 1994 (NSW NPWS Fauna Area External Report: Holsworthy). Group of about 12 observed by a resident at southern end of Badgerys Creek site.

- Forest and heath, but also over grassland in rural areas to feed, including on radiata pine cones.

- No systematically gathered information on population size or movements.

Galah

- Likely to occur in pairs or small flocks.

- Not as common as inland.

- Seasonal, prefers grassland and woodland rather than forest.

Little Corella

- May occur in flocks. "Large flock heard" 23 December 1996 (D. Engel, 1997).

- Not as common as inland.
- Unlikely to occur in large numbers.
- Prefers open grasslands to forest.

Sulphur-crested Cockatoo

- May occur in flocks of a few hundred. "Large flocks" reported by resident at southern end of Badgerys Creek site.
- No systematically gathered information on population size or movements.
- Flocks more likely in grassland habitat rather than forest.

Australian Magpie

- Family groups, also loose flocks.
- Woodland and open grassland rather than forest.
- Not often struck by aircraft, even though moderately common at many aerodromes.

Australian Raven

- Often in groups and loose flocks.
- Woodland and open grassland rather than forest.
- Often feeds at garbage dumps in large numbers.
- Not often struck by aircraft, although moderately common at many aerodromes.

Common Starling

- Often in large, high density flocks.
- Open grassland. Also feeds at garbage dumps.
- Often forms very large roosts.

Common Myna

- Large numbers may be found around buildings, and nearby open grassland, especially if food scraps present or garbage dump nearby.

Grey-headed Flying Fox

- Feeds on flowering and fruiting trees in native forests, gardens and orchards.

- May occur in large numbers, but likely to be widely dispersed over forested areas.

- No significant day time camp known close to airport sites, however large breeding colony at Cabramatta Creek. Other significant camps at Brownlow Hill and Mt Kembla.

Little Red Flying Fox

- Feeds on flowering and fruiting trees in native forests gardens and orchards.

- May occur in moderate numbers, but likely to be widely dispersed over large area.

- No significant day time camp known close to airport sites.

- Larger numbers may fly over airport sites when migrating up or down coastal forest areas.

Appendix 3

Civil Aviation Regulation 96

Civil Aviation Regulation 96

96. (1) In this regulation "aerodrome" means:

(a) an aerodrome established under the Air Navigation Regulations;

(b) a place the use of which as an aerodrome is authorised:

- (i) by a licence granted under regulation 88; or
- (ii) by the Authority under regulation 89; or

(c) an aerodrome in respect of which an arrangement under section 20 of the Act is in force.

(2) Where the Authority is satisfied that the presence of waste foodstuffs in the vicinity of an aerodrome constitutes or may constitute such an attraction to birds as to create a hazard or potential hazard to aircraft using that aerodrome or flying in the vicinity of that aerodrome, the Authority may, by notice in the *Gazette*, declare that area to be an area of land to which this regulation applies.

(3) A person shall not leave waste foodstuffs on, or bring waste foodstuffs onto, an area of land to which this regulation applies.

Penalty: $5,000

(4) The Authority may, by notice in writing, require the owner of land on which waste foodstuffs are, being land within an area of land to which this regulation applies, to remove, within a time specified in the notice, the waste foodstuffs from his or her land to a place outside an area of land to which this regulation applies, or to deal, within a time, and in a manner, specified in the notice, with the waste foodstuffs.

(5) A notice under subregulation (4) may be served personally or by post.

(6) A person shall not fail to comply with the requirements of a notice served on him or her under subregulation (4).

(7) If a person on whom a notice under subregulation (4) is served fails to comply with the requirements of the notice, an officer authorised for the purpose by the Authority may, with such assistance as is necessary and reasonable, enter upon the land and remove or deal with the waste foodstuffs.

Appendix C

Fuel Supply and Storage Risk Report

Second Sydney Airport Environmental Impact Statement
Hazard and Risk - Fuel Supply and Storage Risk Report

Department of Transport and Regional Development

Prepared by
Four Elements

Edited by:

PPK Environment & Infrastructure Pty Ltd

9 Blaxland Road
Rhodes NSW 2138
PO Box 248
Concord West NSW 2138
Australia

Telephone (61 2) 9743 0333
Facsimile: (61 2) 9736 1568

25 August, 1997
58H233A PR_2818

CONTENTS

	Page Number
1 INTRODUCTION	1-1
2 METHODOLOGY	2-1
2.1 SCOPE OF WORK	2-1
2.2 INFORMATION SOURCES	2-1
3 RISK ASSESSMENT CRITERIA	3-1
4 DESCRIPTION OF PROPOSED FUEL SUPPLY AND STORAGE	4-1
4.1 JET A1 FUEL SUPPLY PIPELINE	4-1
4.2 ROAD TRANSPORT OF AVGAS	4-2
4.3 AIRPORT FUEL DEPOT	4-2
4.4 NON- AIRCRAFT FUELLING FACILITIES	4-3
5 HAZARD IDENTIFICATION	5-1
5.1 HAZARDOUS PROPERTIES OF FUELS	5-1
5.2 ROAD TRANSPORT OF AVGAS	5-1
5.3 JET A1 FUEL SUPPLY PIPELINE	5-2
5.3.1 LAND USES IN THE VICINITY	5-2
5.3.2 SENSITIVE ENVIRONMENTAL RECEPTORS	5-3
5.3.3 IDENTIFICATION OF HAZARDOUS EVENTS AND SAFEGUARDS	5-4
5.4 FUEL STORAGE	5-5
5.4.1 LAND USES IN THE VICINITY	5-5
5.4.2 IDENTIFICATION OF HAZARDOUS EVENTS AND SAFEGUARDS	5-5
5.4.3 EFFECTS OF HEAT RADIATION ON PEOPLE	5-7
6 PRELIMINARY RISK ANALYSIS AND ASSESSMENT	6-1
6.1 JET A1 FUEL PIPELINE	6-1
6.1.1 CONSEQUENCE ANALYSIS	6-1
6.1.2 LIKELIHOOD ANALYSIS	6-2
6.1.3 RISK ASSESSMENT AND CONCLUSION	6-2
6.2 FUEL STORAGE	6-2
6.2.1 CONSEQUENCE ANALYSIS	6-2

6.2.2 Likelihood Analysis 6-4
6.2.3 Risk Assessment and Conclusion 6-4

7 Risk Mitigation 7-1

7.1 Introduction 7-1
7.2 Planning Stage 7-1
7.3 Design Stage 7-1
7.4 Construction Stage 7-2
7.5 Operational Stage 7-2

References R-1

1 INTRODUCTION

Four Elements, part of the ERM Mitchell McCotter Consulting Group, was commissioned by PPK Environment & Infrastructure Pty Ltd to undertake a risk assessment of proposed fuel pipelines and storages associated with the Second Sydney Airport Options.

The aim was to assess the risk associated with the supply of fuel to the airport, and the storage of fuel, oil and lubricants at the airport sites from a land use safety planning viewpoint.

2 METHODOLOGY

2.1 SCOPE OF WORK

A number of options have been explored for supply of aviation fuel to the Second Sydney Airport. Options available for supply of Jet A1 fuel to the airport options are by road, rail or direct pipeline from a refinery or storage facility.

According to Second Sydney Airport Planners (1997c), Jet A1 fuel would most likely be supplied to the airport via a dedicated fuel pipeline.

Construction and operation of the fuel supply pipeline would be the subject of a separate environmental impact assessment process under New South Wales legislation. Nevertheless, a preliminary hazard and risk analysis has been undertaken here, based on conceptual design information available at this stage. Preliminary details of the pipeline and its route are provided, and the hazards are identified. The nature and scale of potential accidents and the likelihood of accidents are discussed. Safeguards and other risk mitigation measures recommended for implementation in the subsequent stages of the project are outlined.

AvGas, which has limited usage, would be supplied to the airport in road tankers, as is currently done for Sydney and Bankstown Airports. Preliminary details of road transport are provided in this report and potential risks are discussed.

Details of the quantities and types of fuel, oil and lubricants stored at the airport are provided, and the nature and scale of potential accidents and the likelihood of such accidents is discussed. Land uses in the vicinity of the airport sites are identified and a qualitative discussion on risks to people is provided. Safeguards and other risk mitigation measures recommended for implementation in the subsequent stages of the project are outlined.

2.2 INFORMATION SOURCES

Preliminary details of the fuel supply via pipeline and road, and the storage of fuel, oil and lubricants were provided in the *Regional Infrastructure Report* (Second Sydney Airport Planners, 1997c).

3 RISK ASSESSMENT CRITERIA

The objective of a risk assessment at the planning stage is to assess the hazards and risks to various land uses in the vicinity of the pipeline route or the fuel storage facilities at the airport.

The New South Wales Department of Urban Affairs and Planning has developed qualitative and quantitative risk assessment criteria for land use safety planning, as outlined in *Table 3.1*. These criteria would be applicable to both the fuel supply pipeline along its route and fuel storage facilities at the airport.

Different quantitative criteria are applicable to different land uses, as summarised in *Table 3.1*.

TABLE 3.1 SUGGESTED INDIVIDUAL FATALITY RISK CRITERIA

Land Use	**Individual Fatality Risk (per million per year) Should Not Exceed**
Hospitals, schools, child-care facilities, old age housing	0.5
Residential, hotels, motels, tourist resorts	1
Commercial developments including retail centres, offices and entertainment centres	5
Sporting complexes and active open spaces	10
Industrial	50

Source Department of Urban Affairs and Planning, 1990.

The Department has also suggested risk assessment criteria for individual injury risk in residential areas, and for risk of property damage and accident propagation in a neighbouring industrial operation.

4 DESCRIPTION OF PROPOSED FUEL SUPPLY AND STORAGE

4.1 JET A1 FUEL SUPPLY PIPELINE

Some typical details of a Jet A1 pipeline are shown on *Table 4.1*. These details were obtained in discussions with Second Sydney Airport Planners.

TABLE 4.1 PIPELINE DESIGN AND OPERATIONS DETAILS

Description	Detail
Material of construction	Steel
Design standard	ANSI/ASME B 31.4 1992 Liquid Transportation Systems for Hydrocarbons
Diameter	300 mm
External corrosion protection	Epoxy lined
	Yellow jacket coating
	Cathodic protection
Third party damage protection	Buried in road shoulder
	Warning signs above ground
	Pipe tiles
	1 metre wide easement restrictions
Bridge crossings	Connected to bridge by brackets or placed in service trenches in the deck
Separation from other services	Minimum separation of 1 metre
Fluid	Jet A1 fuel (Class 3 PG III Flammable liquid)
Throughput	1.5 million litres/day (1st stage)
	8 million litres/day (masterplan stage)
Pumping rate	Assumed 350-400 m^3/hr at masterplan stage
Operator	Consortium of oil companies

The route options to each of the airport sites are shown in Second Sydney Airport Planners (1997c).

The pipeline to Badgerys Creek Options would be either routed from Clyde refinery via the M4 Motorway, the Western Sydney Orbital and Elizabeth Drive or via a shorter route from the Plumpton storage facility near Blacktown.

The pipeline route to the two Holsworthy Options would also follow the M4 Motorway and the proposed route of the Western Sydney Orbital. Where the Western Sydney Orbital would intersect with the M5 Motorway/Hume Highway, the pipeline would follow the airport access road to Holsworthy Option A, or the Hume Highway to the Holsworthy Option B airport access road.

4.2 ROAD TRANSPORT OF AVGAS

The demand for AvGas for piston engined aircraft for general aviation and regional airline is very small compared with the jet fuel requirements. For the masterplan stage development a total of 30,000 - 35,000 litres per day would be required. Stage 1 demand would be 10,000 to 15,000 litres per day.

AvGas is only manufactured at the Shell Refinery at Geelong in Victoria, and would be supplied to the Second Sydney Airport by road tankers. This is currently the case for Bankstown and Sydney Airports.

The road tankers would be either standard 40,000 litre tankers or B Double 55-58,000 litre tankers. The routes to be followed would be approved B Double/Tanker routes as specified by the Roads and Traffic Authority (Second Sydney Airport Planners, 1997c).

4.3 AIRPORT FUEL DEPOT

The fuel depot would cater for the requirements of jet and piston engined aircraft. Fuel, oil and lubricants would be stored at the depot. The location of the depot is not beneath flight paths for any airport option. It would contain the following facilities:

- three 5 million litre Jet A1 fuel storage tanks in the first stage. Three additional 10 million litre storage tanks would be required for the masterplan airport. All tanks would be cylindrical, constructed in steel, and installed above ground in a tank farm. Fuel supply to the tanks would be from the airport fuel supply pipeline. Containment bunds would be sized to comply with dangerous goods regulations. State-of-the-art leak detection systems would be fitted to the system. Each tank would be provided with a base foam injection and deluge system for fire fighting;

- pumping facilities for delivery of Jet A1 fuel to aircraft. Jet A1 fuel would be delivered to aircraft by a system of underground pipes with hydrant points at each aircraft gate and some or all stand-off positions.

- four underground AvGas storage tanks of 110, 000 litres capacity each. Tanks would be constructed in steel with fibreglass outer lining for corrosion protection. Supply to the tanks would be by road takers;
- AvGas road tanker access, loading/unloading facilities and car park;
- lubricating and hydraulic oil storage;
- administration building and staff amenities; and
- laboratory.

The design and operational requirements of such facilities are stringent and covered by relevant Australian Standards and Civil Aviation Regulations. These facilities would be operated under a joint operator arrangements similar to those existing at other major airports in Australia.

4.4 NON- AIRCRAFT FUELLING FACILITIES

Fuelling facilities would also be provided on both airside and landside for airport based equipment and vehicles. In addition, there would be one or more service stations for public use. Such facilities would dispense LPG, petrol, diesel fuel and lubricating oils and may also undertake vehicle servicing. The design and operating standard of these facilities would be similar to a commercial service station.

5 HAZARD IDENTIFICATION

5.1 HAZARDOUS PROPERTIES OF FUELS

The *Australian Code for the Transport of Dangerous Goods by Road and Rail* (Commonwealth of Australia, 1992) provides criteria for the classification of dangerous goods according to the predominant type of hazard involved.

With certain exceptions, liquids with flash point below 61 degree Celsius are classified as Class 3 - Flammable Liquids. There are three Packaging Groups within Class 3 designated in decreasing order of hazard by Roman numerals 'I' (greatest danger), 'II' (medium danger), and 'III' (minor danger).

Jet A-1 fuel has a flash point of approximately 40 degree Celsius, an initial boiling point of approximately 150 degree Celsius and is classified as Class 3 Packaging Group III.

AvGas has a flash point of - 40 degree Celsius, an initial boiling point of approximately 30 degree Celsius, and is classified as Class 3 Packaging Group I.

Petrol is classified as Class 3 Packaging Group II.

Diesel is not classified as dangerous goods within the Australian Dangerous Goods Code. However diesel is classified as a combustible liquid Class C1 according to the *Australian Standard for the Storage and Handling of Flammable and Combustible Liquids, AS 1940* (Standards Australia, 1993).

5.2 ROAD TRANSPORT OF AVGAS

For the masterplan stage development a total of 30,000 - 35,000 litres of AvGas per day would be required. This demand could be met with less than one standard tanker per day. The small number of tanker movements indicates that the risks associated with AvGas road transport is unlikely to be significant.

The Department of Urban Affairs and Planning has developed guidelines for the identification of industrial developments which require a consideration of hazards and risks associated with road transport of hazardous materials (Department of Urban Affairs and Planning, 1994). For Class 3 Packaging Group I materials, transport risks are not considered to be significant where cumulative annual traffic movements are less than 500 and peak weekly traffic movements are less than 30. Therefore, AvGas transport risks are not considered any further.

5.3 JET A1 FUEL SUPPLY PIPELINE

5.3.1 LAND USES IN THE VICINITY

The population group closest to the pipeline would be road users. Although some road users could be present at any given time, no single road user is likely to be exposed to risks from the pipeline continuously.

Table 5.1 shows the land uses along various sections of the fuel supply pipeline for the Badgerys Creek airport options.

TABLE 5.1 PIPELINE TO BADGERYS CREEK OPTIONS - LAND USES

Section No.	Section	Approximate Length (Kilometres)	Land Use
1	From Clyde Refinery in Parramatta to Eastern Creek via M4	18.5	suburban
1′	From Plumpton storage facility to Eastern Creek	8	suburban
2	From Eastern Creek to Cecil Park via Western Sydney Orbital	10	mostly rural
3	From Cecil Park to Badgerys Creek via Elizabeth Drive	11	mostly rural

Notes:
1. Source: Land uses identified from Cities for 21st Century, Department of Urban Affairs and Planning, 1995
2. Section 1′ is alternative to Section 1.

Land uses along various sections of the fuel supply pipeline for the Holsworthy Options are shown on *Table 5.2*.

TABLE 5.2 PIPELINE TO HOLSWORTHY OPTIONS - LAND USES

Section No.	Section	Approximate Length (Kilometres)	Land Use
1	From Clyde Refinery in Parramatta to Eastern Creek via M4	18.5	suburban
1′	From Plumpton storage facility to Eastern Creek	8	suburban
2	From Eastern Creek to Cecil Park via Western Sydney Orbital	10	mostly rural
4	From Cecil Park to Casula via Western Sydney Orbital	22	Suburban
5A	From Casula to Holsworthy Option A	12	rural
5B	From Casula to Gilead via Hume Highway	47	suburban
6	From Gilead to Holsworthy Option B	10	rural

Notes:
1. Source: Land uses identified from Cities for 21st Century, Department of Urban Affairs and Planning, 1995
2. Section 1′ is alternative to Section 1.

5.3.2 SENSITIVE ENVIRONMENTAL RECEPTORS

Sensitive environmental receptors along the various sections of the pipeline are shown on *Table 5.3*.

TABLE 5.3 SENSITIVE ENVIRONMENTAL RECEPTORS IN THE VICINITY OF PIPELINE ROUTE

Section No.	Section	Receptor	Minimum Separation (metres)
1	From Clyde Refinery in Parramatta to Eastern Creek via M4	Prospect Reservoir	500
1′	From Plumpton storage facility to Eastern Creek	None identified	-
2	From Eastern Creek to Cecil Park via Western Sydney Orbital	Warragamba pipeline, Upper canal	Crosses
3	From Cecil Park to Badgerys Creek via Elizabeth Drive	None identified	-
4	From Cecil Park to Casula via Western Sydney Orbital	None identified	-
5A	From Casula to Holsworthy Option A	Georges River	Crosses
5B	From Casula to Gilead via Hume Highway	Upper Canal	Crosses
6	From Gilead to Holsworthy Option B	Georges River	Crosses

Notes: 1. From a review of UBD maps.

5.3.3 IDENTIFICATION OF HAZARDOUS EVENTS AND SAFEGUARDS

Pipelines are a safe and conventional mode of transporting petroleum. The engineering technology is well understood. However, hazardous incidents could occur if the pipeline leaks, and if the spilled fuel is ignited. Leaks from properly designed, constructed, operated and maintained pipelines are rare and are primarily caused by inadvertent damage by third parties using earth moving equipment. Other less likely causes include external, internal and stress corrosion, material and construction defects, weather, ground movement, incorrect operation, equipment failure, and sabotage.

Table 5.4 is a Hazard Identification Word Diagram showing the hazardous events identified, their typical causes, possible consequences and the safeguards required.

TABLE 5.4 HAZARD IDENTIFICATION WORD DIAGRAM FOR FUEL PIPELINE

Hazardous Event	Typical Cause	Possible Consequences	Safeguards
Small leak (10 mm hole)	Corrosion. Material defects. Weather.	Liquid pool formed. Some chance of pool fire.	External corrosion: epoxy lining, yellow jacket coating and cathodic protection provided. Internal corrosion: Fluid is clean. Material defects would be detected during testing prior to operation. Pipeline to be designed to withstand environmental influences.
Major leak. (25-50mm hole)	Third party interference	Chance of liquid jet formation. Liquid pool formed. Chance of jet fire. Chance of flash fire. Chance of pool fire. Heat radiation effects on people.	Warning signs would be placed above ground. Pipeline easement restrictions would apply. Risk of third party interference at different sections of the route to be assessed and adequate pipe wall thickness and depth of cover to be provided. The public along the route to be notified about the presence of pipeline and its hazards. Pipeline route to be patrolled at regular intervals. Authority to permit work near easement to be coordinated. Consideration to be given to providing a leak detection system. Emergency response plan to be prepared. Emergency contact telephone numbers to be made available. Isolating valves to be provided at appropriate distances and locations. Consider providing remotely activated valves.
Pipeline rupture.	Corrosion. Third party interference. Material defects. Weather.	Liquid pool formation. High chance of fireball, flash fire and pool fires. Heat radiation effects on people. Escalation to adjacent facilities.	As for small and medium leaks outlined above. Confirm risk levels comply with criteria for various land uses in the vicinity.

5.4 FUEL STORAGE

5.4.1 LAND USES IN THE VICINITY

Distances to the nearest residential area outside the airport boundary from the fuel storage facilities at each airport option are shown in *Table 5.5*.

Also shown in *Table 5.5* are the distances to the airport boundary from the fuel storage depot. Since risk levels reduce at distances away from hazardous facilities, the risk levels at the boundary are the highest that a person outside the boundary could be exposed to. It is usual for risk assessments to evaluate risks at the site boundary.

There would be areas within the airport boundary where members of the public and other airport facilities could be exposed to risks from the fuel storage facilities. It is therefore relevant to identify such areas. Some relevant areas are identified, and the separation between the fuel storage depot and these areas is shown on *Table 5.5*.

TABLE 5.5 SEPARATION DISTANCES (METRES) TO PEOPLE OFF-SITE AND ON-SITE

	Badgerys Creek Option			Holsworthy Option	
Distance to	**A**	**B**	**C**	**A**	**B**
Nearest residential area	>100	>600	>600	> 1,500	>1,500
Nearest boundary	50	600	600	1,500	425
Public Road	50	380	360	75	50
Airport Terminal Area	700	1,000	1,000	1,750	75
Nearest on-site facility	50	100	100	150	50

Notes:
1. Source: Masterplan drawings.
2. Distances are approximate.

5.4.2 IDENTIFICATION OF HAZARDOUS EVENTS AND SAFEGUARDS

The storage and handling of fuels on site has the potential to give rise to a range of types of flammable incidents. In such installations, more serious incidents are relatively rare and the more common types of incidents are relatively minor.

Table 5.6 is a Hazard Identification Word Diagram showing the hazardous events identified, their typical causes, possible consequences and the safeguards required.

TABLE 5.6 HAZARD IDENTIFICATION WORD DIAGRAM FOR FUEL STORAGE FACILITY

Hazardous Event	Typical Cause	Possible Consequences	Safeguards
		JET A1 TANK FARM AREA	
Minor spill/leak	Flange leak. Nozzle failure. Tank or pipeline valve leak. Human error.	Evaporation of flammable liquid. Pool fire if ignited. Escalation to major event.	Design facilities to minimise potential for leak. Minimise potential for leaks/spills during operations. Control ignition sources. Ensure leaks drain away from sensitive equipment. Leak detection is provided. Provide means of isolation of fuel.
Large spill/leak	Tank overfilling. Catastrophic equipment failure. External events.	Spilled liquid contained within bund. Evaporation of flammable liquid. Flash fire if vapour is ignited. Bund fire if spilled liquid is ignited. Escalation to major event.	Control systems to be designed, maintained, and tested to prevent overfilling during operations. Bunding is provided. Leak detection is provided. Provide means of isolation of fuel supply. Control ignition sources.
Pool/Bund Fire	Ignition of liquid pool.	Heat radiation effects on people. Escalation to tanks and other facilities.	Provide fire detection systems. Provide adequate fire fighting facilities. Develop emergency response plans. Provide adequate training to staff.
Tank Fire	Other fires. External ignition sources.	Heat radiation effects on people. Escalation to other tanks and facilities.	Provide fire detection systems. Tanks are provided with base foam injection and deluge system for fire fighting. Control external ignition sources. Develop emergency response plans. Provide adequate training to staff.
		FUEL PUMPING	
Leaks under pressure.	Pump leak. Pipeline leak.	Liquid spray. Unconfined liquid pool. Pool fire if ignited.	As for leaks/spills in Jet A1 Tank Farm.
Liquid spray fire	Ignition of liquid spray.	Heat radiation effects on people. Escalation to other facilities.	As for pool/bund fires in Jet A1 Tank Farm.
		LOADING/UNLOADING AREA	
Minor spill/leak	Leak from hose or other equipment. Tanker overfilling.	As for minor leak in Jet A1 Tank Farm area.	As for minor leak in Jet A1 Tank Farm area.

Hazardous Event	Typical Cause	Possible Consequences	Safeguards
Major spill/leak	Hose rupture. Tanker overfilling. Tanker collision.	Unconfined pool formation. Evaporation of flammable liquid. Flash fire if ignited. Pool fire if ignited. Escalation to major event.	Bunding to be provided. Minimise potential for leaks during operations. Filling operations to be monitored. Control ignition sources. Provide means for fuel isolation.
Fire	Ignition of liquid pool.	As for fires in Jet A1 Tank Farm area.	As for fires in Jet A1 Tank Farm area.

A Jet A1 tank fire and bund fire would be the more serious events on the facility that could have long range heat radiation effects on people. Other events are likely to have short range effects.

5.4.3 EFFECTS OF HEAT RADIATION ON PEOPLE

The main effect of flammable incidents on human beings is injuries or fatalities due to exposure to heat radiation. These effects depend on the intensity of heat radiation and the duration of exposure.

Heat radiation intensity is considerably diminished by opaque barriers such as walls of buildings. People indoors are generally much less susceptible to the effects of heat radiation. People who are outdoors and not shielded by opaque structures are the most susceptible. In the open, heat radiation intensity diminishes rapidly with increasing distance from the source of fire. People can reduce the intensity of incident heat radiation by simply moving away or by shielding themselves, if such options are available.

Effects of exposure to different heat radiation intensities is shown on *Table 5.7*.

TABLE 5.7 EFFECTS OF HEAT RADIATION

Heat Radiation (kW/m^2)	Effect
1.2	Received from sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15 -20 seconds and injury after 30 seconds' exposure.
12.6	Significant change of fatality for extended exposure. High chance of injury.
23	Likely fatality for extended exposure and chance of fatality for instantaneous exposure.
35	Significant chance of fatality for instantaneous exposure.

Source: Department of Urban Affairs and Planning, 1992.

6 PRELIMINARY RISK ANALYSIS AND ASSESSMENT

Risk analysis requires a consideration of both the consequences as well as the likelihood of incidents.

6.1 JET A1 FUEL PIPELINE

A general discussion on the consequences and likelihood of hazardous incidents from liquid petroleum pipelines is provided below.

6.1.1 CONSEQUENCE ANALYSIS

Fuel released in a leak from the bottom of a pipeline may have sufficient momentum to remove earth cover and form a crater. Liquid would rise through the crater, spread around and form a pool.

Fuel released from the top half of the pipeline may have sufficient momentum to form a jet. The liquid falling back on the ground would form a pool. The jet could be ignited, resulting in a jet fire.

Vapour generated from the pool surface would disperse and could be within flammable limits at distances from the pool. The vapour could ignite and result in a flash fire, which in turn would start a pool fire. Fatalities from flash fires would be limited to those within the cloud envelope.

The consequences of pool fires depends on a number of factors, the most important being the dimensions of the liquid pool. Pipeline ruptures could result in large pool sizes, however the size attained by the pool is difficult to predict. Some amount of liquid may flow into road drainage system and may not contribute to the size of the pool. Road contours may also provide a physical barrier and prevent spreading.

An estimate of ignited pool fire diameter following a major leak or pipeline rupture is 25 metres and 50 metres, respectively. The distance to different heat radiation intensities from these pool fires is shown on *Table 6.1*.

TABLE 6.1 DISTANCE IN METRES TO HEAT RADIATION INTENSITY LEVELS

Pool Fire Diameter	4.7 kW/m^2	12.6 kW/m^2	23 kW/m^2	35 kW/m^2
25 metres (major leak)	47	29	21	17
50 metres (rupture)	94	57	42	34

The distance to 12.6 kilowatts per square metre (kW/m^2) from pool fires following a major leak or pipeline rupture is conservatively estimated to be about 30 metres and 60 metres respectively. The chance of a fatality beyond these distances is low. Effect distances for the other flammable incidents identified are expected to be within about 50 metres.

6.1.2 LIKELIHOOD ANALYSIS

Pipeline leaks or ruptures are rare. An estimate of historical frequency of major leaks and ruptures is 5×10^{-4} per kilometre per year and 5×10^{-5} per kilometre per year respectively. New pipelines that are designed, installed and operated to similar or improved standards are expected to have a lower failure rate.

Not all fuel leaks ignite. Although the probability of ignition is somewhat higher in urban areas than in rural areas because of the higher number of ignition sources in urban areas, the probability of ignition is less than 1. The frequency of flammable incidents is obtained by multiplying the pipeline failure frequency by the probability of ignition, and would be lower than the pipeline failure frequency.

6.1.3 RISK ASSESSMENT AND CONCLUSION

A previous risk analysis of a jet fuel pipeline in Sydney indicated that the fatality risk directly above the pipeline was less than 0.5×10^{-6} per year (Cleland, 1990) and was thus well within Department of Urban Affairs and Planning criteria.

Based on past risk assessments and preliminary estimates of consequences and likelihood of flammable incidents, it is concluded that the proposed Jet A1 fuel pipeline could be designed, constructed and operated such that risk levels are within acceptable limits for various land uses in the vicinity of the pipeline. The risk to sensitive environmental receptors could also be controlled within acceptable limits.

6.2 FUEL STORAGE

For this preliminary study, only the more serious incidents, such as a Jet A1 tank fire and a bund fire have been considered.

6.2.1 CONSEQUENCE ANALYSIS

The consequences of pool fires, such as tank fires and bund fires, depend on a number of factors:

- the geometric characteristics of the pool fire, that is., the burndown rate and the physical dimensions of the fire;
- the intensity of thermal radiation emitted by the pool fire, which depends mainly upon fuel type and fire size; and
- the distance and orientation of the observer in relation to the fire.

The supply of oxygen becomes less efficient for larger diameter pool fires, resulting in less radiant and more smoky fire. However, the supply of oxygen could increase with wind speed, and this could result in brighter and more radiant flame.

For this preliminary analysis, the following assumptions have been made:

Jet A1 tank diameter:	25 metres (10 million litre tank);
Bund fire equivalent diameter:	50 metres.

Other data used in calculations are:

Burn down rate for Jet A1 pool fire:	4.2 mm/minute (Mudan, 1984);
Fraction of combustion energy radiated:	10 percent (Mudan, 1984);
Specific gravity:	0.79;
Heat of combustion:	48,000 kJ/kg; and
Height of flame:	2 x pool diameter (Mudan, 1984).

The distance to different heat radiation intensities from tank and bund fires is shown on *Table 6.2*.

TABLE 6.2 DISTANCE IN METRES TO HEAT RADIATION INTENSITY LEVELS

Event	4.7 kW/m^2	12.6 kW/m^2	23 kW/m^2	35 kW/m^2
Tank fire	47	29	21	17
Bund fire	94	57	42	34

The distance to 12.6 kW/m^2 from tank or bund fires is conservatively estimated to be about 30 metres and 60 metres respectively. In the event of tank or bund fire, the chance of fatality beyond these distances is low.

Because of the separation between the airport fuel depot and people on and off site, the chance of fatality during a tank or bund fire outside the fuel depot is considered to be low.

6.2.2 LIKELIHOOD ANALYSIS

The tank farm would be provided with state-of-the-art leak detection systems. Base foam injection systems and deluge systems would be provided for fire fighting. In view of these safeguards, the likelihood of significant tank or bund fires would be low.

6.2.3 RISK ASSESSMENT AND CONCLUSION

Based on preliminary estimates of consequences and likelihood of flammable incidents, it is concluded that the proposed fuel storage depot could be designed, constructed and operated such that risk levels are within acceptable limits for various land uses in the vicinity of the depot. The risk to sensitive environmental receptors could also be controlled within acceptable limits.

7 RISK MITIGATION

7.1 INTRODUCTION

The requirements for hazard and risk management for hazardous facilities and pipelines are well understood. These requirements encompass the planning, design, construction, and operational stages of the project, and are detailed in Statutory Regulations, Government Guidance Notes, Australian and International Standards, and industry practices. Some relevant documents include the National Standard for the Control of Major Hazard Facilities (NOHCS:1014, 1996), and the New South Wales Department of Urban Affairs and Planning's Hazard Industry Planning Advisory Papers.

7.2 PLANNING STAGE

The requirement at the planning stage is to ensure that the location of the pipeline and fuel storage facilities are compatible with land uses in the vicinity. The preliminary assessment undertaken indicates that it would be possible to design and locate the pipeline and fuel storage facilities such that risk levels are within appropriate limits. A separate quantitative risk assessment would be required as part of the separate environmental assessment of the pipeline, to confirm that risks levels are acceptable for various land uses and sensitive environmental receptors in the vicinity of the pipeline route. Societal risk levels from the pipeline may also need to be considered in that quantitative risk assessment.

The preliminary assessment undertaken here indicates that risk levels at residential areas from the fuel storage depot are within commonly accepted risk limits. A quantitative risk assessment may be required to confirm that the risk levels from the fuel storage depot are within limits for other land uses planned in the vicinity.

7.3 DESIGN STAGE

The NSW Department of Urban Affairs and Planning requires certain studies to be undertaken in conjunction with the design of the facilities. The purpose of these studies is to ensure that the facilities are designed to appropriate standards and can be operated safely. These studies include:

- Hazard and Operability Study;

- Updated Hazard Analysis; and
- Fire Safety Study.

Such studies should be undertaken as part of the design of the pipeline and fuel storage facilities.

7.4 CONSTRUCTION STAGE

The Department of Urban Affairs and Planning requires that hazards associated with construction activities are addressed in a Construction Safety Study prior to construction. Such a study should be undertaken prior to construction of the pipeline and fuel storage facilities.

The National Standard for the Control of Major Hazard Facilities specifies requirements for Major Hazard Facilities. The requirements of this Standard should be complied with. A preliminary review of the requirements of this Standard indicates that the operator of fuel storage facilities would be required to notify the relevant public authority at least six months before construction commences.

7.5 OPERATIONAL STAGE

The Department of Urban Affairs and Planning requires that a comprehensive emergency plan and detailed emergency procedures be prepared prior to operations.

The Department of Urban Affairs and Planning also requires the operator to prepare a Safety Management System to ensure ongoing safety. This document specifies all safety related procedures, responsibilities and policies, along with details of mechanisms for ensuring adherence to procedures.

There is also the requirement for periodic independent hazard audit, and for reporting of incidents and near-misses. The requirements of the Department should be complied with.

The National Standard for the Control of Major Hazard Facilities specifies requirements for Major Hazard Facilities. The requirements of this Standard should be complied with. If the fuel storage facilities are classified as Major Hazard Facilities, the operator of fuel storage facilities would be required to submit a safety report prior to commencement of operation, among other requirements.

REFERENCES

Commonwealth of Australia (1992), *Australian Code for the Transport of Dangerous Goods by Road and Rail.*

Department of Urban Affairs and Planning (1990), Risk Criteria for Land Use Safety Planning, *Hazardous Industry Planning Advisory Paper No. 4.*

Department of Urban Affairs and Planning (1994), *Cities for the 21st Century.*

Second Sydney Airport Planners (1997c), *Regional Infrastructure Report,* prepared for the Commonwealth Department of Transport and Regional Development.

Standards Australia (1993), *Australian Standard for the Storage and Handling of Flammable and Combustible Liquids, AS1940.*

Appendix D

Preliminary Site Contamination Investigation Report

Second Sydney Airport Environmental Impact Statement Preliminary Site Contamination Investigation for Sites of Second Sydney Airport Options

---

Department of Transport and Regional Development

PPK Environment & Infrastructure Pty Ltd
9 Blaxland Road
Rhodes NSW 2138
PO Box 248
Concord West NSW 2138
Australia
Telephone: (612) 9743 0333
Facsimile: (612) 9736 1568

25 August, 1997
58H233A PR_1967

Contents

		Page Number
Part A:	Introduction	
Chapter 1	Introduction	1 - 1
	1.1 Scope of Work	1 - 1
	1.1.1 Badgerys Creek	1 - 1
	1.1.2 Holsworthy	1 - 1
	1.1.3 Limitations	1 - 2
Part B:	Existing Environment	
Chapter 2	Description of Airport Options	2 - 1
	2.1 Badgerys Creek	2 - 1
	2.1.1 Option A - The Original Proposal	2 - 1
	2.1.2 Option B - Expanding the Original Proposal	2 - 1
	2.1.3 Option C - North/South Alignment	2 - 1
	2.2 Holsworthy	2 - 1
	2.2.1 Option A (North)	2 - 2
	2.2.2 Option B (South)	2 - 2
Chapter 3	Results of Surveys and Analysis	3 - 1
	3.1 Consultation	3 - 1
	3.1.1 Badgerys Creek	3 - 1
	3.1.2 Holsworthy	3 - 1
	3.2 Review of Existing Information	3 - 1
	3.2.1 Badgerys Creek	3 - 2
	3.2.2 Holsworthy	3 - 3
	3.3 Review of Aerial Photographs	3 - 5
	3.3.1 Badgerys Creek	3 - 5
	3.3.2 Holsworthy	3 - 5

3.4 Site Inspections 3 - 7

3.4.1 Badgerys Creek 3 - 7
3.4.2 Holsworthy 3 - 9
3.4.3 Demolition Ranges and Impact Area E 3 - 10

Chapter 4 Physical Characteristics 4 - 1

4.1 Badgerys Creek 4 - 1

4.1.1 Topography 4 - 1
4.1.2 Geology 4 - 1
4.1.3 Hydrogeology 4 - 2

4.2 Holsworthy 4 - 2

4.2.1 Topography 4 - 2
4.2.2 Geology 4 - 2
4.2.3 Hydrogeology 4 - 3

Chapter 5 Field and Laboratory Program 5 - 1

5.1 Badgerys Creek 5 - 1
5.2 Holsworthy 5 - 1
5.3 Quality Assurance/Quality Control Procedures 5 - 2

Chapter 6 Assessment Criteria 6 - 1

6.1 Soils 6 - 1

6.1.1 Possible Criteria 6 - 1
6.1.2 Assessment Criteria Adopted 6 - 3

6.2 Surface Water 6 - 4

6.2.1 Possible Criteria 6 - 4
6.2.2 Criteria Adopted 6 - 4

Chapter 7 Results of Soil/Water Analysis 7 - 1

7.1 Soils 7 - 1

7.1.1 Heavy Metals 7 - 1
7.1.2 Organic Compounds 7 - 2

7.2 Surface Water 7 - 2

7.2.1 Heavy Metals 7 - 2
7.2.2 Organic Compounds 7 - 9

7.3 Quality Assurance/Quality Control Results 7 - 9

Part C: Assessment of Impacts

Chapter 8 Impacts of Contamination on Airport Options 8 - 1

8.1 Badgerys Creek 8 - 1
8.2 Holsworthy 8 - 1

Part D: Environmental Management

Chapter 9 Environmental Management 9 - 1

Chapter 10 Statement of Limitations and Restrictions 10 - 1

References R - 1

Photographs

List of Figures

Figure 3.1 Holsworthy Military Area - Zones with High Potential of Contamination 3-9

Appendices

Appendix 1 DLWC Records
Appendix 2 Chain of Custody Records
Appendix 3 Laboratory Certificates
Appendix 4 QA/QC Results
Appendix 5 RPD Values for Field Duplicate

Part A: Introduction

CHAPTER 1 INTRODUCTION

PPK conducted a preliminary contamination assessment of sites at Holsworthy and Badgerys Creek as part of preparation of the Draft EIS for the Second Sydney Airport.

1.1 SCOPE OF WORK

The scope of work for this investigation was as outlined below:

1.1.1 BADGERYS CREEK

- review available information regarding land contamination in the original master plan area and extended study area at Badgerys Creek. Information sources were expected to include the 1985 EIS and associated environmental studies;

- identify potential contaminating land uses associated with agriculture including intensive cropping or market gardening, on-site waste disposal and chemical storage facilities. Use aerial photos to assist in the identification of potentially contaminating land uses;

- complete physical inspections of potential "hot spots" and/or typical sites to gain an understanding of the type and extent of potential contamination in the study area;

- broadly identify migration pathways of potential contaminants by examining the geology, drainage pattern, hydrology and hydrogeology of the study area; and

- assess the likely significance of potentially contaminated materials and discuss management options which could be incorporated into the airport development process.

1.1.2 HOLSWORTHY

- review existing available information regarding land contamination in the Holsworthy Military Reserve. Information sources were expected to include the Holsworthy Training Area Environmental Audit Main Report (AXIS Environmental/Australian Museum Business Services Consulting, undated) and associated environmental studies, and discussions with Department of Defence staff at Holsworthy;

- verify locations of potentially contaminated areas reported in the AXIS Environmental/Australian Museum Business Services Consulting study. These were expected to include waste dumps and landfills, chemical and fuel storage facilities, areas filled by imported materials and demolition ranges. Aerial photos were used to assist in identifying features mentioned in the AXIS Environmental/Australian Museum Business Services Consulting study, and determine whether any other potentially contaminated areas existed;

- complete physical inspections of potential "hot spots" and/or typical sites to gain an understanding of the type and extent of potential contamination in the study area and collect representative soil and surface water samples from selected locations for testing;

- broadly identify migration pathways of potential contaminants by examining the geology, drainage pattern, hydrology and hydrogeology of the study area; and

- assess the likely significance of potentially contaminated materials and discuss management options which could be incorporated into the airport development process.

1.1.3 LIMITATIONS

The scope of work was designed to be of a preliminary nature. It was based on the premise that further sampling and analysis may be required in order to assess the extent of any contaminated areas prior to construction of an airport. This is consistent with accepted methodologies for assessing potential for site contamination and determining remediation measures.

The methodology for subsurface sampling was generally based on the NSW Environment Protection Authority's *Sampling Design Guidelines* (NSW Environment Protection Authority, 1995).

A small number of soil and surface water samples were collected from the Holsworthy Military Area. This was because no information was available about potential levels of contamination at the Holsworthy sites. This preliminary sampling was undertaken in areas where the impact of military activities was thought to be highest, to provide indicative chemical data on potential contaminant concentrations.

PART B: EXISTING ENVIRONMENT

CHAPTER 2 DESCRIPTION OF AIRPORT OPTIONS

2.1 BADGERYS CREEK

The three proposed options for the Second Sydney Airport at Badgerys Creek are as follows:

- Option A - the Original Proposal;
- Option B - Expanding the Original Proposal; and
- Option C - North/South Alignment.

2.1.1 OPTION A - THE ORIGINAL PROPOSAL

The preliminary master plan being considered by the EIS for Option A includes existing land owned by the Commonwealth and is generally based on the original runway layout developed for an EIS prepared in 1985. The approximate area of the site is 1,700 hectares.

2.1.2 OPTION B - EXPANDING THE ORIGINAL PROPOSAL

Option B is based on the Original Proposal, however it encompasses a greater overall area. The approximate area of Option B is 2,900 hectares.

2.1.3 OPTION C - NORTH/SOUTH ALIGNMENT

This option is also based on the Original Proposal and encompasses a greater area. The approximate area of Option C is 2,850 hectares.

2.2 HOLSWORTHY

The two proposed options for the Second Sydney Airport at Holsworthy are as follows:

- Option A - Northern Option; and
- Option B - Southern Option.

2.2.1 OPTION A (NORTH)

Option A is located near the centre of the Holsworthy Military Area and on the eastern side of Punchbowl Creek and its tributaries. The approximate area of this site is 4,200 hectares.

2.2.2 OPTION B (SOUTH)

Option B is located between O'Hares Creek and the Woronora Dam catchment. The approximate area of this site is 2,800 hectares.

CHAPTER 3 RESULTS OF SURVEYS AND ANALYSIS

3.1 CONSULTATION

3.1.1 BADGERYS CREEK

The Department of Transport and Regional Development indicated that the only known contaminated site on the existing land owned by the Commonwealth is at Lot 4, The Northern Road, Luddenham.

An interview with a contractor associated with the site located at Lot 4 The Northern Road, Luddenham indicated that remedial works at the property were in the final stages.

3.1.2 HOLSWORTHY

An interview was conducted with the Environmental Officer for the Department of Defence at Holsworthy, Ms Marina Peterson. Ms Peterson indicated that there was a potential for a wide range of contaminants associated with military activities to exist within the Holsworthy Military Area. Ms Peterson stated that these contaminants could potentially be located anywhere within the Holsworthy Military Area. This was because firing of ordnance had not been restricted to any specific areas.

Ms Peterson indicated that potential contaminants could include:

- heavy metals;
- explosives residues; and
- pyrotechnics residues.

She also mentioned the possible existence of small undocumented land fills within the Military Area.

3.2 REVIEW OF EXISTING INFORMATION

Brief summaries of relevant documents which were reviewed are provided in the following sections.

3.2.1 BADGERYS CREEK

Second Sydney Airport Site Selection Programme, Draft Environmental Impact Statement (Kinhill Stearns, 1985) *and Associated Studies.*

No mention was made of site contamination at Badgerys Creek or Holsworthy in the Draft Environmental Impact Statement. Information in the report provided no indications of soil contamination at any of the sites of the airport options.

Explorative Excavation of Buried Materials at Lot 4 The Northern Road, Luddenham, NSW ((Department of Administrative Services, Centre for Environmental Management (July 1995).

This report describes the location of contaminated soil and materials and remedial options at Lot 4 The Northern Road, Luddenham. The materials were dumped at the site by a former liquid waste contractor.

Contamination was reported to be limited to one particular area (the old quarry). Tar and diatomaceous earth mounds located on the property were also noted to be of environmental concern.

Contaminants of concern, which have been identified at the property in the report are:

- Polycyclic Aromatic Hydrocarbons;
- phenols;
- total petroleum hydrocarbons;
- benzene, toluene, ethylbenzene and total xylene (BTEX);
- sulphates; and
- heavy metals.

The report recommends that the contaminated material at the site be excavated and disposed to a secure landfill.

Status Report No. 4 (CL228): Badgerys Creek, Department of Administrative Services, Centre for Environmental Management (DASCHEM) December 1996

This report outlines remedial activities occurring at Lot 4 The Northern Road, Luddenham.

The report indicates estimated quantities of contaminated soils required for disposal to an appropriate licenced landfill facility. The report also indicates that the analysis of samples from the diatomaceous earth mounds for heavy metals showed concentrations exceeding Australian and New Zealand Environment and Conservation Council levels which were further considered capable of leaching to other areas.

Water from the dams was also reported to contain detectable concentrations of Polycyclic Aromatic Hydrocarbons and petroleum hydrocarbons, however the report stated that these concentrations were considered 'insignificant'.

Remediation Program - Lot 4 The Northern Road, Luddenham, NSW, for the Department of Transport and Regional Development - prepared by the DASCHEM, June 1997

The executive summary of this report indicates that contaminated soils which exceeded the 1992 Australia and New Zealand Environment and Conservation Council Guideline levels have been removed from the site. A small area of the site contains buried asphaltic cement, and future use of this part of the site may be restricted. However this material poses no risk to the environment or human health in its current location.

3.2.2 HOLSWORTHY

Holsworthy Training Area Environmental Audit, Main Report for the Department of Defence (AXIS/Australian Museum Business Services Consulting - 1995).

The report contains a brief section entitled "Site Contamination". Discussion on historical records is brief with mention of only the fire tender and early rescue facilities, foam store and battery room. These facilities are located in the Holsworthy base facilities to the north and are well outside the proposed boundaries of the airport options.

Potential sources of contamination over the Holsworthy Military Area as a whole were discussed in the report, including munitions and explosives, pyrotechnics, engineered landfills, imported railway ballast, imported coal waste and other imported material.

Other potential contamination sources were discussed including above ground storage tanks and fuel and chemical storage. The above ground storage tanks were indicated to be filled with water for fire fighting. They are not considered to pose any contamination risk, unless they were previously filled with other products.

Fuel and chemicals were indicated to be stored at the Range Control facilities, which are to the north and outside the boundary of the proposed airport options.

Drums of diesel were indicated to have been stored on the ranges during exercises and there are reports of some spillages. Drums of oil suspected of being waste sump oil were noted at grid reference 092380 (outside proposed airport boundaries).

Two engineered landfills are referred to in the report and indicated to be on the north and south sides of the "Complete Airfield". Although an exact location of these landfills was not shown in the report, the Complete Airfield is located well to the north and outside the sites of the airport options. The complete airfield and landfills are also expected to be located to the east and outside transport corridor options.

Other undocumented landfills are indicated to be located at unknown locations around the site. These could potentially exist within the sites of the airport options.

The report suggests that the following substances have been used at the Holsworthy Military Area and could have contaminated soils on the site:

- explosives which include MNT, DNT, and TNT, RDX, OCTOL, Amatol, CE, PETN, Nitrocellulose, Nitroglycerine, and Nitroguanidine;
- pyrotechnics such as illuminating compositions and signalling compositions;
- other potentially contaminating substances include heavy metals such as lead, mercury and aluminium.

The report indicates that some 20,000 tonnes of railway ballast has been imported into the Holsworthy Military Area since 1992, for road construction and maintenance purposes. Potential contaminants associated with the railway ballast material include heavy metals, sulphate, hydrocarbons and chemicals used to treat railway sleepers.

Coal wash was also reported to have been imported for road construction prior to 1993. The coal wash is considered potentially contaminating due to inherently high acidic levels and sulphate concentrations.

Military Area Master Plan (Peddle Thorp Architects, 1995)

This report focuses on the Holsworthy base facilities. There are few references to areas near the sites of the airport options. No useful information in relation to potential contamination was contained in this report.

3.3 REVIEW OF AERIAL PHOTOGRAPHS

Aerial photographs were inspected in order to assist in the assessment of previous land uses, possible filling of sites and areas generally that could potentially contain contaminated material.

3.3.1 BADGERYS CREEK

PPK inspected aerial photographs for the three combined options dated 1961, 1970, 1978, 1986 and 1994.

The 1961 and 1970 aerial photographs showed minimal farming and agricultural use with water storage dams. The majority of the site area appeared relatively vacant.

The 1978 photograph showed more extensive cultivation particularly in the south-west portion of the site.

The 1986 and 1994 aerial photographs showed an increase in agricultural land use since 1978. No significant land use changes were noted between 1986 and 1994.

3.3.2 HOLSWORTHY

Option A

PPK inspected aerial photographs for the site of Option A dated 1961, 1970, 1978, 1982, 1990 and 1994.

1961 and 1970

The 1961 and 1970 aerial photographs showed that the site had minimal disturbance with the exception of some minor access trails. Stockpiled materials were noted at the junction of a trail in the south-eastern corner of the site and New Illawarra Road.

1978 and 1982

The 1978 and 1982 photographs showed that more trails had been established through the site.

1990

This photograph showed two main access roads running through the site. These road were located:

- through the western side of the site and running in an approximately north to south direction from the Complete Airfield to the north; and

- through the south-east portion of the site in approximately north-east to south-west direction from New Illawarra Road to the east.

Both of these roads were associated with areas of significant disturbances, particularly at the junction of the roads and the various trails.

Numerous trails appeared to run from the two access roads. These trails typically lead to cleared areas with varying amounts of disturbance.

Some areas were noted to be heavily disturbed by what appeared to be crater holes or bunkers. No vegetation appeared to be present in heavily disturbed areas. Some cleared areas also appeared to contain either stockpiled materials, sheds or small structures.

1994

The 1994 photograph indicated that the site has remained relatively unchanged since that time.

Option B

PPK inspected aerial photographs for the site of Option A dated 1947, 1961, 1970, 1984, 1990 and 1994.

1947 and 1961

The 1947 and 1961 photographs showed evidence of portions of the area being cleared. No trails into bushland were evident. In the 1961 photograph, some road construction was apparent.

1970

The 1970 photograph showed numerous rows of what appeared to be stockpiled material or bunker like construction, similar to that noted in the 1970 photograph for the site of Option A.

1984

The 1984 photograph showed some roadwork was undertaken along the main access roads in the southern portion of the site. Heavily worn areas were evident on the majority of trails. No vegetation was visible in heavily disturbed areas.

1990

The 1990 photograph was reasonably similar to the 1984 photograph, however soil or imported fill material stockpiles appeared to exist in two cleared areas in the southern portion of the site.

1994

The 1994 photograph shows a number of trails running from the main access road. More clearing was shown to have occurred, and varying levels of disturbance were evident. A small structure was noted on one trail in the north-west corner of the site.

3.4 SITE INSPECTIONS

3.4.1 BADGERYS CREEK

Inspection of the sites of the airport options was undertaken on 22 January by James Chan and Andrew Cameron of PPK. This was to identify existing land uses which could potentially cause contamination of soils or groundwater.

Option A

During PPK's site inspection the following features were observed:

- Anton Road runs through the north-west corner in a north-south direction. A small airstrip was located near the intersection of Anton and Longleys Roads (Photograph 4);

- a large undeveloped area was located in the central portion. This land appears to only have been used for grazing;

- numerous trotting tracks and general livestock facilities including holding yards and stables existed along Anton, Jackson and Ferndale Roads. Large portions of this area had been cleared;

- a gun club and rifle range are located on Adams Road just inside the site boundary;

- a sediment control basin was located to the east between Taylor and Badgerys Creek Roads (Photograph 5).

- electricity lines and an easement run through the western portion of the site, in a south-west to north-east direction;

- Badgerys Creek flows in a south-west to north-east direction through the central portion of the site and then flows in a north direction through the north-east portion of the site. The creek roughly defines the eastern boundary of the site at the northern end;

- buildings in the north-eastern portion of the site consist mainly of semi-rural type structures, poultry sheds and market gardens (Photograph 1). Numerous water storage dams were identified within the site;

- use of numerous properties for poultry farms and market gardens was noted across the site. Gas storage tanks existed on some of the market garden sites;

- Badgerys Creek Primary School is located at the corner of Pitt and Badgerys Creek Road;

- Atomic Hire is located between Pitt and Longleys Roads;

- a large poultry farm is located in the central east portion of the site (Inghams);

- remedial works were being undertaking at Lot 4 The Northern Road, Luddenham (Photograph 2); and

- the Boral brickworks and quarry is located adjacent to the site, to the east (Photograph 3).

Option B

In addition to the site based observations made for Option A the following observations relate to this option:

- two smaller roads were noted to run north from The Northern Road (Mersey and Derwent Roads) in the south-east portion of the site. Buildings along these roads included rural sheds and workshops, residences, poultry sheds and market gardens. A number of properties were noted to have trucks and truck workshop type operations which could potentially result in hydrocarbon contamination;

- small farms and semi rural/light industrial type developments are located in the southern portion of the site; and

- a large dairy operation is present in the south-west portion of the site. This facility is also used as a storage facility for organic fertilisers. Chemicals and pesticide storage and storage of fuel in underground storage tanks was also noted.

Option C

In addition to the observations made for Option A the following features are relevant to this option:

- the southern corner of Option C is characterised by semi rural and light industrial type developments; and

- the south-eastern portion is dominated by the Overseas Telecommunications Commission and Army Communication properties. These properties were generally fully cleared with a low grass cover.

3.4.2 HOLSWORTHY

The sites of the Holsworthy options were inspected by James Chan and Andrew Cameron on 29 January and 17 February 1997. This was to identify potentially contaminating land uses. *Figure 3.1* shows some of the areas discussed.

Option A

During PPK's site inspection the following significant features were observed:

- Demolition Range 1 is located within the south-east portion of the site of Option A;

- Demolition Range 2 is located within the south-west portion of the site of Option A;

- Williams Creek and Valley run through the central portion of the site;

- New Illawarra Road extends into the south-east portion of the site. Large portions of the road have been sealed with roadbase, coal wash was observed along some areas (Photograph 6); and

- Woronora Dam and Lake Woronora are located approximately one kilometre south of the site.

Option B

During PPK's site inspection the following main features were observed:

- The eastern boundary of the site is defined by an access road which runs from the Complete Airfield and New Illawarra Road to the north;

- the Coach Road runs in an approximately north-south direction and through the western portion of the site;

- Impact Area E was centrally located within the site and was noted to contain numerous exploded ordnances; and

- Punchbowl Creek and Valley run through the centre of the site in a north-south direction.

3.4.3 DEMOLITION RANGES AND IMPACT AREA E

Demolition Range No. 1

Demolition Range No. 1 was inspected by PPK on 17 February, 1997. The area had significant soil disturbance as a result of explosive use. This was evident from the large number of craters and holes and spent munitions littering the area (Photograph 7). Some of these craters contained discoloured water (Photograph 8). Surface soils in the vicinity were also discoloured. Some rubble was also present in the area (Photograph 9).

Demolition Range No. 2

Demolition Range No. 2 was inspected by PPK on 29 January, 1997. It is located within the south-west portion of the site of Option A. Demolition Range No. 2 includes a quarry, demolition area and an observation area. A significant amount of soil disturbance was noted in these areas. Stockpiles of soil and rubble were located in the quarry area (*Photographs 10* and *11*).

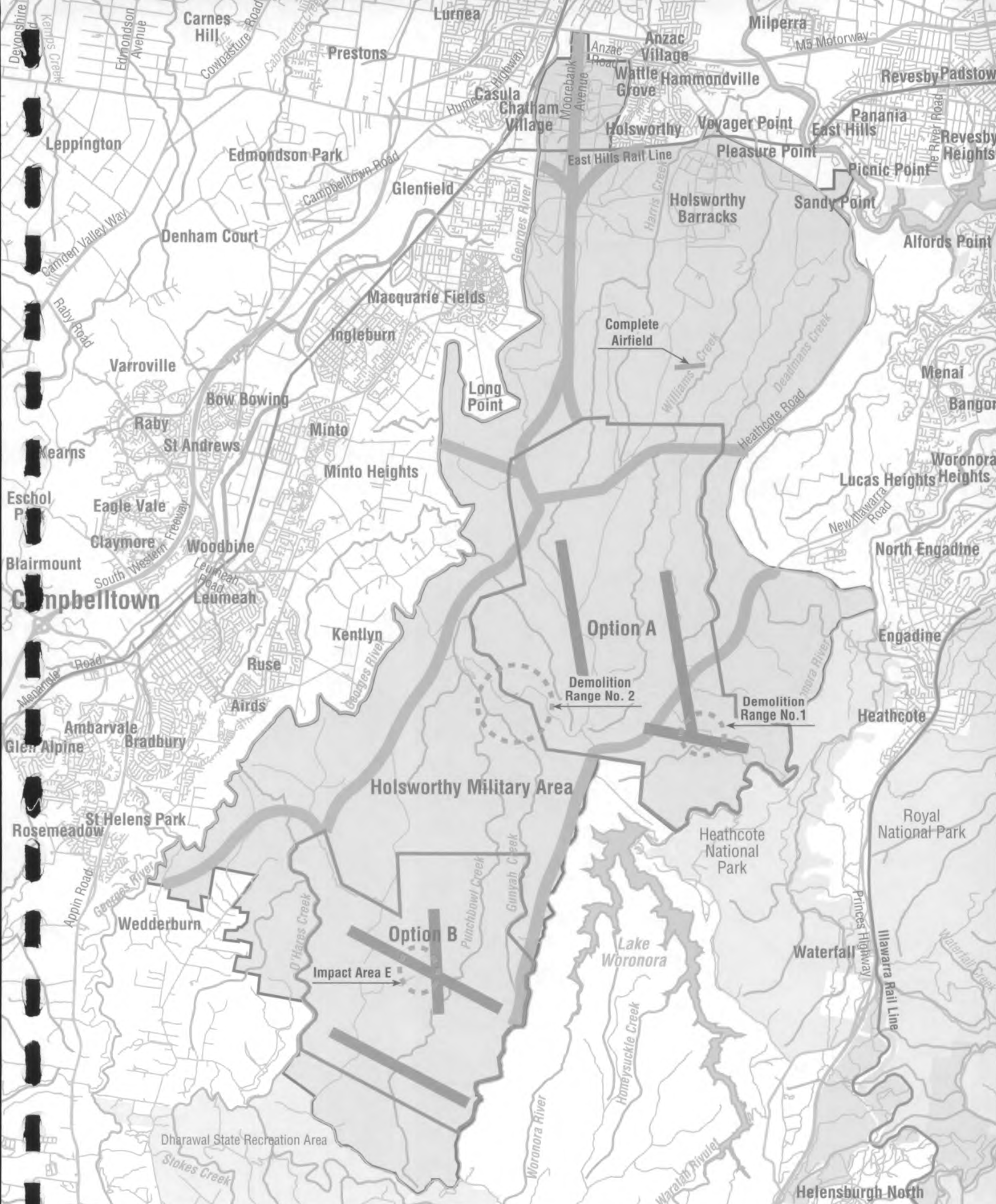


Figure 3.1
Holsworthy Military Area - Zones with High Potential of Contamination

Boundary of Airport Options
Alternative Road and Rail Access Corridors

Impact Area E

Impact Area E was inspected by PPK on 29 January, 1997. The impact area is located central to the site of Option B and was accessed via a trail running east from the Coach Road. Numerous exploded ordnances were observed in this area (*Photograph 12*).

CHAPTER 4 PHYSICAL CHARACTERISTICS

4.1 BADGERYS CREEK

4.1.1 TOPOGRAPHY

The proposed airport site is located in the south-west portion of the Cumberland Plain, on the eastern side of the elevated ridge system dividing the catchments of the Nepean River and South Creek. The Cumberland Plain has an average elevation of about 20 metres above sea level in the north, rising to about 150 metres in the south around Bringelly, Camden and Campbelltown, a distance of 50 kilometres. The elevated ridge system on which the site is located begins to rise at Orchard Hills in the north and extends to Bringelly and Cobbitty, where it broadens into an elevated plain.

4.1.2 GEOLOGY

Reference to the 1:100,000 Geological Series Sheet for Penrith, indicates that most of the site is underlain by Triassic rocks (Bringelly Shale) and unconsolidated Quaternary sediments.

Bringelly Shale

The Bringelly Shale is the uppermost unit of the Wianamatta Group and underlies the surface soils under the majority of the site. Bringelly Shale is interpreted as a coastal alluvial plain which grades up from a lagoonal-coastal marsh sequence at the base to a more increasingly terrestrial, alluvial plain sediments to the top of the formation. Lithology's which comprise the Bringelly Shale are:

- claystone and siltstone;
- laminite;
- sandstone;
- coal and highly carbonaceous claystone; and
- tuff.

Quaternary Alluvium

Quaternary alluvium appears as accumulated surficial deposits along the main creeks in the area. These creeks include Cosgrove Creek to the north and

Badgerys Creek to the south of the airport options. The alluvium typically comprises fine grained sand, silt and clay.

4.1.3 HYDROGEOLOGY

A search of the Department of Land and Water Conservation records located four registered bores within a three kilometre radius of the site. Department of Land and Water Conservation records are contained in *Appendix 3* for reference. A review of these records indicates that the depth to groundwater in these bores varies between 23.8 metres and 24.0 metres. Nearby groundwater bore details indicate use for domestic, stock and industry water supply.

The groundwater flow direction is anticipated to be in a westerly direction to the west of the Luddenham dyke and in a north-easterly direction to the east of the dyke.

4.2 HOLSWORTHY

4.2.1 TOPOGRAPHY

The site in general comprises steep, rugged terrain ranging from above 200 metres in the south to below 50 metres in the north and west. The landform consists of a series of ridges and gullies containing deep entrenched creek systems. Drainage is generally north via the Georges River.

4.2.2 GEOLOGY

Reference to the 1:100,000 Geological Series Sheet for Wollongong - Port Hacking and Penrith, indicates that the majority of the site is underlain by Triassic rocks (Hawkesbury Sandstone and Ashfield Shale) and with some Quaternary and Tertiary sediment deposits to the north of the site.

Hawkesbury Sandstone

Hawkesbury Sandstone consists of about 95 percent quartoze sandstone, with the remaining five percent consisting of siltstone/fine sandstone laminite, siltstone and claystone interbeds. The sandstone varies from fine to coarse grained, with the major part being medium grained. Angular clusts of dark grey claystone and siltstone are common near claystone and siltstone interbeds, and in places form an apparent interformational breccia.

The interbeds of laminite, siltstone and claystone generally occurs as lenses within the sandstone and are commonly referred to as "shale lenses". They are usually mid to dark grey in colour, lensoidal in shape, and grade into the overlying sandstone or have sharp boundaries. These lenses vary in thickness from a few millimetres to more than 10 metres. Their lateral extent can sometimes exceed a kilometre, although most are much smaller.

Ashfield Shale

The Ashfield Shale rests within an apparent disconformity on either the Mittagong Formation, or where this is absent, the Hawkesbury Sandstone. This unit forms the basal unit of the Wianamatta Group and where present varies in thickness from 40 metres to 60 metres. The unit consists of dark grey to blue-black siltstone with interbedded laminite horizons. The bedding is usually uniform and less than 50 millimetres thick, although sporadic siderite concentrations and beds up to 300 millimetres thick are present in some places. The sandstone content of the unit increases towards the top, but no significant lateral variation has yet been detected.

Quaternary Alluvium

Quaternary alluvium appears as accumulated surficial deposits along Williams Creek, in the north-eastern corner of the airport site. The alluvium typically comprises fine grained sand, silt and clay.

Undifferentiated Sediments

Alluvial sediments, probably of Tertiary age occur as river terraces adjacent to the Georges River in the Holsworthy to Liverpool area. These sediments consist of up to 15 metres of clayey sand, silt and clay. In general, the clay is extremely plastic and consists of quartz, kaolinite, illite and mixed-layered clay, while the sand consists of subrounded quartz grains. A well developed lateritic soil profile, developed on the alluvium, consists of bands of lateritic ironstone pebbles and red-grey mottled zones.

4.2.3 HYDROGEOLOGY

A search of the Department of Land and Water Conservation records located three registered bores within a three kilometre radius of the site. The Department of Land and Water Conservation records are contained in *Appendix 3* for reference. A review of these records indicates that the depth to groundwater in these bores varies between 35.9 metres and 42.3 metres. Nearby groundwater bore details indicate use for domestic, irrigation, stock and industry water supply.

The general groundwater flow direction is anticipated to be in a northerly direction. However, more localised groundwater directions within the site are considered to be influenced by localised topographic affects.

CHAPTER 5 FIELD AND LABORATORY PROGRAM

5.1 BADGERYS CREEK

No soils or water samples were collected from the Badgerys Creek site. No discrete areas of contamination were apparent, apart from the site at Lot 4, The Northern Road, Luddenham. It was reasoned that it would be difficult to obtain representative soil samples from the sites of the airport options at Badgerys Creek.

5.2 HOLSWORTHY

A total of 18 near surface soil samples (grab samples) and two water samples were collected from the Holsworthy Military Area for preliminary assessment of contaminant concentrations commonly associated with the use of explosives. Due to the heavy use of the Demolition Ranges, in comparison with other parts of the Holsworthy Military Area, they were expected to have the highest levels of contamination and thus sampling concentrated on these areas. Soil samples were collected from the following locations:

- Demolition Range No. 1 (15 samples);
- Demolition Range No. 2 (one sample); and
- Impact Zone E (two samples).

Fieldwork was undertaken on 29 January and 17 February, 1997. Soil samples were collected from locations considered most likely to indicate contamination, such as craters created from the use of explosives and visibly disturbed soil.

Water samples were collected from water which had collected in craters and depressions located in Demolition Range No. 1.

Deeper soil samples were not collected as the near surface horizons were considered to be most susceptible to contamination from explosive residues.

Analytes selected for testing were a suite of heavy metals comprising Aluminium, Barium, Calcium, Copper, Mercury, Potassium, Magnesium, Sodium, Lead, Antimony, Strontium and explosive compounds HMX, RDX, 2.4-DNT, 2.6-DNT, 2-MNT, 4-MNT and 2.4.6-TNT.

Soil samples analysed were typically collected from the depth range of 0 metres to 0.1 metres. The samples were placed into 250 millilitre glass jars, and then stored under chilled conditions (four degrees Celsius) until being dispatched to the laboratory under Chain of Custody procedures. Chain of Custody records are presented in *Appendix 4*.

The laboratory analysis was undertaken by Amdel Laboratories, which is accredited by the National Association of Testing Authorities for the analysis which it conducted on this project.

Groundwater was not sampled in this site assessment. No surface water samples or samples of sediment were obtained from streams or creeks in this investigation.

5.3 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

To ensure the integrity of the data, Quality Assurance/Quality Control procedures were followed both in the field and in the laboratory.

Field duplicate samples were collected and dispatched to the laboratory as "blind duplicates" (*Table 5.1*). The original and duplicate sample were analysed for the same range of analytes so that the influence of soil homogeneity and laboratory validity could be assessed.

TABLE 5.1 DUPLICATE SAMPLES

Original Sample	Duplicate Sample
GS10	GS10D

The laboratory conducted its own internal quality programme, which included analysing laboratory generated duplicates of particular soil samples for the same parameters. This enabled repeatability of the analytical procedures to be assessed by the laboratory.

In addition, standard solutions were analysed by the laboratory for the same parameters as the soil samples, to check instrument accuracy.

CHAPTER 6 ASSESSMENT CRITERIA

6.1 SOILS

6.1.1 POSSIBLE CRITERIA

To determine the significance of any contamination detected it is necessary to define suitable criteria for assessment.

Three sets of criteria are currently used by the NSW Environment Protection Authority for assessing the degree of contamination in soils. These criteria are:

- Environmental and Health Investigation Levels from the *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites* (Australian and New Zealand Environment and Conservation Council/National Health and Medical Research Council, 1992).

- *Guidelines for Assessing Service Station Sites* (NSW Environment Protection Authority, 1994); and

- the Dutch Intervention Values from *Environmental Quality Objectives in the Netherlands* (Ministry of Housing, Spatial Planning and Environment, 1994).

The NSW Environment Protection Authority uses a combination of Australian and New Zealand Environment and Conservation Council/National Health and Medical Research Council levels and the threshold values for Sensitive Land Use published in the Service Station Guidelines as its primary evaluation criteria. The Dutch Intervention Values are used by the Environment Protection Authority when considered appropriate.

Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites

The Environmental Investigation Levels in the Guidelines are generally used to indicate whether soil is suitable for unrestricted land use (including residential and other, sensitive land uses). These values are based on threshold levels for phytoxicity and uptake of contaminants which may result in impairment of plant growth or reproduction or unacceptable residue levels. If analyte concentrations are above the Environmental Investigation Levels further investigation is generally recommended to identify the source and extent of the contamination.

The Health Investigation Levels in the Guidelines are generally used to determine whether there is a potential threat to human health and hence further assessment may be required. These levels, which have been published for only a very limited range of chemicals, can be applied instead of Environmental Investigation Levels if environmental exposure pathways are limited, or, if there are no Environmental Investigation Levels for the particular chemical of concern.

Guidelines for Assessing Service Station Sites

Threshold concentrations for Sensitive Land Uses are contained within the NSW Environment Protection Authority Guidelines for Assessing Service Station Sites (1994). These levels are primarily designed for the redevelopment of former service station sites. However, the levels can also be used to assess other commercial/industrial site uses.

Some of the levels quoted in these guidelines are derived from work carried out by the Dutch Government and some are based upon the Australian and New Zealand Environment and Conservation Council/National Health and Medical Research Council (1992) Investigation Levels.

Environmental Quality Objectives in the Netherlands

The Dutch Intervention Levels are used worldwide to assess soil contamination and are widely used as a guide as to whether remediation is necessary. According to the Dutch authorities, exceedance of these values suggests that further investigation should be carried out (in the short term) to determine the urgency of clean up, although the actual risk of exposure and the potential for the contamination to spread should also be taken into account.

PPK understands that the Dutch Intervention Values are not considered by the NSW Environment Protection Authority as "clean up" criteria, but are often used as values to trigger remediation. The Intervention Values generally indicate unacceptably high levels of contamination.

It should also be noted that the appropriateness of these levels depends upon the future use of the site and the results of a Risk Assessment.

In the absence of suitable criteria, the Dutch Target Values, which have been set at very low levels, have been employed as an arbitrary reference value to establish a baseline condition. If the Target Value is lower than the naturally occurring background levels, the Target Value should be set to background level.

6.1.2 ASSESSMENT CRITERIA ADOPTED

A combination of criteria discussed in *Section 6.1.1* have been used as the assessment criteria for the various analytes of concern. These assessment criteria are presented in *Table 6.1*.

Where no Environmental Investigation Levels exist, Australian and New Zealand Environment and Conservation Council/National Health and Medical Research Council Health Investigation Levels, or, the threshold concentrations for Sensitive Land Use (NSW Environment Protection Authority, 1994) have been used. Dutch Intervention Values have been used to assess the analytical results only where no published Australian and New Zealand Environment and Conservation Council/National Health and Medical Research Council criteria exists.

There are no readily available published guidelines for concentrations of many of the explosive related compounds that were tested for in soil samples from the Holsworthy Military Area.

TABLE 6.1 CONTAMINANT INVESTIGATION THRESHOLDS FOR SOILS

Analyte	Australia and New Zealand Environment and Conservation Council Guideline Criteria[1] (mg/kg)	Dutch Intervention Levels[2] (mg/kg)
Metals		
Aluminum	-	-
Antimony	20	-
Barium	-	625
Calcium	-	-
Copper	60	190
Lead	300	530
Magnesium	-	-
Mercury	1	10
Potassium	-	-
Sodium	-	-
Strontium	-	-
Explosive Related Compounds		
HMX	-	-
RDX	-	-
2.4.6-TNT	-	-
2.6-DNT	-	-
2.4-DNT	-	-
2-MNT	-	-
4-MNT	-	-

Sources:
1. Australia and New Zealand Environment and Conservation Council/National Health and Medical Research Council (1992).
2. Ministry of Housing, Spatial Planning and Environment (1994).

6.2 SURFACE WATER

6.2.1 POSSIBLE CRITERIA

There are a number of possible criteria available for assessing concentrations of contaminants within surface water. These include:

- NSW Clean Waters Act Regulations - Schedule 2 (1972);
- *Australian Water Quality Guidelines for Fresh and Marine Waters* (Australian and New Zealand Environment and Conservation Council (1992)).

6.2.2 CRITERIA ADOPTED

Concentrations quoted in the NSW Clean Waters Regulations (1972) represent legally enforceable concentration limits for surface water discharged from a site, therefore they have been used as the primary assessment criteria for this investigation. The Australian Water Quality Assessment Criteria are used to provide guidance on whether environmental impacts on aquatic ecosystems could potentially occur. They have been used as Secondary Criteria for this investigation. Criteria are summarised in *Table 6.2*. No readily available published guidelines are available for concentrations of many of the explosive related compounds tested for in the water samples.

TABLE 6.2 CONTAMINANT INVESTIGATION THRESHOLDS FOR SURFACE WATER

Analyte	Clean Waters Act Regulations, 1972 (milligrams per litre)	Australian Water Quality Guidelines, 1992 (milligrams per litre)
Metals		
Aluminum	-	-
Antimony	-	-
Barium	1	-
Calcium	-	-
Copper	1	0.005
Lead	0.05	0.005
Magnesium	-	-
Mercury	0.001	0.0001
Potassium	-	-
Sodium	-	-
Strontium	-	-
Phosphorus	-	0.01 - 0.1

Analyte	Clean Waters Act Regulations, 1972 (milligrams per litre)	Australian Water Quality Guidelines, 1992 (milligrams per litre)
Explosive Related Compounds		
HMX	-	-
RDX	-	-
2.4.6-TNT	-	-
2.6-DNT	-	-
2.4-DNT	-	-
2-MNT	-	-
4-MNT	-	-
RDX	-	-

Sources:
1. Clean Waters Act Regulations, Schedule 2 (1972).
2. Protection of Aquatic Ecosystems, Australian Water Quality Guidelines, Australian and New Zealand Environment and Conservation Council (1994).

CHAPTER 7 RESULTS OF SOIL/WATER ANALYSIS

Laboratory Certificates and Analysis reports are provided in *Appendix 4* and a summary of the results is presented in *Tables 7.1* to *7.6*.

7.1 SOILS

7.1.1 HEAVY METALS

A copper concentration of 501 milligrams per kilogram was detected in one of the 18 soil samples selected for analysis (sample GS05). This exceeded the Australia and New Zealand Environment and Conservation Council Guideline value of 60 milligrams per kilogram. Copper concentrations in the remaining 17 samples collected from Demolition Range No. 1 were typically at background levels or below detection limits (refer *Table 7.1*).

Antimony, lead and mercury concentrations were below Australia and New Zealand Environment and Conservation Council Guideline concentrations and Dutch Intervention Levels. Barium concentrations were below the Dutch Intervention Levels.

Other heavy metal analytes were not considered to be of significant environmental concern, however, are included as common constituents of explosive residues. Metals in this category include magnesium, sodium, potassium, calcium, strontium and phosphorus. For these particular metals, no guidelines exist in Australia for their concentrations in soils.

Concentrations recorded in soil samples were generally above detection limits. In two samples collected from Impact Zone E and Demolition Range 2 respectively, sodium and strontium concentrations were below detection limits.

Aluminium concentrations ranged from 1,920 to 2,980 milligrams per kilogram (parts per million) in Impact Zone E, from 2,710 to 17,500 milligrams per kilogram, in Demolition Range 1. In Demolition Range 2, the only sample tested had an aluminium concentration of 7,040 milligrams per kilogram. These aluminium concentrations, while elevated, do not exceed any criteria used in Australia for assessing soil contamination. Environmental and health risks associated with such concentrations are not known, but may need to be investigated.

Concentrations of other analytes, magnesium, sodium, potassium, calcium and strontium, did not exhibit such high concentrations, and the variations between the sampling locations were generally less.

7.1.2 ORGANIC COMPOUNDS

Concentrations of compounds 2.4-DNT, 2.6-DNT, 2-MNT, 4-MNT and 2.4.6-TNT were below laboratory practical detection limits in all 18 soil samples analysed.

7.2 SURFACE WATER

7.2.1 HEAVY METALS

Concentrations of heavy metals in surface water samples were less than the practical quantitation detection limit criteria for both samples with one exception. The concentration of copper in sample GS03 exceeded the Australian Water Quality Guidelines level, and was below the Clean Waters Act limit. This is not considered to be of significance, but may indicate some potential for off-site migration of contaminants via stormwater.

Table 7.1:
SUMMARY OF SOIL ANALYTICAL RESULTS
Heavy Metals of Environmental Concern (Cu, Sb, Pb, Ba and Hg)

Sample	Location	Metals (milligrams per kilogram)				
		Cu	Sb	Pb	Ba	Hg
GS01	Demolition Range 1	12	nd	17	19	nd
GS02	Demolition Range 1	11	nd	9	16	nd
GS05	Demolition Range 1	501	nd	21	29	nd
GS06	Demolition Range 1	48	nd	10	19	nd
GS07	Demolition Range 1	23	nd	26	29	nd
GS08	Demolition Range 1	26	nd	53	20	nd
GS09	Demolition Range 1	7	nd	13	14	nd
GS10	Demolition Range 1	15	nd	27	15	nd
GS11	Demolition Range 1	11	nd	16	17	nd
GS12	Demolition Range 1	25	nd	47	20	nd
GS13	Demolition Range 1	36	nd	65	28	nd
GS14	Demolition Range 1	<5	nd	13	20	nd
GS15	Demolition Range 1	28	nd	40	11	nd
GS16	Demolition Range 1	<5	nd	15	24	nd
GS17	Demolition Range 1	19	nd	11	87	nd
HW2	Impact Zone E	12	nd	21	9.7	nd
HW3	Impact Zone E	9	nd	11	5.9	nd
HW5	Demolition Range 2	nd	nd	32	11	0.060
Laboratory Practical Quantitation Limit		5	5	5	0.5	0.05
ANZECC Guideline Criteria		60	20	300	-	1
Dutch Intervention Level		190	-	530	625	10

Bold	Indicates values exceed ANZECC Criteria (1992)
Bold (shaded)	Indicates values exceed Dutch Intervention Levels (1994)

Cu = Copper
Sb = Antimony
Pb = Lead
Ba = Barium
Hg = Mercury

nd = not detected

Table 7.2:
SUMMARY OF SOIL ANALYTICAL RESULTS
Metals Associated with Explosives (Mg, Na, K, Ca, Sr, Al and P)

Sample	DM1 Location	Metals (milligrams per kilogram)						Total Phosphorus
		Mg	Na	K	Ca	Sr	Al	
GS01	Demolition Range 1	170	78	800	1640	16	7170	135
GS02	Demolition Range 1	133	23	760	332	13	7660	139
GS05	Demolition Range 1	293	47	1120	2200	25	11500	167
GS06	Demolition Range 1	179	6	880	210	15	9680	143
GS07	Demolition Range 1	286	31	1260	2040	25	13100	197
GS08	Demolition Range 1	320	34	820	2940	16	13600	195
GS09	Demolition Range 1	189	15	280	919	11	4710	63
GS10	Demolition Range 1	155	19	580	2510	12	6330	146
GS11	Demolition Range 1	151	24	680	1430	14	7280	410
GS12	Demolition Range 1	129	30	740	879	17	5840	136
GS13	Demolition Range 1	168	12	1100	771	23	9560	172
GS14	Demolition Range 1	289	20	860	398	13	17500	146
GS15	Demolition Range 1	165	27	380	749	8	4620	102
GS16	Demolition Range 1	126	19	780	1190	19	6170	188
GS17	Demolition Range 1	638	47	840	1140	38	2710	386
HW2	Impact Zone E	122	60	140	403	6	1920	33
HW3	Impact Zone E	121	nd	140	160	nd	2980	67
HW5	Demolition Ramge 2	184	nd	580	77	nd	76040	118
Laboratory Practical Quantitation Limit		5	5	10	20	5	5	10
ANZECC Guideline Criteria		-	-	-	-	-	-	-
Dutch Intervention Level		-	-	-	-	-	-	-

Bold	Indicates values exceed ANZECC Criteria (1992)
Bold	Indicates values exceed Dutch Intervention Levels (1994)

Mg = Magnesium
Na = Sodium
K = Potassium
Ca = Calcium
Sr = Strontium
Al = Aluminium

nd = not detected

Table 7.3:
SUMMARY OF SOIL ANALYTICAL RESULTS
Chemicals Associated with Explosives

Sample	Location	Explosives (milligrams per kilogram)						
		HMX	RDX	2,4,6-TNT	2.6-DNT	2.4-DNT	2-MNT	4-MNT
GS01	Demolition Range 1	nd	<0.2 [1]	nd	nd	nd	nd	nd
GS02	Demolition Range 1	nd	<0.2 [1]	nd	nd	nd	nd	nd
GS05	Demolition Range 1	nd	<0.5 [1]	nd	nd	nd	nd	nd
GS06	Demolition Range 1	nd	<0.5 [1]	nd	nd	nd	nd	nd
GS07	Demolition Range 1	nd	<1 [1]	nd	nd	nd	nd	nd
GS08	Demolition Range 1	nd	<1 [1]	nd	nd	nd	nd	nd
GS09	Demolition Range 1	nd	nd	nd	nd	nd	nd	nd
GS10	Demolition Range 1	nd	nd	nd	nd	nd	nd	nd
GS11	Demolition Range 1	nd	<0.5 [1]	nd	nd	nd	nd	nd
GS12	Demolition Range 1	nd	<0.5 [1]	nd	nd	nd	nd	nd
GS13	Demolition Range 1	nd	<0.2 [1]	nd	nd	nd	nd	nd
GS14	Demolition Range 1	nd	nd	nd	nd	nd	nd	nd
GS15	Demolition Range 1	nd	<0.2 [1]	nd	nd	nd	nd	nd
GS16	Demolition Range 1	nd	<0.5 [1]	nd	nd	nd	nd	nd
GS17	Demolition Range 1	nd	<0.5 [1]	nd	<0.5 [1]	nd	nd	nd
HW2	Impact Zone E	<0.5 [1]	<0.5 [1]	nd	nd	nd	nd	nd
HW3	Impact Zone E	nd	nd	nd	nd	nd	nd	nd
HW5	Demolition Range 2	nd	nd	nd	nd	nd	nd	nd
Laboratory Practical Quantitation Limit		0.1	0.1	0.1	0.1	0.1	0.1	0.1
ANZECC Guideline Criteria			-	-	-	-	-	-
Dutch Intervention Level			-	-	-	-	-	-

Bold	Indicates values exceed ANZECC Criteria (1992)
Bold	Indicates values exceed Dutch Intervention Levels (1994)

[1] Increased PQL due to matrix interference

nd = not detected

Table 7.4:
SUMMARY OF WATER ANALYTICAL RESULTS
Heavy Metals of Environmental Concern (Cu, Sb, Pb, Ba and Hg)

Sample	Concentrations (milligrams per litre)				
	Cu	Sb	Pb	Ba	Hg
GS03	0.07	nd	nd	nd	nd
GS04	nd	nd	nd	nd	nd
Laboratory Practical Quantitation Limit	0.05	0.1	0.05	0.05	0.001
Australian Water Quality Guidelines	0.005	-	0.005	-	0.0001
Clean Waters Regulations (1972)	1	-	0.05	1	0.001

Bold	Indicates value exceeds Australian Water Quality Guidelines for Protection of Aquatic Ecosystems (1992)
Bold	Indicates value exceeds Clean Waters Regulations limits (1972)

Cu = Copper
Sb = Antimony
Pb = Lead
Ba = Barium
Hg = Mercury

nd = not detected

Table 7.5: SUMMARY OF WATER ANALYTICAL RESULTS
Analytes Associated with Explosives (Mg, Na, K, Ca, Sr, Al and P)

Sample	Metals (milligrams per litre)						Total Phosphorus
	Mg	Na	K	Ca	Sr	Al	
GS03	0.87	10	2.4	21	nd	0.42	**0.13**
GS04	0.93	9.5	1.3	5.3	nd	0.37	**0.29**
Laboratory Practical Quantitation Limit	**0.1**	**0.1**	**0.1**	**0.1**	**0.5**	**0.05**	**0.1**
Australian Water Quality Guidelines	-	-	-	-	-	-	**0.01 - 0.1**
Clean Waters Regulations (1972)	-	-	-	-	-	-	-

Bold	Indicates value exceeds Australian Water Quality Guidelines for Protection of Aquatic Ecosystems (1992)
Bold (shaded)	Indicates value exceeds Clean Waters Regulations Limits (1972)

Mg = Magnesium

Na = Sodium

K = Potassium

Ca = Calsium

Sr = Strontium

Al = Aluminium

nd = not detected

Table 7.6:
SUMMARY OF WATER ANALYTICAL RESULTS
Chemicals Associated with Explosives

Sample	Explosives (milligrams per litre)						
	HMX	RDX	2,4,6-TNT	2.6-DNT	2.4-DNT	2-MNT	4-MNT
GS03	nd [1]	nd	nd	nd	nd	nd	nd
GS04	nd	nd	nd	nd	nd	nd	nd
Laboratory Practical Quantitation Limit	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Australian Water Quality Guidelines	-	-	-	-	-	-	-
Clean Waters Regulations (1972)	-	-	-	-	-	-	-

Bold	Indicates value exceeds Australian Water Quality Guidelines for Protection of Aquatic Ecosystems (1992)
Bold	Indicates value exceeds Clean Waters Regulations limits (1972)

[1] Increased PQL due to matrix interference

nd = not detected

7.2.2 ORGANIC COMPOUNDS

Concentrations of 2.4-DNT, 2.6-DNT, 2-MNT, 4-MNT and 2.4.6-TNT were below laboratory practical detection limits for both samples.

7.3 QUALITY ASSURANCE/QUALITY CONTROL RESULTS

Field and laboratory procedures outlined in *Section 5.2* were used to ensure the integrity of the data produced by the investigation.

Relative percentage differences values were calculated for field and laboratory duplicates. They show the magnitude of the differences between two samples, in relative terms. Values for metals are summarised in *Appendix 5*. As organic compounds were below detection limits, relative percentage differences were not calculated for these results.

Relative percentage differences values for field duplicates were slightly greater than anticipated. This is attributed to the non-homogeneous nature of the matrices with the original and duplicate samples.

Relative percentage differences values for laboratory duplicates were within the expected range.

PART C: ASSESSMENT OF IMPACTS

CHAPTER 8 IMPACTS OF CONTAMINATION ON AIRPORT OPTIONS

8.1 BADGERYS CREEK

Review of available information and site observations has indicated that a number of potentially contaminating activities have been conducted at the sites of the Badgerys Creek options, including market gardening, poultry farming, repair of trucks, storage of fuel and chemicals.

The physical characteristics of the sites suggests that potential contamination migration pathways are associated with the various surface water collection streams and creeks.

Further review of the physical characteristics has indicated the soils at the site would be expected to have a low permeability. Given the expected soil characteristics and considering the depth to groundwater is greater than 20 metres, the potential for significant contamination migration through soil and/or groundwater is considered low.

Soil sampling would need to be carried out prior to redevelopment of the area for use as an airport. This would indicate whether concentrations of pesticides and agricultural chemicals are within accepted limits for commercial use, and identify specific areas where other localised contamination may exist, for example, hydrocarbon contamination in the vicinity of underground fuel tanks.

No significant differences in terms of potential for contamination exist between Badgerys Creek Options A, B and C. This is because Options B and C include the site of Option A, and similar activities have been conducted on the sites of all three options.

8.2 HOLSWORTHY

The current use of the Holsworthy Military Area for military activities means that there is a high probability of contaminated soil existing on the sites of the airport options. Three of the most potentially contaminated areas, Demolition Range No. 1, Demolition Range No. 2 and Impact Area E were sampled, and soil and water samples analysed for likely compounds associated with explosives.

Concentrations of the heavy metals considered to be of environmental concern were typically below the accepted guideline values commonly used for residential land use, with the exception of the copper concentration in a sample of disturbed soil from Demolition Range No.1. Concentrations of organic compounds were below detection limits.

The laboratory results indicate that in general, heavy metal and organic contamination associated with areas of the site where explosives have been detonated, or ordnance has exploded, is not as significant as would be expected. A more comprehensive soil sampling and testing program would be necessary to confirm this.

The appropriate time for undertaking this level of investigation would be prior to airport construction (if either Holsworthy option is selected) after use of such areas for military purposes has ceased. Otherwise, areas that are investigated could become re-contaminated. There is considerable danger associated with unexploded ordnance at Holsworthy which would make any investigation hazardous, unless specific occupational health and safety measures are developed and adhered to.

Review of available information has indicated there is likely to be a number of undocumented landfills within the Holsworthy Military Area, which potentially contain contaminated materials.

Other potential sources of contamination include imported railway ballast and coal waste, which have generally been used for road construction across the site.

There are no significant differences in potential for contamination between the sites of Options A and B. The site of Option A contains two demolition ranges, while the site of Option B contains Impact Area E. Since firing of ordnance was not restricted to specific areas on the site, both sites have equal probability of being contaminated by heavy metals and explosives residues. The limited sampling undertaken to date suggests that levels of chemical contamination may not be as high as would normally be expected from the past and current use of the site as a firing range.

No sampling of sediments in creeks and watercourses or groundwater was undertaken during this investigation. Chemical residues could have been washed into watercourses by rain and may have collected in sediments. This should be investigated prior to airport construction, if either of the Holsworthy options is selected.

Part D: Environmental Management

CHAPTER 9 ENVIRONMENTAL MANAGEMENT

For both Badgerys Creek and Holsworthy, it is likely that the amount of soil with concentrations exceeding acceptable levels for commercial use would be insignificant, in comparison with the volume of earthworks proposed. Therefore on site disposal, by using such soil as fill material, may be a viable management option, provided steps are taken to minimise future risks to environmental and human health. This applies to both Badgerys Creek and Holsworthy sites.

If only small amounts of soil were found to exceed acceptable concentrations for commercial use, offsite disposal could be considered. Larger volumes may require special on-site containment cells to be constructed, and integrated into the design of the airport options.

For Holsworthy in particular, detailed sampling and testing of any currently disturbed material, and of any material contained in undocumented landfills would be necessary, before it is used for fill material or disposed off site.

Extreme caution should be used at Holsworthy when investigating the site, due to the presence of unexploded ordnance, on the surface, hidden below the surface and within the undocumented landfills. Clearing of unexploded ordnance would be necessary prior to intrusive investigations associated with drilling or sampling subsurface soils or groundwater. Specific occupational health and safety procedures would need to be developed prior to commencing fieldwork, and strictly adhered to.

CHAPTER 10 STATEMENT OF LIMITATIONS AND RESTRICTIONS

This assessment was restricted to the agreed upon scope of services. No representations or warranties are made concerning the nature or quality of the soil and water, or any other substance on the property, other than the visual observations and analytical data as stated in this report.

On all sites varying degrees of non-uniformity of the vertical and horizontal soil or groundwater conditions are encountered. Hence no sampling technique can completely eliminate the possibility that samples are not totally representative of soil and/or groundwater conditions encountered. The sampling can only reduce this possibility to an acceptable level.

It should also be recognised that site conditions, including contaminant extent and concentrations can change with time. This is particularly relevant if this report is used after a protracted delay, such that further investigation of the site may be necessary.

In preparing this report, PPK has relied upon certain verbal information and documentation provided by the client and/or third parties. Except as discussed, PPK did not attempt to independently verify the accuracy or completeness of that information, but did not detect any inconsistency or omission of a nature that might call into question the validity of any of it. To the extent that the conclusions in this report are based in whole or in part on such information, they are contingent on its validity. PPK assumes no responsibility for any consequences arising from any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to PPK.

Within the limitations of the agreed upon scope of services, this assessment has been undertaken and performed in a professional manner, in accordance with generally accepted practices, using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. No other warranty, express or implied, is made.

This report is based upon the scope of services, and is subject to the Limitations and Restrictions, defined herein. It has been prepared for the exclusive use of the Second Sydney Airport Draft EIS. No other person or organisation is entitled to rely upon any part of it without the prior written consent of PPK. The Department of Transport and Regional Development may release all or part(s) of this report to third parties, however, such third party in using or relying on this report agrees that it shall have no legal recourse against PPK or their parent or subsidiaries, and shall indemnify and defend them from and against all claims arising out or, or in conjunction with, such use or reliance.

REFERENCES

Airservices Australia (1996), *The Long Term Operating Plan for Sydney (Kingsford Smith) Airport and Associated Airspace - Report Summary*, Commonwealth of Australia, Canberra.

Australian and New Zealand Environmental Conservation Council and National Health and Medical Research Council, (1992) *Australian and New Zealand Guidelines for the Management of Contaminated Sites.*

AXIS/Australian Museum Business Services Consulting (1995), *Holsworthy Training Area Environmental Audit, Main Report for the Department of Defence.*

Coalition of Liberal and National Parties (1996), *Putting People First, Coalition Policy on Sydney Airport and Sydney West Airport*, Commonwealth of Australia, Canberra.

Department of Administrative Services, Centre for Environmental Management (1995), *Explorative Excavation of Buried Materials at Lot 4 The Northern Road, Luddenham, NSW.*

Department of Administrative Services (1996), Centre for Environmental Management December 1996, *Status Report No. 4 (CL228): Badgerys Creek.*

Department of Administration Services (1997) Centre for Environmental Management, *Remediation Program Lot 4 The Northern Road, Luddenham, NSW* for the Department of Transport and Regional Development, Report CL228, June 1997.

Department of Transport and Regional Development (1996), *Location and Development of the Second Sydney Airport, The Proposal*, 5 August 1996, Sydney West Airport Taskforce, Canberra.

Kinhill Stearns (1985), *Second Sydney Airport, Site Selection Programme, Draft Environmental Impact Statement*, Kinhill Stearns and the Department of Aviation.

Minister for Transport and Regional Development (1996), *Media Release*, "Environmental Impact Statement for Holsworthy", 21 May, 1996.

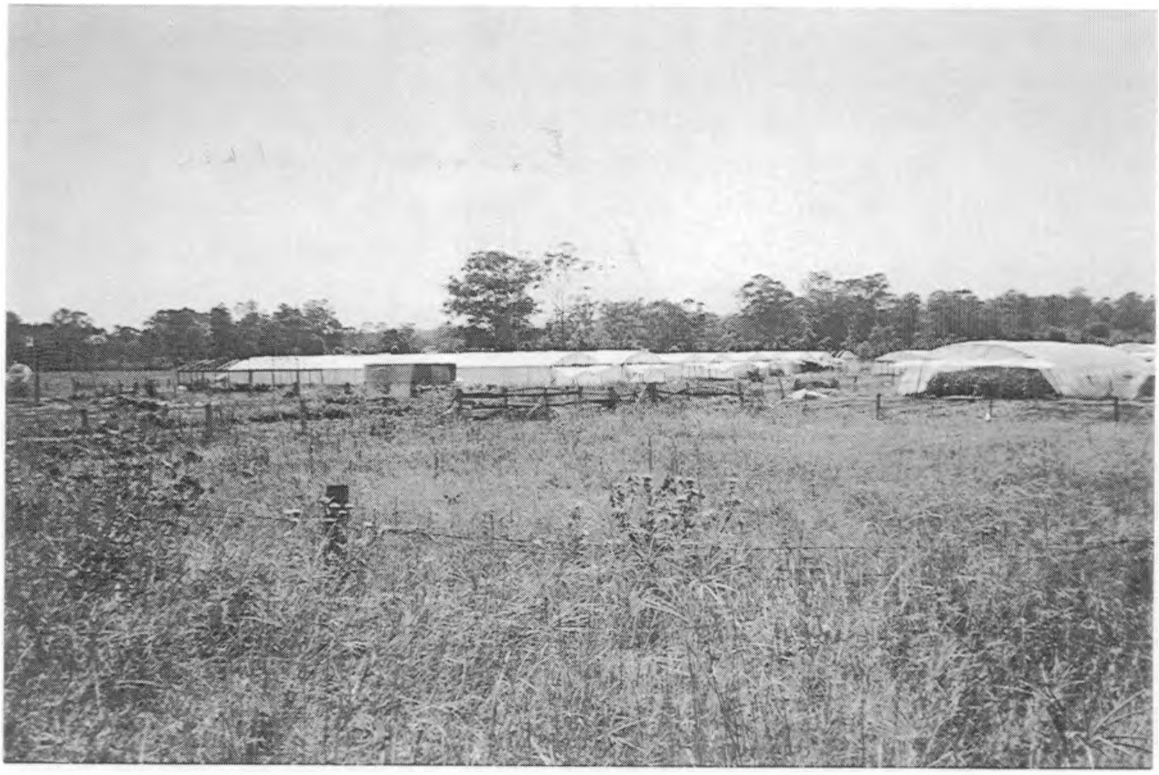
Ministry of Housing, Spatial Planning and the Environment, (1994) *Risk Assessment and Environmental Quality Division Directorate of Chemicals,* *External Safety and Radiation Protection, Environmental Quality Objectives in the Netherlands.*

NSW Clean Waters Act, (1970) - Regulations Schedule 2.

Peddle Thorp Architects, (1995), *Military Area Master Plan.*

Senate Select Committee on Aircraft Noise in Sydney (1995), *Falling on Deaf Ears? Report of the Senate Select Committee on Aircraft Noise in Sydney,* Commonwealth of Australia.

Photographs



PHOTOGRAPH 1: Market Gardens

PHOTOGRAPH 2: Remedial works occuring at Lot 4 the Northern Road, Luddenham.

PHOTOGRAPH 3: The Boral quarry.

PHOTOGRAPH 4: Entrance to airfield.

PHOTOGRAPH 5: Sediment Control Basin.

PHOTOGRAPH 6: Road covered in coal wash.

PHOTOGRAPH 7: Spent munitions

PHOTOGRAPH 8: Crators containing water, which appeared to be discoloured.

PHOTOGRAPH 9: Rubble found in the area.

PHOTOGRAPH 10: Stockpiled soil.

PHOTOGRAPH 11: Stockpiled soil.

PHOTOGRAPH 12: Spent munitions.

Appendix 1

DLWC Records

DEPARTMENT OF LAND AND WATER CONSERVATION
Centre for Natural Resources

WATER DATA DISCLAIMER

Warning to Clients:

Water data have been supplied to the Department of Land and Water Conservation (DLWC) by various sources. In some cases, analyses, plots and other data presentations make use of information on the DLWC archive. Because of the historical nature of the archive, there may well be errors and omissions in the data, or the quality of the information may make it unsuitable for the intended purpose.

Data integrity may not have been examined before use in analytical programs and the DLWC makes no guarantee that they conform to any guidelines.

Users of these data should be aware that the use and any interpretation of the data is at their own risk and the DLWC will not be held responsible for any decisions made based on these data.

For more information, please contact:

Contact name:	Jenny Wood
Postal Address:	Department of Land and Water Conservation PO Box 3720 Parramatta NSW 2124
Position:	Water Quality Officer, Water Quality Services
Direct telephone:	(02) 9895 7621
Direct FAX:	(02) 9895 7867
e-mail:	jennywood@dlwc.nsw.gov.au

Date/Time: 07-Feb-1997 1:47 PM
User: JHARLOW
Report: RMGW001D.QRP
System: Groundwater

DEPARTMENT OF LAND & WATER CONSERVATION

Work Summary

LAND & WATER CONSERVATION

GW032310

Converted From HYDSYS

License :

Work Type : Bore open thru rock
Work Status: (Unknown)
Construct. Method: Rotary
Owner Type : Private

Authorised Purpose(s)

Intended Purpose(s)
DOMESTIC
STOCK

Commenced Date :
Completion Date : 01-Jan-1969
FinalDepth : 152.40 m
Drilled Depth : 152.40 m

Contractor Name :
Driller :

Property :
GWMA :
GW Zone :

Standing Water Level : m
Salinity : mg/L invalid code
Yield : L/s

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
	Form A:	CUMBERLAND	WEDDERBURN	9
	Licensed:			

Region: 10 - SYDNEY SOUTH COAST
River Basin : 213 - SYDNEY COAST - GEORGES RIVER
Area / District:

CMA Map : 9029-1S APPIN
Grid Zone : 56/1 **Scale :** 1:25,000

Elevation m (A.H.D.)
Elevation Source: (Unknown)

Northing : 6218420
Easting : 299050

Latitude (S) : 34° 9' 21"
Longitude (E) : 150° 49' 13"

GS Map : 0075D1 **AMG Zone:** 56 **Coordinate Source :** GD.,ACC.MAP

Construction

Negative depths indicate Above Ground Level H-Hole P-Pipe,OD-Outside Diameter;ID-Inside Diameter;C-Cemented,SL-Slot Length A-Aperture GS-Grain Size,Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Threaded Steel	-0.30	9.60	152			Suspended in Clamps

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
29.80	29.90	0.10	Consolidated			0.01			(Unknown)
60.90	61.00	0.10	(Unknown)	35.90		0.11			(Unknown)

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.91	0.91	Soil	Soil	
0.91	6.10	5.19	Sandstone Yellow Soft	Sandstone	
6.10	10.67	4.57	Sandstone Yellow	Sandstone	
10.67	13.72	3.05	Sandstone Grey Shale Seams	Sandstone	
13.72	18.29	4.57	Sandstone Yellow	Sandstone	
18.29	24.69	6.40	Sandstone Cream	Sandstone	
24.69	25.91	1.22	Shale Grey Sandy Soft	Shale	
25.91	27.43	1.52	Sandstone Grey Hard	Sandstone	
27.43	60.96	33.53	Sandstone Hard Fine Water Supply	Sandstone	
60.96	103.63	42.67	Sandstone Grey Hard Fine Water Supply	Sandstone	
60.96	103.63	42.67	Shale Seams	Shale	
103.63	105.16	1.53	Conglomerate Dark Grey Sandstone	Conglomerate	
105.16	111.25	6.09	Sandstone Grey	Sandstone	
111.25	112.17	0.92	Shale Dark Grey	Shale	
112.17	120.09	7.92	Sandstone Grey	Sandstone	
120.09	129.54	9.45	Sandstone Coarse	Sandstone	
129.54	135.33	5.79	Shale Grey	Shale	
135.33	142.04	6.71	Sandstone Cream	Sandstone	
142.04	143.26	1.22	Sandstone Hard	Sandstone	
142.04	143.26	1.22	Shale Bands	Shale	
143.26	152.40	9.14	Sandstone Grey Hard	Sandstone	

*** End of GW032310 ***

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW038159

Converted From HYD...

License :

Work Type : Bore open thru rock
Work Status: (Unknown)
Construct. Method: Cable Tool
Owner Type : Other Govt

Authorised Purpose(s)	Intended Purpose(s)
	DOMESTIC
	STOCK

Commenced Date : | **FinalDepth :** 121.90 m
Completion Date : 01-Nov-1974 | **Drilled Depth :** 121.90 m

Contractor Name :
Driller :

Property :
GWMA :
GW Zone :

Standing Water Level : m
Salinity : mg/L (Unknown)
Yield : L/s

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
	Form A:	CUMBERLAND	WEDDERBURN	41
	Licensed:			

Region: 10 - SYDNEY SOUTH COAST
River Basin : 213 - SYDNEY COAST - GEORGES RIVER
Area / District:

CMA Map : 9029-1S APPIN
Grid Zone : 56 1 **Scale :** 1:25,000

Elevation : m (A.H.D.)
Elevation Source: (Unknown)

Northing : 6220950 **Latitude (S) :** 34° 7' 58"
Easting : 298420 **Longitude (E) :** 150° 48' 50"

GS Map : 0075D1 **AMG Zone:** 56 **Coordinate Source :** GD.,ACC MAP

Construction

Negative depths indicate Above Ground Level H-Hole P-Pipe OD-Outside Diameter ID-Inside Diameter C-Cemented SL-Slot Length A-Aperture GS-Grain Size Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details

(No Construction Details Found)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
12 30	42 60	0 30	Consolidated	42 30		0 01			(Unknown)

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0 00	0 60	0 60	Clay Sandy	Clay	
0 60	14 93	14 33	Sandstone Yellow Hard	Sandstone	
14 93	16 45	1 52	Sandstone Grey Silty	Sandstone	
16 45	34 13	17 68	Sandstone Yellow Hard	Sandstone	
34 13	42 36	8 23	Sandstone	Sandstone	
42 36	69 49	27 13	Sandstone Grey	Sandstone	
69 49	121 92	52 43	Sandstone Grey Silty	Sandstone	

***** End of GW038159 *****

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW063062

Converted From HYDSYS

License : 10BL126198 NASSO, M A

Work Type : Bore
Work Status: (Unknown)
Construct. Method: Rotary
Owner Type : Private

Authorised Purpose(s)	Intended Purpose(s)
DOMESTIC	IRRIGATION
INDUSTRIAL	
STOCK	

Commenced Date :
Completion Date : 01-Jan-1989
FinalDepth : 151.00 m
Drilled Depth : 0.00

Contractor Name :
Driller :

Property :
GWMA :
GW Zone : -

Standing Water Level : m
Salinity : mg/L (Unknown)
Yield : L/s

Site Details

Site Chosen By

	County	Parish	Portion/Lot DP
Form A:	CUMBERLAND	BRINGELLY	L7 (20)
Licensed:	CUMBERLAND	BRINGELLY	LOT6 DP126824

Region: 10 - SYDNEY SOUTH COAST
River Basin : 212 - HAWKESBURY RIVER
Area / District:

CMA Map : 9030-3S WARRAGAMBA
Grid Zone : 56/1 Scale : 1:25,000

Elevation : m (A.H.D.)
Elevation Source: (Unknown)

Northing : 6243010
Easting : 289570

Latitude (S) : 33° 55' 56"
Longitude (E) : 150° 43' 24"

GS Map : 0056C4 AMG Zone: 56

Coordinate Source : GD.,ACC.MAP

Construction

Negative depths indicate Above Ground Level H-Hole,P-Pipe,OD-Outside Diameter,ID-Inside Diameter,C-Cemented SL-Slot Length,A-Aperture GS-Grain Size,Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Steel	0.00	0.00	159			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments

(No Drillers Log Details Found)

*** End of GW063062 ***

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW072454

Converted From HYD…

License :			
		Authorised Purpose(s)	Intended Purpose(s)
Work Type :	Bore		DOMESTIC
Work Status:			IRRIGATION
Construct. Method:	Rotary Air		
Owner Type :	Private		

Commenced Date :		FinalDepth :	162.00 m
Completion Date :	16-Dec-1994	Drilled Depth :	162.00 m

Contractor Name :
Driller :

Property :		Standing Water Level :	m
GWMA :		Salinity :	mg/L Good
GW Zone :		Yield :	L/s

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
	Form A:	CUMBERLAND	WEDDERBURN	L10 DP3221
	Licensed:			

Region:	10 - SYDNEY SOUTH COAST	CMA Map :	9029-1S	APPIN	
River Basin :	213 - SYDNEY COAST - GEORGES RIVER	Grid Zone :	56/1	Scale :	1:25,000
Area / District:					
Elevation :	0.00	Northing :	6217872.6	Latitude (S) :	34° 9' 37"
Elevation Source:		Easting :	297605.3	Longitude (E) :	150° 48' 16"
GS Map :	AMG Zone: 56	Coordinate Source :			

Construction

Negative depths indicate Above Ground Level H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	P V C	0.00	162.00	[illegible]			Driven into Hole

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
[illegible]	90.00	30.00	Consolidated	24.00		[illegible]			Good

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00		Soil	
1.00	6.00	5.00		Clay	
6.00	162.00	156.00		Sandstone	

*** End of GW072454 ***

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW072774

Converted From HYDSYS

License :

Work Type : Bore
Work Status:
Construct. Method: Rotary
Owner Type : Private

Authorised Purpose(s)	Intended Purpose(s)
	G/WATER XPLORE

Commenced Date :
Completion Date : 26-Oct-1994

FinalDepth : 30.00 m
Drilled Depth : 19.00 m

Contractor Name :
Driller :

Property :
GWMA :
GW Zone :

Standing Water Level : m
Salinity : mg/L
Yield : L/s

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
	Form A:	CUMBERLAND	CLAREMONT	L1 DP542395
	Licensed:			

Region: 10 - SYDNEY SOUTH COAST
River Basin : 212 - HAWKESBURY RIVER
Area / District:

CMA Map :
Grid Zone :
Scale :

Elevation : 0.00
Elevation Source:

Northing : 6249933.9
Easting : 292549 4

Latitude (S) : 33° 52' 14"
Longitude (E) : 150° 45' 26"

GS Map :
AMG Zone: 56
Coordinate Source : GD..ACC.GIS

Construction

Negative depths indicate Above Ground Level H-Hole P-Pipe OD-Outside Diameter ID-Inside Diameter C-Cemented SL-Slot Length A-Aperture GS-Grain Size Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	P V C	-0 50	17 00	50			
1	1	Casing	P V C	29 00	30 00	50			
1	1	Opening	(Unknown)	17 00	29 00	50		1	Plastic, SL 0mm; A 0mm
1	1	Annulus	(Unknown)	17 00	29 00	0			GS -2mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

(No Water Bearing Zone Details Found)

illers Log

rom (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0 00	0 50	0 50	Hard Yellow Brown, Mottled, Dry Clay	Clay	
0 50	1 40	0 90	Stiff, Red-brown, Mottled, Moist, Plastic Clay	Clay	
1 40	2 00	0 60	Stiff, Grey, Moist, Plastic Clay	Clay	
2 00	3 50	1 50	Stiff, Red Brown To Grey, Mottled, Slightly Mo	Clay	
3 50	4 50	1 00	Hard To Stiff, Red-brown, Mottled, Dry Clay	Clay	
4 50	5 00	0 50	Hard To Stiff, Grey To Brown, Mottled Dry Cla	Clay	
5 00	6 00	1.00	Weak, Grey, Fissile, Dry Shale	Shale	
6 00	8 50	2 50	Med Strength, Grey, Fissile, Dry Shale, Minor C	Shale	
8 50	9 00	0 50	Siltstone/sandstone Hard, Grey, Massive, Silt To	Siltstone	
9 00	10 50	1 50	Carbonaceous Shale Medium Strenght, Dark Gr	Shale	
10 50	11 00	0 50	Weak, Dark Grey To Black, Fissile Dry Carb Sh	Shale	
11 00	18 00	7 00	Med Strength, Dark Grey, Fissile, Dry Carb Shl	Shale	
18 00	19 00	1 00	Hard Grey, Massive Silt To Very Fine Grained	Siltstone	
19 00	21.50	2 50	Carbonaceous Shle, Med Strength, Dark Grey,	Shale	
21.50	22.50	1 00	Slsn And Sdsn, Hard, Grey, Massive, Silt To Ve	Siltstone	
22 50	24 00	1 50	Carb Shale, Med Strength, Dark Grey Fissile, D	Shale	
24.00	26 00	2 00	Slsn/sdsn And Carb Shale Interbeded	Siltstone	
26 00	30.00	4 00	Carbonaceous, Med Strength, Dark Grey, Fissil	Shale	

***** End of GW072774 *****

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW100136

License : 10BL144703 PULO, CHARLES

Work Type : Bore
Work Status:
Construct. Method: Rotary
Owner Type :

Authorised Purpose(s)	Intended Purpose(s)
STOCK	

Commenced Date :
Completion Date : 27-Nov-1991

FinalDepth : 110.70 m
Drilled Depth : 110.70 m

Contractor Name : WATERMIN DRILLERS
Driller : 1530 JONES, Clive Francis

Property :
GWMA : -
GW Zone : -

Standing Water Level : m
Salinity : mg/L
Yield : L/s

Site Details

Site Chosen By

	County	Parish	Portion/Lot DP
Form A:	CUMBERLAND	CLAREMONT	LT10 DP32026
Licensed:	CUMBERLAND	CLAREMONT	LT10 DP32026

Region: 10 - SYDNEY SOUTH COAST
River Basin :
Area / District:

CMA Map :
Grid Zone : **Scale :**

Elevation : m (A.H.D.)
Elevation Source:

Northing :
Easting :

Latitude (S) :
Longitude (E) :

GS Map : **AMG Zone:** **Coordinate Source :**

Construction

Negative depths indicate Above Ground Level;H-Hole,P-Pipe,OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture,GS-Grain Size Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0 00	0 00				
1		Hole	Hole	0 00	39 60	165			Rotary Air
1		Hole	Hole	39 60	110 70	165			Rotary Air

NO Wordinates

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
39 60	39 90	0 30		23.80		0 60	39 90		Salty

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0 00	0 30	0 30	TOPSOIL		
0 30	1 50	1 20	BROWN CLAY		
1 50	11 60	10 10	RED CLAY		
11 60	39 60	28 00	YELLOW SANDSTONE		
39 60	80 20	40 60	GREY SHALE		
80 20	110 70	30 50	BLACK SHALE		

*** End of GW100136 ***

*** End of Report ***

Land & Water Conservation

Water Quality Archive Samples & Results Report

Variable	Sample No.	Bot	Time	Date	Value	Flag	Qual	Acc.
** Station = GB032310								
2010.12 Electrical Conductivity @ 25C (Microsiem	1969001628		0	01/01/1969	297.0000000		40	4
2100.12 pH (pH units)	1969001628		0	01/01/1969	6.5000000		40	4
2125.12 Bicarbonate as HCO3 (Milligrams/Litre)	1969001628		0	01/01/1969	114.7120000		40	4
2301.12 Calcium as Ca - total (Milligrams/Litre)	1969001628		0	01/01/1969	20.0200000		40	4
2681.12 Iron as Fe - total (Milligrams/Litre)	1969001628		0	01/01/1969	0.0000000	ND	40	4
** Subtotal **								
							200	20
*** Total ***								
							200	20

Date/Time: 07-Mar-1997 3:39 PM
User: JBRODERI
Report: RMGW001D.QRP
Executable: S:\G5\PROD\GROUND.EXE
Exe Date: 20-Feb-1997
System: Groundwater
Database: S_coast

LAND & WATER CONSERVATION

DEPARTMENT OF LAND & WATER CONSERVATION
Work Summary

GW073533

Converted From HYDSYS

License :

Authorised Purpose(s)	Intended Purpose(s)
	DOMESTIC

Work Type : Bore
Work Status:
Construct. Method:
Owner Type : Private

Commenced Date : FinalDepth : 330.00 m
Completion Date : 01-Jan-1990 Drilled Depth : 0.00

actor Name :
Driller :

Property : Standing Water Level :
GWMA : Salinity :
GW Zone : Yield :

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
	Form A:	CUMBERLAND	BRINGELLY	L7 DP2650
	Licensed:			

Region: 10 - SYDNEY SOUTH COAST CMA Map :
River Basin : 212 - HAWKESBURY RIVER Grid Zone : Scale :
Area / District:

Elevation : 0.00 Northing : 6242949.3 Latitude (S) : 33° 55' 58"
Elevation Source: Easting : 289513.8 Longitude (E) : 150° 43' 22"

GS Map : AMG Zone: 56 Coordinate Source : GD.,ACC.GIS

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
	Casing	P.V.C	0.00	0.00	50			

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)

(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments

(No Drillers Log Details Found)

Chemical Treatment

Treatment	Method	Duration	Source

(No Chemical Treatment Details Found)

Development

Method	Time Taken	Other Development Method

(No Development Details Found)

Appendix 2

Chain of Custody Records

CHAIN-OF-CUSTODY

Laboratory Name:	Amdel
Address:	5 Kelray Place Asquith NSW 2077
Fax Number:	(02) 9482 1734
Phone Number:	(02) 9482 1922
Contact Name:	Amanda Gavin

RUST PPK Job No. (Quote on all correspondence)
58H233A.008

Results Expected By/On:	a.s.a.p. 26/2/97
Fax Results To:	Andrew Cameron
Fax Number:	736 1568
Phone Number:	743 0333
Invoice To:	RUST PPK

Analysis Required

Date Sampled	Time	Sample I.D	Container Size	Sample Location	Medium *	Preservative Type	Filtered (x)	No. of Containers	Explosives MNT, DNT, TNT, RDX, HMX	Total Phosphorus	Acid Soluble metals Mg, Na, K, Ca, Ba, Sr	Cr, Sb, Pb, Al	Mercury		Sampled By	Company	Signature	Remarks Lab No's
17/2/97		GS1	250ml	DM1	S	ICE		1							A. Cameron	Rust PPK		E16190
		GS2			S			1										91
		GS3			W			4										92
		GS4			W			4										93
		GS5			S			1										94
		GS6																95
		GS7																96
		GS8																97
		GS9																98
		GS10																99
		GS11																200
		GS12																01
		GS13																2
		GS14																3
		GS15																4
		GS16																5

Relinquished By (Name):	Andrew Cameron	Received By (Name):	Ben Wacket	Relinquished By (Name):		Received By (Name):	VINITA SINGH.
Date:	19/2/97	Date:	19-2-97	Date:		Date:	19/2/97
Company:	RUST/PPK	Company:	AMDEL	Company:		Company:	Comvoch · RECEIVED
On Behalf Of:		On Behalf Of:		On Behalf Of:		On Behalf Of:	
Signature:		Signature:		Signature:		Signature:	18 19 FEB 1997

7E00286

Comments: Testing as per Amdel quote dated 20 January by Geoff Anderson.

* Legend: S = Soil, W = Water, F = Filter
T = Tube

RUST PPK

RUST PPK Pty Ltd
9 Blaxland Road,
RHODES NSW 2138.

Environmental and Geotechnical Services

Appendix 3

Laboratory Certificates

amdel

10 MAR 1997

ENVIRONMENTAL AND INDUSTRIAL SERVICES DIVISION
Trading as Australian Analytical Laboratories Pty Ltd
ACN 001 491 667

Correspondence to:
PO BOX 514
HORNSBY NSW 2077

5 Kelray Place
ASQUITH NSW 2077
Telephone: (02) 9482 1922
Facsimile: (02) 9482 1734

CERTIFICATE OF ANALYSIS

Contents :

1) Cover Page
2) Analysis Report Pages : 1 to 10
3) QA/QC Appendix

REPORT No : 7E00286

ATTENTION : Mr Andrew Cameron

CLIENT : Rust PPK

SAMPLES : 16 Soils, 2 Waters

REFERENCE : 58H233A.008

DATE RECEIVED : 19/02/97

DATE REPORTED : 05/03/97

Method	Description
E1042	Moisture (%w/w)
E122	Explosive Compounds
E121	Explosive Compounds
* E517	Phosphorous (Total)
W022.3	Total Phosphate
E320	Metals Preparation - Soils
E340	Metals by ICP-AES
E370	Metals by ICP-MS
E310	Metals Preparation - Waters(Dissolved)
E340	Metals by ICP-AES
E350	Mercury
E350	Mercury

* The performance of this test is not covered by NATA registration for this laboratory

RESULTS

All samples were analysed as received.

This report relates specifically to the samples received. Results relate to the source material only to the extent that the samples as supplied are truly representative of the sample source.

This report replaces any preliminary results issued on :28-02-97

PLEASE SEE ATTACHED PAGES FOR RESULTS

R.G. MOONEY B.Sc.(Hons), Dip.F.D.A., M.R.A.C.I.
Authorising Chemist

amdel

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

	Lab No	E16190	E16191	E16194	E16195	E16196
	Sample Id	GS01	GS02	GS05	GS06	GS07
Analyte	PQL					
E1042 Moisture Content	-	9.7	13	33	31	34
E122 Explosive Compounds in Soil						
HMX	**0.1**	nd	nd	nd	nd	nd
RDX	**0.1**	<0.2*	<0.2*	<0.5*	<0.5*	<1*
2.4.6-TNT	**0.1**	nd	nd	nd	nd	nd
2.6-DNT	**0.1**	nd	nd	nd	nd	nd
2.4-DNT	**0.1**	nd	nd	nd	nd	nd
2-MNT	**0.1**	nd	nd	nd	nd	nd
4-MNT	**0.1**	nd	nd	nd	nd	nd
3-MNT	**0.1**	nd	nd	nd	nd	nd

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate
* : Increased PQL due to matrix interference

amdel

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

	Lab No	E16197	E16198	E16199	E16200	E16201
	Sample Id	GS08	GS09	GS10	GS11	GS12
Analyte	PQL					
E1042 Moisture Content	-	22	8.3	9.4	13	13
E122 Explosive Compounds in Soil						
HMX	**0.1**	nd	nd	nd	nd	nd
RDX	**0.1**	<1*	nd	nd	<0.5*	<0.5*
2.4.6-TNT	**0.1**	nd	nd	nd	nd	nd
2.6-DNT	**0.1**	nd	nd	nd	nd	nd
2.4-DNT	**0.1**	nd	nd	nd	nd	nd
2-MNT	**0.1**	nd	nd	nd	nd	nd
4-MNT	**0.1**	nd	nd	nd	nd	nd
3-MNT	**0.1**	nd	nd	nd	nd	nd

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate
* : Increaced PQL due to matrix interference

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

Analyte	Lab No	E16202	E16203	E16204	E16205	E16206
	Sample Id	GS13	GS14	GS15	GS16	GS17
	PQL					
E1042 Moisture Content	-	41	23	5.5	11	2.5
E122 Explosive Compounds in Soil						
HMX	**0.1**	nd	nd	nd	nd	nd
RDX	**0.1**	<0.2*	nd	<0.2*	<0.5*	<0.5*
2.4.6-TNT	**0.1**	nd	nd	nd	nd	nd
2.6-DNT	**0.1**	nd	nd	nd	nd	<0.5*
2.4-DNT	**0.1**	nd	nd	nd	nd	nd
2-MNT	**0.1**	nd	nd	nd	nd	nd
4-MNT	**0.1**	nd	nd	nd	nd	nd
3-MNT	**0.1**	nd	nd	nd	nd	nd

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate
* : Increased PQL due to matrix interference

amdel

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

Analyte	Lab No	E16207	CB			
			CONTROL			
	Sample Id	GS10D	BLANK			
	PQL					
E1042 Moisture Content	-	10	--			
E122 Explosive Compounds in Soil						
[illegible]X	**0.1**	nd	nd			
RDX	**0.1**	nd	nd			
2.4.6-TNT	**0.1**	nd	nd			
2.6-DNT	**0.1**	<0.2*	nd			
2.4-DNT	**0.1**	<0.2*	nd			
2-MNT	**0.1**	nd	nd			
4-MNT	**0.1**	nd	nd			
3-MNT	**0.1**	nd	nd			

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate
* : Increased PQL due to matrix interference

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

	Lab No	E16192	E16193	CB		
				CONTROL		
	Sample Id	GS03	GS04	BLANK		
Analyte	PQL					
E121 Explosive Compounds in Water						
HMX	**0.02**	<0.1*	nd	nd		
RDX	**0.02**	nd	nd	nd		
[illegible]6-TNT	**0.02**	nd	nd	nd		
2.6-DNT	**0.02**	nd	nd	nd		
2.4-DNT	**0.02**	nd	nd	nd		
2-MNT	**0.02**	nd	nd	nd		
4-MNT	**0.02**	nd	nd	nd		
3-MNT	**0.02**	nd	nd	nd		

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate
* : Increased PQL due to matrix interference

amdel

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

	Lab No	E16190	E16191	E16194	E16195	E16196
	Sample Id	GS01	GS02	GS05	GS06	GS07
Analyte	PQL					
Total Phosphorus	**10**	135	139	167	143	197
Metals in Soils						
Magnesium	5	170	133	293	179	286
Sodium	5	78	23	47	6	31
Potassium	**10**	800	760	1120	880	1260
Calcium	**20**	1640	332	2200	210	2040
Strontium	5	16	13	25	15	25
Copper	5	12	11	501	48	23
Antimony	5	nd	nd	nd	nd	nd
Lead	5	17	9	21	10	26
Aluminium	5	7170	7660	11500	9680	13100
Metals in Soils						
Barium	**0.5**	19	16	29	19	29
Mercury	**0.05**	nd	nd	nd	nd	nd

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

Analyte	Lab No	E16197	E16198	E16199	E16200	E16201
	Sample Id	GS08	GS09	GS10	GS11	GS12
	PQL					
Total Phosphorus	**10**	195	63	146	410	136
Metals in Soils						
Magnesium	5	320	189	155	151	129
Sodium	5	34	15	19	24	30
Potassium	**10**	820	280	580	680	740
Calcium	**20**	2940	919	2510	1430	879
Strontium	5	16	11	12	14	17
Copper	5	26	7	15	11	25
Antimony	5	nd	nd	nd	nd	nd
Lead	5	53	13	27	16	47
Aluminium	5	13600	4740	6330	7280	5840
Metals in Soils						
Barium	**0.5**	20	14	15	17	20
Mercury	**0.05**	nd	nd	nd	nd	nd

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate

amdel

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

	Lab No	E16202	E16203	E16204	E16205	E16206
	Sample Id	GS13	GS14	GS15	GS16	GS17
Analyte	PQL					
Total Phosphorus	**10**	172	146	102	188	386
Metals in Soils						
Magnesium	5	168	289	165	126	638
Sodium	5	12	20	27	19	47
Potassium	**10**	1100	860	380	780	840
Calcium	**20**	771	398	749	1190	1140
Strontium	5	23	13	8	19	38
Copper	5	36	nd	28	nd	19
Antimony	5	nd	nd	nd	nd	nd
Lead	5	65	13	40	15	11
Aluminium	5	9560	17500	4620	6170	2710
Metals in Soils						
Barium	**0.5**	28	20	11	24	87
Mercury	**0.05**	nd	nd	nd	nd	nd

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

Analyte	Lab No / Sample Id / PQL	E16207 / GS10D	CB CONTROL BLANK
Total Phosphorus	**10**	122	nd
Metals in Soils			
Magnesium	5	193	nd
Sodium	5	26	nd
Potassium	**10**	720	nd
Calcium	**20**	3630	nd
Strontium	5	14	nd
Copper	5	19	nd
Antimony	5	nd	nd
Lead	5	89	nd
Aluminium	5	7990	nd
Metals in Soils			
Barium	**0.5**	17	nd
Mercury	**0.05**	nd	nd

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate

amdel

Job Number : 7E00286
Client : Rust PPK
Reference : 58H233A.008

	Lab No	E16192	E16193	CB		
				CONTROL		
	Sample Id	GS03	GS04	BLANK		
Analyte	PQL					
W022 Total Phosphate as P	**0.1**	0.13	0.29	nd		
Dissolved Metals in Waters						
Magnesium	**0.1**	0.87	0.93	nd		
[illegible]um	**0.1**	10	9.5	nd		
Potassium	**0.1**	2.4	1.3	nd		
Calcium	**0.1**	21	5.3	nd		
Strontium	**0.5**	nd	nd	nd		
Copper	**0.05**	0.07	nd	nd		
Antimony	**0.1**	nd	nd	nd		
Lead	**0.05**	nd	nd	nd		
Aluminium	**0.05**	0.42	0.37	nd		
Barium	**0.05**	nd	nd	nd		
E350 Mercury in Water	**0.001**	nd	nd	nd		

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate

amdel

Job Number : 7E00155

Client : Rust PPK

Reference : 58H233A.008

Analyte	Lab No / Sample Id / PQL	E15063	E15064	E15066	CB	
					CONTROL	
	Sample Id	HW2	HW3	HW5	BLANK	
Analyte	PQL					
E1042 Moisture (%w/w)	-	18	22	18		
Total Phosphorus	10	33	67	118	nd	
Metals in Soils						
Magnesium	5	122	121	184	nd	
Sodium	20	60	nd	nd	nd	
Potassium	20	140	140	580	nd	
Calcium	20	403	160	77	nd	
Strontium	5	6	nd	nd	nd	
Copper	5	12	9	nd	nd	
Antimony	5	nd	nd	nd	nd	
Lead	5	21	11	32	nd	
Aluminium	5	1920	2980	7640	nd	
Barium	0.5	9.7	5.9	11	nd	
cury	0.05	nd	nd	0.060	nd	

PQL = Practical Quantitation Limit

LNR = Samples Listed not Received

nd = Less than PQL

-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified

Waters : mg/L (ppm) unless otherwise specified

Leachates : mg/L (ppm) in leachate

amdel

Job Number : 7E00155
Client : Rust PPK
Reference : 58H233A.008

	Lab No	E15063	E15064	E15066	CB	
					CONTROL	
	Sample Id	HW2	HW3	HW5	BLANK	
Analyte	PQL					
E122 Explosive Compounds in Soil						
HMX	**0.1**	<0.5*	nd	nd	nd	
RDX	**0.1**	<0.5*	nd	nd	nd	
[illegible]6-TNT	**0.1**	nd	nd	nd	nd	
2-MNT	**0.1**	nd	nd	nd	nd	
4-MNT	**0.1**	nd	nd	nd	nd	
3-MNT	**0.1**	nd	nd	nd	nd	

PQL = Practical Quantitation Limit
LNR = Samples Listed not Received
nd = Less than PQL
-- = Not Applicable

Soils : mg/kg (ppm) dry weight unless otherwise specified
Waters : mg/L (ppm) unless otherwise specified
Leachates : mg/L (ppm) in leachate
* Matrix interference / PQL increased

Appendix 4

QA/QC Results

amdel

QA/QC APPENDIX NO. 7E00286

Method	Description
E122	Explosive Compounds
E121	Explosive Compounds
E517	Phosphorous (Total)
W022.3	Total Phosphate
E340	Metals by ICP-AES
E370	Metals by ICP-MS
E350	Mercury
E350	Mercury

Chromatography QA/QC

	Yes	No	N/A
Retention Time Window Within Acceptance Criteria(±2%)	√		
Check Standard Within Acceptance Criteria(±10%)	√		
Recalibration Within Acceptance Criteria(±15%)	√		

Other QA/QC

	Yes	No	N/A
Holding time conforming With Method Specification	√		
Chain of Custody Attached	√		

N/A=Not Applicable

Comments

1. Laboratory QA/QC including Duplicates, Matrix Spike Duplicates, and check/reference samples are included in this QA/QC appendix. (Where applicable)
2. Inter-Laboratory proficiency trial results available on request. (Where applicable)
3. Surrogate description and recoveries are recorded in the Report. (Where applicable)
4. Acceptance criteria for specific analytes as are listed on each QA/QC page.
5. Practical Quantitation Limit (PQL is typically 2-10 x method detection limit (MDL)
6. PQL's are matrix dependent and are increased accordingly where sample extracts are diluted.

R.G. MOONEY B.Sc.(Hons), Dip.F.D.A., M.R.A.C.I.
Authorising Chemist

amdel

Job Number : 7E00286

QAQC : Matrix Spike / Check Solution

Analyte	Level (ppm)	Level Detected Result1 (ppm)	Result2 (ppm)	Recovery Details Rec 1 (%)	Rec 2 (%)	Average (%)	RPD (%)
E122 Explosive Compounds in Soil							
HMX	2	2.0	2.0	100%	100%	100%	0%
RDX	2	1.8	2.1	90%	105%	98%	15%
2.4.6-TNT	2	1.9	1.9	95%	95%	95%	0%
2.6-DNT	2	1.8	2.1	90%	105%	98%	15%
2.4-DNT	2	1.9	2.0	95%	100%	98%	5%
2-MNT	2	1.9	2.0	95%	100%	98%	5%
NT	2	1.8	1.8	90%	90%	90%	0%
3-MNT	2	2.0	2.0	100%	100%	100%	0%

PQL = Practical Quantitation Limit

(S) Soils : mg/kg (ppm) dry weight
(W) Waters : mg/l (ppm)

nd = Not Detected
-- = Not Applicable

All results are within the acceptance criteria:

Refer to Amdel-Sydney Quality Control Manual SPM-01 3rd Edition 1/7/96

amdel

Job Number : 7E00286

QAQC : Duplicates

Analyte	PQL	Dupl 1	Dupl 2	Average	RPD (%)
E122 Explosive Compounds in Soil					
HMX	**0.1**	nd	nd		
RDX	**0.1**	<0.2*	<0.2*		
2.4.6-TNT	**0.1**	nd	nd		
2.6-DNT	**0.1**	nd	nd		
2.4-DNT	**0.1**	nd	nd		
2-MNT	**0.1**	nd	nd		
4-MNT	**0.1**	nd	nd		
NT	**0.1**	nd	nd		

PQL = Practical Quantitation Limit

(S) Soils : mg/kg (ppm) dry weight
(W) Waters : mg/l (ppm)
* : Increased PQL due to matrix interference

nd = Not Detected
– = Not Applicable

All results are within the acceptance criteria:

Refer to Amdel-Sydney Quality Control Manual SPM-01 3rd Edition 1/7/96

amdel

Job Number : 7E00286

QAQC : Matrix Spike / Check Solution

Analyte	Level (ppm)	Level Detected Result1 (ppm)	Level Detected Result2 (ppm)	Recovery Details Rec 1 (%)	Recovery Details Rec 2 (%)	Recovery Details Average (%)	Recovery Details RPD (%)
E121 Explosive Compounds in Water							
HMX	0.2	0.20	0.20	100%	100%	100%	0%
RDX	0.2	0.19	0.23	95%	115%	105%	20%
2.4.6-TNT	0.2	0.22	0.19	110%	95%	103%	15%
2.6-DNT	0.2	0.21	0.21	105%	105%	105%	0%
2.4-DNT	0.2	0.20	0.22	100%	110%	105%	10%
2-MNT	0.2	0.22	0.23	110%	115%	113%	5%
[illegible]NT	0.2	0.19	0.20	95%	100%	98%	5%
3-MNT	0.2	0.19	0.19	95%	95%	95%	0%

PQL = Practical Quantitation Limit

(S) Soils : mg/kg (ppm) dry weight
(W) Waters : mg/l (ppm)

nd = Not Detected
-- = Not Applicable

All results are within the acceptance criteria:

Refer to Amdel-Sydney Quality Control Manual SPM-01 3rd Edition 1/7/96

amdel

Job Number : 7E00286

QAQC : Matrix Spike / Check Solution

Analyte	Level (ppm)	Level Detected		Recovery Details			
		Result1 (ppm)	Result2 (ppm)	Rec 1 (%)	Rec 2 (%)	Average (%)	RPD (%)
Metals in Soils							
Magnesium	50	50	50	100%	100%	100%	0%
Sodium	50	51	52	102%	104%	103%	2%
Potassium	50	50	50	100%	100%	100%	0%
Calcium	50	46	47	92%	94%	93%	2%
Strontium	50	52	51	104%	102%	103%	2%
[illegible]ninium	50	51	51	102%	102%	102%	0%
Metals in Soils							
Barium	5.0	4.3	4.3	86%	86%	86%	0%
Mercury	0.50	0.47	0.48	94%	96%	95%	2%

PQL = Practical Quantitation Limit

(S) Soils : mg/kg (ppm) dry weight
(W) Waters : mg/l (ppm)

nd = Not Detected
-- = Not Applicable

All results are within the acceptance criteria:

Refer to Amdel-Sydney Quality Control Manual SPM-01 3rd Edition 1/7/96

amdel

Job Number : 7E00286

QAQC : Duplicates

Analyte	PQL	Dupl 1	Dupl 2	Average	RPD (%)
Total Phosphorus	**10**	135	135	135	0%
Metals in Soils					
Magnesium	5	142	170	156	17%
Sodium	5	48	78	63	47%
Potassium	**10**	720	800	760	10%
Calcium	**20**	1380	1640	1510	17%
Strontium	5	14	16	15	13%
Copper	5	12	12	12	0%
.mony	5	nd	nd		
Lead	5	17	17	17	0%
Aluminium	5	5980	7170	6575	18%
Metals in Soils					
Barium	**0.5**	19	19	19	0%
Mercury	**0.05**	nd	nd		

PQL = Practical Quantitation Limit

(S) Soils : mg/kg (ppm) dry weight
(W) Waters : mg/l (ppm)

nd = Not Detected
-- = Not Applicab

All results are within the acceptance criteria:

Refer to Amdel-Sydney Quality Control Manual SPM-01 3rd Edition 1/7/96

amdel

Job Number : 7E00286

QAQC : Matrix Spike / Check Solution

Analyte	Level (ppm)	Level Detected		Recovery Details			
		Result1 (ppm)	Result2 (ppm)	Rec 1 (%)	Rec 2 (%)	Average (%)	RPD (%)
Dissolved Metals in Waters							
Magnesium	50	50	50	100%	100%	100%	0%
Sodium	50	51	52	102%	104%	103%	2%
Potassium	50	50	50	100%	100%	100%	0%
Calcium	50	46	47	92%	94%	93%	2%
Strontium	2.0	2.07	2.03	104%	102%	103%	2%
Copper	1.0	0.95	0.94	95%	94%	95%	1%
mony	1.0	0.98	1.0	98%	100%	99%	2%
Lead	1.0	0.95	0.95	95%	95%	95%	0%
Aluminium	1.0	1.0	1.0	100%	100%	100%	0%
Barium	0.50	0.51	0.51	102%	102%	102%	0%
E350 Mercury in Water	0.12	0.12	0.12	100%	100%	100%	0%
W022 Total Phosphate as P	1.0	1.0	1.0	100%	100%	100%	0%

PQL = Practical Quantitation Limit

(S) Soils : mg/kg (ppm) dry weight
(W) Waters : mg/l (ppm)

nd = Not Detected
-- = Not Applicable

All results are within the acceptance criteria:

Refer to Amdel-Sydney Quality Control Manual SPM-01 3rd Edition 1/7/96

amdel

24 FEB 1997

Registered No. 1464

This Laboratory is registered by the National Association of Testing Authorities, Australia. The test(s) reported herein have been performed in accordance with its terms of registration. This document shall not be reproduced except in full.

ENVIRONMENTAL AND INDUSTRIAL SERVICES DIVISION
Trading as Australian Analytical Laboratories Pty Ltd
ACN 001 491 667

Correspondence to:
PO BOX 514
HORNSBY NSW 2077

5 Kelray Place
ASQUITH NSW 2077
Telephone: (02) 9482 1922
Facsimile: (02) 9482 1734

CERTIFICATE OF ANALYSIS

Contents :
1) Cover Page
2) Analysis Report Pages : 1 to 2
3) QA/QC Appendix

REPORT No : 7E00155

ATTENTION : Mr Andrew Cameron

CLIENT : Rust PPK

SAMPLES : 6 x soils

REFERENCE : 58H233A.008

DATE RECEIVED : 31/01/97

DATE REPORTED : 17/02/97

	Method	Description
	E1042	Moisture (%w/w)
	E122	Explosive Compounds
*	E517	Phosphorous (Total)
	E320	Metals Preparation - Soils
	E340	Metals by ICP-AES
	E350	Mercury
	HOLD	Samples on Hold

* The performance of this test is not covered by NATA registration for this laboratory

RESULTS

All samples were analysed as received.
This report relates specifically to the samples received. Results relate to the source material only to the extent that the samples as supplied are truly representative of the sample source.
This report replaces any preliminary results issued on :14-02-97

PLEASE SEE ATTACHED PAGES FOR RESULTS

R.G. MOONEY B.Sc.(Hons), Dip.F.D.A., M.R.A.C.I.
Authorising Chemist

amdel

QA/QC APPENDIX NO. 7E00155

Method	Description
E122	Explosive Compounds
E517	Phosphorous (Total)
E340	Metals by ICP-AES
E370	Metals by ICP-MS
E350	Mercury

Chromatography QA/QC

	Yes	No	N/A
Retention Time Window Within Acceptance Criteria(±2%)	√		
Check Standard Within Acceptance Criteria(±10%)	√		
Recalibration Within Acceptance Criteria(±15%)	√		

Other QA/QC

	Yes	No	N/A
Holding time conforming With Method Specification	√		
Chain of Custody Attached	√		

N/A=Not Applicable

Comments

1. Laboratory QA/QC including Duplicates, Matrix Spike Duplicates, and check/reference samples are included in this QA/QC appendix. (Where applicable)
2. Inter-Laboratory proficiency trial results available on request. (Where applicable)
3. Surrogate description and recoveries are recorded in the Report. (Where applicable)
4. Acceptance criteria for specific analytes as are listed on each QA/QC page.
5. Practical Quantitation Limit (PQL is typically 2-10 x method detection limit (MDL)
6. PQL's are matrix dependent and are increased accordingly where sample extracts are diluted.

R.G. MOONEY B.Sc.(Hons), Dip.F.D.A., M.R.A.C.I.
Authorising Chemist

amdel

Job Number : 7E00155

QAQC : Matrix Spike / Check Solution

Analyte	Level (ppm)	Level Detected Result1 (ppm)	Result2 (ppm)	Recovery Details Rec 1 (%)	Rec 2 (%)	Average (%)	RPD (%)
Total Phosphorus	1	nd		--			
Metals in Soils							
Magnesium	50	49	49	98%	98%	98%	0%
Sodium	50	60	60	120%	120%	120%	0%
Potassium	50	40	40	80%	80%	80%	0%
Calcium	50	45	44	90%	88%	89%	2%
Strontium	50	51	51	102%	102%	102%	0%
per	50	53	53	106%	106%	106%	0%
Antimony	50	52	51	104%	102%	103%	2%
Lead	50	51	49	102%	98%	100%	4%
Aluminium	50	52	52	104%	104%	104%	0%
Metals in Soils							
Barium	5.0	4.7		94%			
Mercury	0.50	0.48	0.50	96%	100%	98%	4%

PQL = Practical Quantitation Limit

(S) Soils : mg/kg (ppm) dry weight
(W) Waters : mg/l (ppm)

nd = Not Detected
-- = Not Applicable

All results are within the acceptance criteria:

Refer to Amdel-Sydney Quality Control Manual SPM-01 3rd Edition 1/7/96

amdel

Job Number : 7E00155

QAQC : Matrix Spike / Check Solution

Analyte	Level (ppm)	Level Detected Result1 (ppm)	Level Detected Result2 (ppm)	Recovery Details Rec 1 (%)	Recovery Details Rec 2 (%)	Recovery Details Average (%)	Recovery Details RPD (%)
E122 Explosive Compounds in Soil							
HMX	-	--	--				
RDX	2	1.8	1.9	90%	95%	93%	5%
2.4.6-TNT	2	1.5	1.6	75%	80%	78%	5%
2-MNT	-	--	--				
4-MNT	-	--	--				
3-MNT	-	--	--				

PQL = Practical Quantitation Limit

(S) Soils : mg/kg (ppm) dry weight
(W) Waters : mg/l (ppm)

nd = Not Detected
-- = Not Applicable

All results are within the acceptance criteria:

Refer to Amdel-Sydney Quality Control Manual SPM-01 3rd Edition 1/7/96

Appendix 5

RPD Values for Field Duplicate

TABLE 5.1 SUMMARY OF SOIL LABORATORY ANALYTICAL RESULTS

Sample	Location	Heavy Metals				
		Copper	Antimony	Lead	Barium	Mercury
GS01	DM1	12	nd	17	19	nd
GS02	DM1	11	nd	9	16	nd
GS05	DM1	**501**	nd	21	29	nd
GS06	DM1	48	nd	10	19	nd
GS07	DM1	23	nd	26	29	nd
GS08	DM1	26	nd	53	20	nd
GS09	DM1	7	nd	13	14	nd
GS10	DM1	15	nd	27	15	nd
GS11	DM1	11	nd	16	17	nd
GS12	DM1	25	nd	47	20	nd
GS13	DM1	36	nd	65	28	nd
GS14	DM1	<5	nd	13	20	nd
GS15	DM1	28	nd	40	11	nd
GS16	DM1	<5	nd	15	24	nd
GS17	DM1	19	nd	11	87	nd
Laboratory Practical Quantitation Limit		<5	<5	<5	<0.5	<0.5
ANZECC Guideline Criteria		60	20	300	-	1
Dutch Intervention Level		190	-	530	625	10

Note: All expressed in milligrams per kilogram.
Bold indicates values exceed NSW Environment Protection Authority Criteria for Sensitive Land Use.
Shaded indicates values exceed Dutch Intervention Levels.

Appendix E

Bush Fire Report

Second Sydney Airport Environmental Impact Statement Hazards and Risks Bush Fire Report

---

Department of Transport and Regional Development

Prepared by:
John Travers and Associates

and

PPK Environment & Infrastructure Pty Ltd
9 Blaxland Road
Rhodes NSW 2138
PO Box 248
Concord West NSW 2138
Australia
Telephone: (612) 9743 0333
Facsimile: (612) 9736 1568

25 August, 1997
58H233A PR_1620

Contents

		Page Number
Part A:	Introduction	
Chapter 1	Introduction	1 - 1
Chapter 2	Methodology	2 - 1
	2.1 Aims and Scope of Work	2 - 1
	2.2 Information Sources	2 - 1
	2.3 Review of Previous Work	2 - 2
Part B:	Existing Environment	
Chapter 3	Existing Environment	3 - 1
	3.1 Environmental Context	3 - 1
	3.1.1 Badgerys Creek	3 - 1
	3.1.2 Holsworthy	3 - 2
	3.2 Fire Management	3 - 5
	3.2.1 Introduction	3 - 5
	3.2.2 Statutory Context	3 - 6
	3.2.3 Fire Fighting Capability in New South Wales	3 - 8
	3.2.4 Hazard Management	3 - 11
Part C:	Assessment of Impacts	
Chapter 4	Impacts of Badgerys Creek Options	4 - 1
	4.1 Construction Phase	4 - 1
	4.1.1 Risk of Bush Fires Due to Airport construction	4 - 1
	4.1.2 Effect of Bush Fires on Airport Construction	4 - 1
	4.2 Operational Phase	4 - 2
	4.2.1 Risk of Bush Fires Due to Airport Operations	4 - 2
	4.2.2 Effect of Bush Fires on Airport Operations	4 - 3

CHAPTER 5 IMPACTS OF HOLSWORTHY OPTIONS 5 - 1

5.1 CONSTRUCTION PHASE 5 - 1

5.1.1 RISK OF BUSH FIRES DUE TO AIRPORT CONSTRUCTION 5 - 1
5.1.2 EFFECT OF BUSH FIRES ON AIRPORT CONSTRUCTION 5 - 2

5.2 OPERATIONAL PHASE 5 - 2

5.2.1 RISK OF BUSH FIRES DUE TO AIRPORT OPERATIONS 5 - 2
5.2.2 EFFECT OF BUSH FIRES ON AIRPORT OPERATIONS 5 - 3

PART D: ENVIRONMENTAL MANAGEMENT

CHAPTER 6 ENVIRONMENTAL MANAGEMENT 6 - 1

6.1 BADGERYS CREEK OPTIONS 6 - 1

6.1.1 CONSTRUCTION 6 - 1
6.1.2 OPERATIONS 6 - 2

6.2 HOLSWORTHY OPTIONS 6 - 3

6.2.1 HOLSWORTHY OPTION A - CONSTRUCTION 6 - 3
6.2.2 HOLSWORTHY OPTION A - OPERATIONS 6 - 6
6.2.3 HOLSWORTHY OPTION B - CONSTRUCTION 6 - 9
6.2.4 HOLSWORTHY OPTION B - OPERATIONS 6 - 11

PART E: SUMMARY OF IMPACTS

CHAPTER 7 SUMMARY OF BUSHFIRE IMPACTS 7 - 1

7.1 BADGERYS CREEK OPTIONS 7 - 1
7.2 HOLSWORTHY OPTIONS 7 - 1

REFERENCES R - 1

APPENDIX

Appendix 1 Definitions and Terms

PART A: INTRODUCTION

CHAPTER 1 INTRODUCTION

John Travers and Associates was commissioned by PPK Environment & Infrastructure Pty Ltd to undertake a bush fire study for the Second Sydney Airport Draft EIS. The study covers the proposed airport options at Holsworthy and Badgerys Creek and is a component of the Hazard and Risk Study, reported in *Technical Paper No. 10 - Hazards and Risks.*

This work was undertaken in accordance with Guidelines developed for the Draft EIS by Environment Australia (formerly Commonwealth Environment Protection Authority). According to the Guidelines (p.15), it was necessary to 'assess fire risks, including bush fire risk, and discuss fire control and management proposals'.

CHAPTER 2 METHODOLOGY

2.1 AIMS AND SCOPE OF WORK

The aims of the bush fire study are to:

- provide background to existing fire management of the sites;
- establish potential 'bush fire threats' to aircraft operations and airport infrastructure; and
- assess the management regime required to manage the bush fire threat.

The study is not designed to provide detailed management strategies and or tactics. Further detailed studies would be required to provide long term management and operational information following airport site selection and infrastructure design. A number of assumptions have been made in the preparation of this report. These are noted in the text. Two key assumptions are that:

- management of the lands from a bush fire perspective will be consistent with current New South Wales practice; and
- removal of unexploded ordnance outside the proposed airport boundaries at Holsworthy is unlikely to occur.

2.2 INFORMATION SOURCES

Information was sought from neighbours such as Campbelltown City Council, Liverpool City Council, Sydney Water, Sutherland Fire Control, Ciba-Geigy, Bureau of Meteorology, National Parks and Wildlife Service as well as from the Holsworthy Army Range Control Centre.

Reliable fire history information was not available from any organisation contacted with respect to the Holsworthy sites. No records have been kept to determine location of fire ignition, duration of fire, extent of burn, ignition source and control and management difficulty.

No assistance was provided by Liverpool Council with respect to assessment of the Holsworthy options. However, this did not hinder the investigations. Personal contact with officers from Campbelltown Fire Control Office provided the majority of fire history information for the Holsworthy options.

2.3 REVIEW OF PREVIOUS WORK

No previous bush fire investigations of Badgerys Creek or Holsworthy have been undertaken by John Travers and Associates or others.

PART B: EXISTING ENVIRONMENT

CHAPTER 3 EXISTING ENVIRONMENT

3.1 ENVIRONMENTAL CONTEXT

Holsworthy and Badgerys Creek are opposites in terms of the fire potential of their respective landscapes.

Badgerys Creek is a grassy gently sloping landscape that does not have a history of wildfire. Holsworthy is a dissected plateau with steep in-accessible terrain and a long history of uncontrolled wildfire.

The type of vegetation within the areas of the two sites reflects these differences.

3.1.1 BADGERYS CREEK

Landscape and Vegetation

Options A, B and C for Badgerys Creek are located on similar terrain which consists of grassed paddocks. Occasional trees and or patches of forests follow creek lines or fence lines.

Neighbouring Bushland Communities and Conservation Status

Neighbouring communities consist of privately owned farms. There are no areas of extensive forest/woodland/shrub landscapes that have been set aside as conservation or recreational reserves.

Bush Fire Threat

The landscape surrounding the sites of the airport options at Badgerys Creek consists mainly of grassed areas, due to the existence of hobby farms and small scale agricultural activities. Little forest and shrub vegetation remains except along the verges of Badgerys Creek. No stands of woodland forest that would constitute a significant bush fire hazard exist in the vicinity of the proposed airport sites. However, poor fire management of the existing grassland could result in a potential fire threat.

There is the potential for bush fire ignition as a result of vehicle accidents on rural roads, arson, or careless use of equipment or fire on neighbouring lands. A similar risk is created by industrial activities carried out nearby. Fires that break out in these zones may not be extinguished quickly enough to stop spread amidst adjacent rural lands.

Overall existing bush fire threat is minimal due to the low slope characteristics of the area. In general terms, it is devoid of shrub and forests that could contribute to excessive and prolonged fire incidents. The threat from grass fires can be managed with either continual grazing practices by animals or by the regular slashing or mowing of grasses.

3.1.2 HOLSWORTHY

The proposed sites for Holsworthy Option A (north) and Holsworthy Option B (south) are some 10 kilometres apart. They occupy areas of land that have a history of regular fires, due to both accidental fires from farm lands and garbage tips as well as Army induced fires from the firing range.

Landscape and Vegetation

The landscape of Holsworthy Option A and Holsworthy Option B are similar across the majority of the vegetation and terrain. The vegetation is of a type that is prone to fire recurrence.

The Heath-Woodland vegetation community of Holsworthy is an open landscape that enables wind to penetrate and fan fires allowing the full impact of hot and dry winds to be felt. Little forest cover is provided by the woodland trees. This increases evaporation and eventual soil moisture loss. The landscape is also prone to lightning strikes. Current use of the Holsworthy Military Area for artillery range practice means fires regularly occur across the landscape.

Neighbouring Bushland Communities and Conservation Status

The landscapes neighbouring Holsworthy Military Area to the east, south-east and south are a combination of lands conserved within Heathcote National Park, Dharawal State Recreation Area and other lands managed by Sydney Water. Dharawal State Recreation Area is jointly managed with Sydney Water as a Catchment Special Area. The remaining bushland landscapes fall within local government areas.

Bush Fire Threat

Fire behaviour throughout the Holsworthy Military Area is complex because of the variation in combustible fuels (both living plant cover and litter) occurring on the dissected plateau landscape. The inaccessible terrain and the exposure of the plateau to winds makes fire control difficult. Unexploded ordnance creates additional fire suppression problems. Currently there are very few assets that require protection and this reduces the need for active fire suppression responses at the present time.

Most bush or grass fires occur during the period 10.00 hours to 20.00 hours with the highest intensity occurring usually between 12.00 to 17.00 hours. In times of extreme fire danger (less than six days per year on average) the period would extend from 06.00 hours to 24.00 hours.

Under this scenario it is likely that fires burning from the west would travel from Campbelltown to Sutherland shire in six to 24 hours with mopping up occurring over a period of between 24-72 hours (Turrin, pers. comm., 1997, Banks, pers. comm., 1997).

The presence of high fuel loads in combination with high temperatures, low humidity and strong winds creates a very high potential for major bush fires. Fuel management will therefore be a high priority for the functional operation of the airport.

Due to the type of open landscape of Heath/Woodland vegetation community the potential for lightning ignition is high whilst the "rapid rate-of-spread" of a fire is also potentially high due to the unimpeded path of wind through the open landscape. Clearing work during construction may reduce this impact.

The fire history of Holsworthy indicates that fires will burn from west to east and with some degree of regularity.

Exposure to bushland areas is considerably less for the site of Option B than for the site of Option A. The site of Option B lies closer to the built up areas of Campbelltown than the site of Option A, therefore there is less bushland on the western side in comparison to Option A.

Considerable bush fire prone land exists to the south-west and north-west of the sites of the airport options. The Woronora Catchment Area, which is under the management of Sydney Water is a large tract of bushland to the east. However, it is not seen as a significant threat because bush fires at Holsworthy have historically burnt from west to east and smoke dispersal has followed this direction.

Bushland west of the airport boundaries is limited in its ability to create a significant "fire front" due to the presence of residential lands in Campbelltown and Wedderburn. Fuels in and around the O'Hares Creek landscape are capable of producing significant localised fire behaviour.

In the zone between the southern boundary of the site of Option B and O'Hares Creek, the landscape is capable of producing a wide fire front, due to southerly wind changes.

Future expansion of the Wedderburn and Appin urban areas may increase the incidence of fires in that region. Such fires are likely to be arson or accident-related.

Current Fire Management

Within the Holsworthy Military Area there is a high occurrence of regular fires due to exploding ordnance, lightning and other (unknown) fires entering the site. As such there is a highly modified fire regime occurring across the landscape. Due to a lack of fire history records greater than 5 years no potential impact can be extrapolated.

A network of fire trails has been developed through the Holsworthy Military Area to assist in fire suppression operations. Generally these trails run north-south.

The Parliamentary Standing Committee on Disaster Management heard evidence from Sutherland Council in 1994 that the Holsworthy Military Area is prone to bush fires. Council also stated that the unexploded ordnance made fire fighting a dangerous activity. This meant that fire fighting activities were restricted to the roads and trails, and any use of fire to control wildfire (backburning) was limited to burns within either natural fire breaks such as roads, creeks or cliff lines. Fire fighting operations have lengthened by virtue of the extent of these natural boundaries.

Sutherland Council also argued that the Army used fire fighting equipment and communications systems which were not compatible with the Councils fire fighting service. It also claimed that the Army was not effective in its representation on the local bush fire management committee due to bureaucratic decision making processes.

Sutherland Council has a long history in fire management. It was the first local government to employ a full time fire control officer and was a prime catalyst in the development of residential planning regimes for bush fire prone areas. It was instrumental in creating perimeter roads around new developments at Menai and nearby areas.

Liverpool Council chose not to assist the preparation of this report. However in the past, Liverpool Council's volunteer bush fire service has played a significant role in the suppression of bush fires at Holsworthy.

Campbelltown local government area is separated from Holsworthy by deep ravines (Georges River and O'Hares Creek). The Holsworthy Military Area is only accessible via the 'Woolshed' Road. As response time from the nearest brigade to the range is approximately 45 minutes the capability for an effective fire suppression assistance from Campbelltown is limited.

Generally the Army must rely on its own fire fighting resources. When assistance is required, neighbouring authorities such as Campbelltown and /or Liverpool Councils are called upon. Where assistance is required, the request has to be made early, as the type of vegetation on the Holsworthy Military Areas enables fires to spread quickly. In large fire events it is not unusual for such outside assistance to be required for up to four days.

3.2 FIRE MANAGEMENT

3.2.1 INTRODUCTION

Bush fire is a natural phenomena in Australia. In NSW and Victoria, major bush fires which have occurred in 1939, 1985, 1991, 1994 and 1997 have resulted in death and significant property losses. In between these major fires many thousands of smaller fires have occurred. These did not become large fires due to the efforts of fire fighters and/or easing weather conditions. Simply put, small fires do not become large fires if they are extinguished early.

Fire management is a term used by land managers and fire controllers. It is a general term used to encapsulate the *prevention, use and control* of fire in bush and grass land.

If no fire management occurs history tells us that bush or grass fires may cause loss of life or at the very least injury, asset damage or destruction, ecological impact on plant and animal species, or a loss of soil and humus. For the sake of brevity in this discussion, grass fires are also referred to as bush fires.

In south-eastern Australia during mid February 1983, two thousand homes were destroyed and seventy one lives were lost. This event was known as "Ash Wednesday". Many hundreds of separate fires occurred over a 36-72 hour period.

In January 1994, the New South Wales bush fires occurred over a period of some 14 days.

Four lives were lost during the NSW fires. Two fire fighters lost their lives due to industrial accidents involving trees; one life was lost from a direct fire event at Como/Janalli; and a further person lost his life from a heart attack while assisting a neighbour in the protection of a home.

The NSW Coronial Inquiry into the 1994 bush fires delivered extensive findings into the deaths and the management of the fire fighting forces and the land management authorities. In general terms the Coroner reinforced what has been said many times before by other inquiries and committees, that is fuel (hazard) management must be carried out with regular vigour and with public participation.

This is particularly so when public lands are involved. In 1989, five years before the New South Wales fires, major changes to fire management occurred. These changes brought about significant advances in fuel and operational management planning. While these changes were brought about with full government support, implementation by local government was less than satisfactory.

3.2.2 STATUTORY CONTEXT

Bush fire management in New South Wales is directly related to the Bush Fires Act 1949 and indirectly related to many other Acts. *Table 3.1* depicts the legislation that affects fire management either directly or indirectly.

TABLE 3.1 BUSH FIRE RELATED LEGISLATION

Act	Bush Fire Related Aims of the Legislation
Bush Fires Act, 1949	Lives and property protection, use and control of fire, planning, co-ordination and funding
Fire Brigades Act, 1989	Buildings protection
Forestry Act, 1916	Forest protection
National Parks and Wildlife Service Act, 1974	Heritage protection
Environmental Planning and Assessment Act, 1979	Heritage protection and impact assessment
Threatened Species Conservation Act, 1995	Species survival and enhancement
Clean Waters Act, 1970	Water quality (burning impact)
Clean Air Act, 1961	Air quality (burning restrictions)
Soil Conservation Act, 1938	Soil stability (burning restrictions)

Generally the various acts of legislation refer to potential impact of fire upon lives and property, plants and animals, places of heritage significance, the use of fire as a hazard reduction tool and the use of fire to burn combustible wastes.

A revised *Bush Fires Act* has recently been exhibited by the New South Wales Government for public comment (Friday, March 21 1997). This draft *Rural Fires Bill 1997* proposes changes to current infrastructure and management.

The use of fire can have an impact upon native plant and animal species, communities and or their individual habitats. The impact may be positive or it may also be negative. Planning for expected wildfires and controlled fires (prescribed burns) will lessen the cumulative negative impact on the environment.

Depending on the conservation status of a bushland community, the development of a fire management plan will consider the biodiversity within an area and prescribe an appropriate plan to achieve management objectives.

An assessment of the likely impact of fire management actions and programs would need to be implemented. Possible management actions include the construction of new fire trails, remote fire lookout towers (video linked), remote weather stations, remote water tanks, dams on road sides, staging areas for fire vehicles, and helicopter operational and separate strategic medivac (medical evacuation) sites.

The proposals for fuel management programs will also require environmental assessment and management regimes to ensure impact is contained and controlled. The standard approach is to assess the fire management programs according to the Part V of the *Environmental Planning and Assessment Act, 1979*.

Lands that have been affected by fire fighting operations should be considered for immediate rehabilitation works. This may involve erosion management and or revegetation of areas.

Recent legislation (*Threatened Species Conservation Act, 1995*) has amended the *Environmental Planning and Assessment Act, 1979* and the *National Parks and Wildlife Service Act, 1974*. This requires an eight point test of significance on "Threatened Species" to be considered where certain activities are proposed to be carried out that may affect threatened species, populations and communities. The factors to be taken into account in deciding whether there is a significant effect are set out in Section 5A of the *Environmental Planning and Assessment Act, 1979*.

Under those amendments a Species Impact Statement is required to be prepared where a proposed activity is located on an area identified as critical habitat, which is likely to significantly affect threatened species, populations or ecological communities or their habitats. Where a Species Impact Statement is required the applicant (not the consultant) is required to seek the National Parks and Wildlife Service Director-General's requirements to carry out the Species Impact Statement.

If fire trails are required to be constructed or reconstructed, effective drainage and soil management should be a prime construction objective. All new trails and any proposed upgrading of trails should be carried out according to the Soil Conservation Service guidelines.

3.2.3 FIRE FIGHTING CAPABILITY IN NEW SOUTH WALES

In New South Wales for fire fighting carried out in the urban areas e.g. Sydney, Newcastle and Wollongong (and some large regional centres) the NSW Fire Brigades have overall responsibility. In the rural areas of the state (inclusive of the peripheral local government areas to Sydney, Newcastle and Wollongong and most of the regional centres) the Volunteer Bush Fire Service provides fire protection management.

The Volunteer Bush Fire Services is managed by individual local Councils, which provide administration for the Volunteer brigades. The Service is funded by Insurance Companies (75 percent), local government (12.5 percent) and the State Government (12.5 percent). The funds are distributed to Local Government by the Department of Bush Fire Services, which also provides administrative, training, education and other functional policy support to Local Government.

Other fire fighting organisations are the NSW National Parks and Wildlife Service and State Forests of New South Wales. Both these organisations are regionally based across the whole of the state and consist of highly trained professional fire fighters and fire managers. Organisations such as Sydney Water are also geared to combat fires in their own lands by way of trained fire fighters and through the preparation of fire management plans.

Co-ordination

The combination of fire fighting and land management agencies is an effective co-ordinated model in New South Wales. Despite differences in land management responsibilities, the specific areas of fire fighting, training and planning are standardized across the State through the principle of co-ordinated fire management. For emergency fire fighting, a centralised management structure is actuated. The current Chief Co-ordinator of Fire Fighting who heads this structure, is also the NSW Commissioner of the Department of Bush Fire Services.

Fire fighting services and land management agencies are guided in policy direction by a Co-ordinating Committee. This Committee is made up of the heads of peer organisations and is responsive to the *Bush Fires Act 1949*. The Committee is headed by the Chief Co-ordinator who has the responsibility for taking charge of fire fighting when they consider that an emergency declaration is required. In practice this occurs when the local Bush Fire Management Committee meets and decides that such action should occur.

Bush Fire Management Committees are established in local government areas to manage fires within their boundaries. The committee comprises elected officials of local government, town planners, fire managers, environmental representatives, land management and fire fighting agencies. They are not sub committees of Councils.

If a fire is of such concern that a higher level of command and control is required, declaration of an emergency is recommended by the Executive of the local Bush Fire Management Committee. An emergency is usually declared when multiple fire fighting agencies are required to assist at a fire. This is normally because local resources are considered to be insufficient.

Emergencies may also be declared under Section 41F of the *Bush Fires Act 1949* by the Chief Co-ordinator where in their opinion, deteriorating weather conditions require such action to be initiated. The Chief Co-ordinator has over-riding powers when working with land management authorities and fire fighting agencies, however individual command still rests with each respective organisation.

Management

Fire management involves a complex set of operational activities. The centre focus of all operational activities is to achieve operational preparedness. This involves ensuring the readiness of both personnel and equipment. As small fires can become big fires, efficient suppression of fire is the primary aim of fire controllers. Staff training is ongoing, as is the maintenance of vehicles and equipment and fire trails which provide access. Poor access means dangerous conditions for fire fighters and ultimately a lessened capability to control fires.

As technology has advanced so to has the ability to predict and respond to fires. 'Real-time' predictive modelling allows managers to predict certain events with a degree of accuracy. Lightning detection systems allow lightning strikes to be located. Reliable predictive weather forecasts are now available. These advances do not extinguish fires more quicker, however they allow safer fire operations to occur.

Where fires occur across local government boundaries, planning processes and co-ordination policies enable contiguous management of the fire and or fires without any significant structural changes to command and/or control functions.

Planning

The principle process of achieving co-ordinated planning is through Section 41(A) Fire Management Plans (*Bush Fires Act, 1949*). These Plans provide a basis of community protection within a local government area. This is achieved through a consultative approach by a local Bush Fire Management Committee. The aim of the planning framework is to detail requirements for co-ordinated fire management practices for protection of:

- life and property;
- community assets and values; and
- natural and cultural heritage and to decrease the severity and intensity of wildfires.

Each local government area is required to prepare a Section 41A Fire Management Plan to the Co-ordinating Committee for approval. The plans take the following form :

- Operational Plan - this defines what the fire fighting authorities will do; and
- Fuel Management Plan - this describes the management of hazardous fuels.

Aerial Suppression

The use of aircraft in the suppression of bush fires is not new to New South Wales. Aircraft were initially used in 1968 by the Forestry Commission of New South Wales for strategic management operations, aerial incendiarism for hazard reduction burning and backburning operations (Personal communication Mr. Bob Richmond, Former NSW Chief Co-ordinator Fire Fighting).

Prior to this date, ad hoc use of aircraft was common for aerial reconnaissance operations during bush fires and other day to day management operations. New South Wales has regularly used both fixed wing and rotary winged aircraft (helicopters) effectively in fire fighting and off-season hazard reduction operations since that time.

Over the intervening 30 years, economies of scale have allowed both fixed wing aircraft and rotary wing aircraft to play a significant role in providing increased fire protection for the community.

While aircraft are able to provide a wide range of services to assist fire managers, they are however, "specialist units" and therefore require specialist management support to undertake their individual tasks. The former Forestry Commission of New South Wales (now State Forests) and the NSW National Parks and Wildlife Service operate separate fleets of aircraft that are utilised for fire management operations on a regular basis.

Both organisations have developed considerable skills in aerial fire fighting operations. However they are unable to take the next step, to have multiple "fire bomber" aircraft at their disposal and create an aerial fire fighting wing. This is the approach used in the USA, Canada, Italy and Spain.

The aerial fire fighting wing approach is costly and uses larger aircraft. These aircraft are not able to be used in Australia with the same economies of scale and or operational benefits as occurs overseas due to a lack of significant water bodies. The aerial fire fighting wing approach has been considered by both empirical review and assessment carried out by the CSIRO (Project Aquarius).

Rugged and remote terrain is the precursor for the use of helicopters. Quick response to these fires through good 'fire intelligence' such as lightning detection equipment, regular aerial reconnaissance on days of high fire danger and skilful interpretation of advancing weather patterns via remote weather stations all play a role in being able to get to small fires.

There are many other examples of small fires that escaped to create what has been written into history as large and destructive fire events. However, it must be remembered that a total extinguishment policy on all fires is not achievable. It may also be considered to be impractical based on a low level of threat and risk to the surrounding community and their assets. In other words some fires may burn in an uncontrolled fashion and potentially not affect lives or property. However there may be ecological impacts upon plant and animal communities.

More over, "quick and total" extinguishment of a fire has a downside by default. If all fires are extinguished then a greater commitment to regular hazard management operations is required to ward off significant uncontrolled fire events. When a fire does get out of control on lands that have not been burnt regularly the intensity of that fire is far greater and has a naturally greater probability to increase its rate of spread (speed and spread). An example of this is the Byadbo fire of 1988.

Following research into the Byadbo fire, Barclay (1993) concludes that the use of aircraft to bombard a small fire in a remote location is significant in the suppression of small bush fires on days of high fire danger. Obviously, significant economic and environmental savings could be then attributed to the potential success of early extinguishment of such fires.

3.2.4 HAZARD MANAGEMENT

Use of Fire

Fire has long been used as a tool to reduce the build up of excess fuels. Fuel, oxygen and heat are required to sustain fire. As fuel is the only element that is capable of manipulation by man, fire suppression is only achieved through fuel management programs.

Broadly, the strategic use of fire by land managers of natural areas falls into three main categories:

- hazard reduction - removal of hazards, that is fuel (leaves, twigs, branches and living plants/trees);
- vegetation management/manipulation - management of vegetation to achieve ecological objectives via the maintenance, enhancement and alteration of an existing natural and/or modified vegetative community; and
- habitat protection/improvement - management of vegetation for the protection of soils (nutrients), seed banks for germination, stability of slope and quality of habitat for plants and animals.

Other uses of fire include:

- agricultural management (stubble removal, creation of fresh spring feed, weed control, pre harvest management, for example cane and forest floor cleaning);
- forestry operations (seed bed management); and
- more traditional uses such as access for hunting, creation of fresh grass for winter feed and land clearing.

Fuel (hazard) management is described as the manipulation or modification of fuel to reduce the threat of bush fire to life, property and the environment (Department of Bush Fire Services). It includes both the common use of fire for fuel reduction and its more specialised use as a management tool for maintaining particular vegetation communities or habitats. The intensity of the fire varies with a number of factors, including vegetation type, slope, aspect, micro-climate and so on.

The rate of fuel build up varies according to the vegetation community, micro-climate, fire history, the presence of micro-organisms and other factors such as soil and litter moisture.

Risk of damage from bush fire is a complex matter to determine, although it is generally acknowledged that the greater the fuel volume, the greater is the risk of a serious fire. Therefore the main aim of burning potential fuel is to reduce the amount of fuel available to burn. Any subsequent fire will therefore generate less heat, travel more slowly, have a lower flame height, be less likely to spot forward and begin new outbreaks, do less damage to standing vegetation and ultimately be easier to suppress.

Implementation of fuel management programs via fuel reduction burns is normally carried out in the cooler months of the year e.g. Autumn. This enables greater control of the fire so as to maintain it within the prescribed boundaries; and to lessen any impact upon tree canopy scorch.

These burns are sometimes not as successful as planned, due to only a small percentage of the bush being burnt or failure of fire to spread. This can be due to excessively cool and/or moist fuel.

In more rugged and remote areas, aerial incendiaries are dropped from helicopters or light planes. These begin fires and usually burn down slope towards creek beds and or rivers.

To control wildfires, incendiaries are sometimes used to burn out larger areas. This occurs if fuel loads are considered to be high and the time is judged to be right for such action to be implemented. This has been a common fire management strategy in the past. It is particularly useful where a lack of access trails restricts immediate suppression of a fire.

In recent times, opportunities for fuel reduction burning have been limited due wet autumns and excessively dry winters and springs. This situation inhibits effective hazard management operations.

Other Methods of Fuel Management

A number of mechanical, chemical and other methods may be used for fuel management. The choice of method depends on consideration of physical, social, economic and environmental factors. These include:

- mechanical removal - for example, the use of slashers and tractors to reduce fuel levels and construct fire breaks;

- hand clearing - this is labour intensive and is rarely used for fuel management except in small areas of special value, for example a bushland reserve surrounded by urban development;

- slashing/mulching - this involves the cutting of fuel and leaving it on the ground. Mulching is the cutting of the fuel into 'fine fuel' components;

- clearing - using a variety of machinery to remove fuel and or create fire breaks, sometimes to mineral earth (wholesale clearing). Selected clearing aims to retain specific native vegetation while reducing the amount of undergrowth and litter;

- chemical - herbicides are used to suppress vegetation growth. While not commonly used as a means of fuel management it is generally favoured for difficult to get to (small) areas; and

- grazing - grazing by animals is a traditional and effective method of reducing hazardous fuels.

Generally, burning of fuel is the most common and cost effective means of reducing fuel loads from the abovementioned methods.

Management Tools

Fire managers use a variety of tools to provide information on the potential for bush fires to 'begin and/or spread'. Predictive tools include the 'daily' weather indices of temperature (maximum and minimum), wind speed, wind direction and relative humidity.

Broad based indices are used to define areas of the state that are under more or less fire danger. This is measured by way of prolonged drought or rapid moisture loss in soils and vegetation. These indices are as follows:

- Fire Danger Index - measures the potential for fire danger ;
- Keetch - Byhram Drought Index - measures the moisture loss in vegetation; and
- Drought Index - Measures soil dryness.

Other predictive tools used by fire managers are the;

- McArthur Meter Forest Fire Index - Measures the fire behaviour potential in forests; and
- McArthur Meter Grassland Index - Measures the fire behaviour potential in grasslands.

Several predictive computer modelling tools are used to predict the 'rate and spread' of fires. During prolonged fire fighting operations, the use of other more sophisticated 'operational tools' aids in fire fighting. These include:

- Infra-Red Mapping - this involves mapping the perimeters of fires to portray the changes in shape and rate of spread. It is generally used as a macro tool and is usually carried out by fast moving jet aircraft which can cover large areas quickly;

- Line Scanning - this aids in the specific location of fire edges. It is generally used as a micro tool. It is usually carried out by helicopter; and

- Forward Looking Infra-Red Radar - this enables people to see through smoke. It is usually carried out by helicopter.

Monitoring Fire Weather

In New South Wales 'fire weather' is monitored by the Bureau of Meteorology. The Bureau provides 'spot forecasts' for specific areas, which aid in the development of fire fighting strategies, particularly if a 'weather change' is expected. The spot forecasts have a major impact on the safety of fire fighters and/or the potential for evacuating people who may be affected by such a change. The Bureau also provides staff to go into the field during fire events and provide a field based weather service. Local remote weather stations are also used as intelligence gathering devices.

Other weather based technologies used in fire fighting are 'lightning detection' systems. These detect all lightning strikes and map the movement of these strikes in real time. This information is important for considering lightning potential in areas which have a 'dry fuel state'. This technology, coupled with fuel state maps produced each week by the Bureau and with local knowledge assists in the development of fire suppression strategies.

Bush Fire Smoke

Smoke is a byproduct from the combustion of bush and grass fire/s. Apart from the gases that are produced by fires, a varying amount of particulate matter (uncombusted material and other micro solid residues) is also discharged into the atmosphere from material undergoing combustion. Bush fire smoke and the high amounts of particulate matter it contains are known to cause breathing problems in asthma sufferers.

Smoke with high amounts of particulate matter can also damage jet engines. Hot air associated with fires, particularly in 'rising convection columns', is also known to reduce the efficiency of jet engines.

The darkness of the smoke is an indication of the intensity of a fire. Dark smoke indicates high amounts of uncombusted material rising into the air. White smoke is indicative of moist fuels burning and little uncombusted material rising.

Dependent on the fuel type and the weather indices of the day, the intense heat of a fire can create a convection column. This takes the form of a whirling mass of hot air that rises vertically, taking with it uncombusted materials such as branches, leaves, twigs etc.

Fire History and Cause

Fire history information is used to determine the past frequency of fire events and the types of fire events that occurred. Mapping of fire history enables 'probable causes' to be considered on the basis of mapping the 'point of origin' for example, camp sites and or roads/trails. This information then allows land managers to determine whether it is necessary to tighten access or increase management controls for those particular areas.

Fire history is also important for fire ecology studies and the development of fuel management strategies and/or policies for specific areas. It is also an important factor in fire management planning at the urban bushland interface. Urban Development often reduces the available natural bushland areas by separating contiguous landscapes. The resulting change in landscape may also change the fuel type and its combustibility.

In 1995 the NSW Department of Bush Fire Services detailed a number of causes of fires which have been summarised in *Table 3.2* below:

TABLE 3.2 SCHEDULE OF CAUSES OF REPORTED FIRES - 1994/95

Causes	Number of Fires	Percent of Total
1. Miscellaneous - unknown	3,933	36.1
2. Burning off - legal	2,574	23.7
3. Burning off - illegal	1,402	12.9
4. Lightning	497	4.6
5. Incendiarism	419	3.9
6. Miscellaneous - unknown	376	3.5
7. Motor Vehicles	373	3.4
8. Domestic/children	334	3.1
9. Camps/cooking	247	2.3
10. Power Lines	230	2.1
11. Rubbish Tips	214	2.0
12. Farm Equipment	113	1.0
13. Industry	55	0.5
14. Sawmills	44	0.4
15. Smokers	38	0.3
16. Trains	34	0.3
Total	**10,883**	**100.0**

Source: Annual Report Department of Bush Fire Services 1994/95.

The above figures are estimates only. They are based on information supplied by the National Parks and Wildlife Service, State Forests and Local Government Councils.

Of the 10,883 fires in New South Wales during 1994/95, 'miscellaneous unknown fires' accounted for 36.1 percent of the total fires. The figure for the previous year (1993/94) amounted to 37.2 percent. The figure for the following year (1995/96) was 29.9 percent.

The figures in *Table 3.2* provide a basis for assessing probable causes of fires. However they do not indicate the size of each fire. For example, while lightning only accounted for 497 fires (4.6 percent) it is likely that these fires may have been the most significant in terms of fire size and resources used to suppress the fire. The 16 causes noted can be further reduced to three main categories, as follows:

- natural ignition - spontaneous combustion, lightning and/or friction;
- accidental fire - careless personal actions, careless use of machines, lack of maintenance on machines, faulty equipment; and
- deliberate ignition - arson.

Education programs may have an impact in reducing 'accidental fires' but the rate of natural fire ignitions is fairly constant. The occurrence of deliberate fires was notable during the January 1994 bush fires where significant resources were required from all over Australia to fight fires that were lit by arsonists (Senate Standing Committee, 1994). While the state of panic that resulted was minimal, it provided further issue for emergency services to deal with.

PART C: ASSESSMENT OF IMPACTS

CHAPTER 4 IMPACTS OF BADGERYS CREEK OPTIONS

As bushfire impacts of Badgerys Creek Options A, B and C are similar, they have been grouped together in the following discussion.

4.1 CONSTRUCTION PHASE

4.1.1 RISK OF BUSH FIRES DUE TO AIRPORT CONSTRUCTION

The construction phase will slightly increase the risk of bush or grass fires in comparison to the type of activity that currently occurs over the landscape.

Increased use of machinery would result in greater incidence of accidental fire ignition from sparks or other similar sources, which may cause fires to occur.

In NSW, fires burning from the north-west have historically been the most destructive. They are driven by hot and dry winds originating from the central Australian deserts. Such fires are more likely to occur during the bush fire danger period extending from October to March. Fires burning from the south-west are more likely to occur between February and September (Bureau of Meteorology, 1993).

For all three Badgerys Creek airport options, the area of land between Adams Road, The Northern Road and Elizabeth Drive constitutes the main bushfire hazard as it lies on the north-western side of the three airport sites. This land is approximately 200 hectares in size and is capable of producing significant smoke and surface flames if left in its natural state.

Fires occurring on external lands are likely to invade the airport construction zone unless a planned vegetation clearance process is implemented. This may occur via air blown embers or from flames passing through the grasslands.

The Planning and Design Report (Second Sydney Airport Planners, 1997a) states that site clearing will occur in a north-west to south-east direction. This will significantly limit the potential for fires to enter the airport site during construction.

4.1.2 EFFECT OF BUSH FIRES ON AIRPORT CONSTRUCTION

In the event of a bush fire, the degree of impact on airport construction activities would depend upon wind direction and wind speed. Drifting smoke plumes are likely to be the main source of impact, affecting on-site activities, construction traffic entering and leaving the site and traffic on major roads within the area surrounding the airport sites. This situation is likely to occur between 1.00 pm and 6.00 pm, the peak periods for both local road traffic and aircraft movements.

Impacts of fires on airport construction activities would depend on the degree of cleared land or the staging of the peripheral development works.

The proposed staging plan identifies the construction of temporary roads following the provision of perimeter security fencing. Equipment required to carry out fencing would be subject to fire threat during this process.

The type of vegetation that covers the sites of the Badgerys Creek options is not conducive to high intensity fire regimes. However, grasses are capable of moderate fire intensity and a fast rate of spread. This means that fires are potentially able to 'run' very fast given the right extremes in weather conditions.

Impacts are likely to be more smoke than flame resulting in a probable rapid exodus of construction staff. Machinery may be at risk, along with fuel storages and combustible materials such as timber, tyres or fabric that may be temporarily stored on site.

The level of risk to construction staff is not judged to be high, given that there are a considerable number of potential exit routes from the site.

Emergency management of fires occurring during construction would not be hindered due to the ease of access over the gentle terrain conditions. However because fire knows no boundaries, a fire is likely to move through the airport site/s and continue onto neighbouring lands, subject to the existence of available grass or shrub fuels.

Both The Northern Road and Elizabeth Drive would act as significant fire breaks where fire suppression operations can occur with a high expectation for total extinguishment.

4.2 OPERATIONAL PHASE

4.2.1 RISK OF BUSH FIRES DUE TO AIRPORT OPERATIONS

The risk of bush and or grass fires on the airport operational zone would be minimal due to the nature of the landscape following development. Regular mowing of grass aprons will eliminate the capability for grass fires to occur. Any fires occurring within airport facilities are unlikely to spread beyond the airport boundary.

Lands external to the airport zone are likely to remain a potential fire hazard unless a change of land use occurs. Of particular risk is the potential impact from grass fires on the periphery of the airport within a distance of one kilometre.

4.2.2 EFFECT OF BUSH FIRES ON AIRPORT OPERATIONS

The main impacts on airport operations of fires in areas surrounding the airport relate to the effects of smoke plumes. It is unlikely that flames will impact upon airport operations because nearby public roads would act as strategic fire breaks.

Grass fires burning under strong winds (greater than 20 kilometres per hour) cause smoke to lay close to the ground before dissipating. In lower wind speeds (less than 15 kilometres per hour) smoke rises gently and can develop a wide curtain across a landscape for some 0 to 500 metres above ground. Cured grass burns quickly and produces dense dark coloured smoke which would impact upon visibility for aircraft and ground operations.

Wind direction and strength would determine whether airport operations are likely to be affected by smoke. Potential impacts include restrictions on vehicular access and egress from the airport, operational problems with air conditioning systems, potential loss of night-time vision by pilots and increased risk of aircraft crashes due to smoke being drawn into jet engines.

CHAPTER 5 IMPACTS OF HOLSWORTHY OPTIONS

The impacts of Holsworthy Option A and Option B are not greatly different, therefore both options have been considered together in this discussion.

5.1 CONSTRUCTION PHASE

5.1.1 RISK OF BUSH FIRES DUE TO AIRPORT CONSTRUCTION

During the construction period, there is potential for fires to begin and spread. This will be a risk to workers and others utilising the site and must be managed effectively.

Clearing of underbrush and tree stands will create a large amount of combustible material. Vegetation is proposed to be broken down by chipping. Storage of the unchipped material could constitute a significant fire hazard whilst this process is occurring.

Clearing may also start fires by machinery scraping sandstone rocks and causing sparks. Under medium to high wind situations in times of high to extreme fire danger, fires are likely to occur and spread unless action is taken to either suppress or extinguish them quickly.

Access roads or haul roads of 50 metres width would not be sufficient to prevent the spread of fire. Additional areas of cleared land will also be required. In areas where this is topographically impossible, fire trails would need to be made early in the construction phase.

Temporary roads are proposed to be constructed following site clearing and establishment of construction facilities and temporary services. Lack of adequate access and egress during this period could cause further bush fire risk.

Water spraying trucks used for dust suppression would be able to be used as fire suppression equipment of a temporary nature.

As the construction activities are planned to occur for 20 hours per day, this is likely to increase the probability of fires occurring during the bush fire danger period, since many fires have human related causes, for example, cigarettes or sparks from machinery.

Fires could also occur if clearance of unexploded ordnance is undertaken in high fire danger periods.

5.1.2 EFFECT OF BUSH FIRES ON AIRPORT CONSTRUCTION

In the event of a bush fire, the degree of impact on airport construction activities would depend upon wind direction and wind speed. Drifting smoke plumes are likely to be the main source of impact, affecting on-site activities, construction traffic entering and leaving the site and traffic on major roads within the area surrounding the airport sites. This situation is likely to occur between 1.00 pm and 6.00 pm, the peak period for local road traffic movements.

Isolation of the construction site from fire fighting services would create concerns for the safety of workers. However, large (60 to 90 megalitre) dams are proposed to be constructed and filled from run-off prior to bulk filling operations being commenced. These would provide adequate supplies of water for fire fighters.

Evacuation management will be a critical consideration for all persons on site. An effective road system is critical in this respect.

There is a high potential for construction activities to be stopped due to bush fires and or extensive smoke pluming in the area.

5.2 OPERATIONAL PHASE

5.2.1 RISK OF BUSH FIRES DUE TO AIRPORT OPERATIONS

The risk of bush and or grass fires on the airport operational zone will be minimal due to the nature of the landscape following development. Regular mowing of grass aprons will eliminate the capability for grass fires to occur. Any fires occurring within airport facilities are unlikely to spread beyond the airport boundary.

The landscape within the boundaries of Holsworthy Option A and B will consist of an artificial landscape devoid of trees and shrubs. There will therefore be a negligible quantity of combustible fuel available on site. Grass aprons are not seen as a fire problem due to regular maintenance schedules.

Lands external to the airport zone are likely to remain a potential fire hazard unless a change of land use occurs.

The potential for bush fires to occur in the heavily forested landscape external to the proposed airport operational area is significant. The fire history whilst not adequately documented is however known to be of regularity and high suppression difficulty (pers Comm. Lido Turrin, Campbelltown Council Rural Fire Service).

Increased public access to such areas, because of the proposed roadways, could result in greater risk of bushfires due to human related causes, such as cigarettes or car crashes.

5.2.2 EFFECT OF BUSH FIRES ON AIRPORT OPERATIONS

Bush fires are capable of impeding or stopping airport operations due to the threat of direct flames, showering of airborne embers and the impact of smoke on visibility, air-conditioning systems and personal health.

Due to the large amount of bushland that surrounds both airport sites, bush fire related incidents could impact upon the main northerly access roads as well as the utility service corridors. It is not likely that fire via direct flame would enter the airport zone other than on the external peripheral zones.

As bushfires are able to develop significant plumes of dark smoke, airport operations could be affected by as much as six to eight hours (for example, every two to five years) with a potential for a longer impact period of 12 to 24 hours on an irregular basis (for example, every 10 to 30 years).

These estimates are based on the likelihood of no suppression operations occurring. If effective suppression capability is provided, there should be little material impact and airport closures, would be unlikely.

However, main roads could be cut off due to heavy smoke, and vehicle accidents could occur, further complicating vehicle management on those roads.

A lack of fire management planning and associated activities would see impacts such as:

- restrictions on aircraft operations;
- air-conditioning shutdown;
- loss of external electrical supply;
- vehicle accidents and or chokes on main arterial roads;
- exacerbation of health problems, for example, asthma, and or other respiratory conditions;
- the need to initiate major evacuation or incident management systems to cater for airport operational breakdown; and
- airport closure.

Vegetation within the Holsworthy Military Area is readily combustible and creates dark smoke plumes under hot and dry weather conditions. The dark colour of the smoke indicates that a significant amount of particulate matter would be present in the plume.

Without rapid extinguishment strategies the development of a fire front emanating from the Campbelltown/Wedderburn/Ingleburn area could grow to 200 to 800 metres in width, although it is more likely to be less than 400 metres. Regardless, this could create a significant smoke plume or potentially a convection column with high amounts of particulate matter.

Smoke with a high proportion of particulate matter is potentially able to affect the efficiency of jet engines. Propeller driven aircraft are less susceptible to engine failure in a similarly smoke-polluted atmosphere. Helicopters can generally manoeuvre around the smoke plume to take off or land.

Depending on wind speed, the smoke would be likely to lay across both of the north south runways for a height of approximately zero to 400 metres as it travelled in a south easterly or easterly direction. Disbursement of smoke would be dependent on the separation distance between the fire, the airport runways being used and the wind velocity.

If current military activities such as firing live ordnance cease as a consequence of establishing the airport, the incidence of fires caused by such actions would also cease.

The airport may need to shut down temporarily in the event of a fire, to permit fire fighting to proceed in a safe manner.

PART D: ENVIRONMENTAL MANAGEMENT

CHAPTER 6 ENVIRONMENTAL MANAGEMENT

6.1 BADGERYS CREEK OPTIONS

6.1.1 CONSTRUCTION

Emergency Evacuation and Fire Fighting Access

During construction, emergency evacuation would be likely to occur through many informal site entry points. However, the potential for such a situation is highly unlikely due to the limited extent of fuels during construction and the existence of the fire breaks by way of the presence of The Northern Road and Elizabeth Drive.

Proposed external roads as shown by the Master Plans allow fast and effective access to the airport sites for fire fighting.

Fire Fighting

Grass fires burning towards the airport site from neighbouring lands would require active suppression by the provision of perimeter fire breaks with fast access to those fire breaks.

Bush fires are usually suppressed by using fire as a back burning tool and or the use of water. Grass fires are often not controlled, but if they are, it is only by the application of water. This is due to the speed of travel and the usual capability to fight grass fires on the move from a fire tanker. Reticulated water (for example, water hydrants) for fighting fires would not be a primary requirement.

Existing dams or storage tanks (for example, six to eight vessels or dams of 100,000 litres) would provide adequate supplies of water to fight fires within the construction zone, and fires entering the site from external sources. Bulk water carriers, such as retired fuel tankers, could also be considered as "available fire fighting equipment".

All construction staff should be trained in basic fire fighting techniques and in procedures for summoning help if small fires get out of control.

Fire Prevention

In view of the private ownership of the land surrounding the site's airport options there is the potential for lands to be revegetated in the future or sold to local Councils as public open space. In this situation bush fire hazards may arise and will require ongoing fuel management regimes. It is envisaged that the construction phase may be in the order of five to eight years. This is a significant period in terms of vegetation growth.

Management of fuels and bush fire hazard outside the airport boundaries will not be within the powers of the airport operator. Therefore during construction the management of grass fuels will be the responsibility of local Councils through the enforcement of Section 13 Notices under the *Bush Fires Act, 1949*. These Notices require bush fire hazard reduction to be carried out by the land owner in a given period and to a certain standard. If hazard reduction is not carried out, Council can then serve a Section 14 Notice which enables Council to carry out the works at the owner's expense.

Without fuel management agreements or plans for fuel management being in place, airport construction would be at risk.

Whilst the residual undeveloped lands within the airport boundaries carry the potential for grass fire, this threat can be managed by either grazing or mowing, all of which can be coordinated by airport staff.

Within the airport construction zone, potential sources of ignition should be managed effectively to reduce the potential for fires. This may include storing flammable liquids, fuels and other materials in cleared areas, mowing or otherwise keeping grasses under control and ensuring that fire extinguishers are used when "hot work", such as welding or metal cutting is being undertaken.

6.1.2 OPERATIONS

Emergency Evacuation and Fire Fighting Access

Access roadways to the airport should provide adequate access for fire fighting, while emergency evacuation is occurring. Emergency Plan developed for the airport should include evacuation procedures for grass fires in its scope.

Fire Fighting

A dedicated airport fire fighting crew should be able to fight small grass fires which occur within the airport boundaries. Emergency Plans for the airport should define at what point external assistance is summoned to assist with controlling grass fires. Fire fighting facilities and procedures should be developed for the airport.

Fire Prevention

Combustible materials at the airport such as fuels and waste paper and vegetation should be stored well away from grassed areas. All airport vehicles should carry fire extinguishers to control small fires, and staff should be trained in how to fight small fires, and when to summon assistance.

Communication should be established with local Councils or relevant organisations to enable early warning of fires from external sources which may affect airport operations.

6.2 HOLSWORTHY OPTIONS

6.2.1 HOLSWORTHY OPTION A - CONSTRUCTION

The main bush fire threat relates to bushland surrounding outside the airport sites which would not be cleared as part of airport construction. Some risk is associated with on-site activities before clearing of the site has been completed.

Emergency Evacuation and Fire Fighting Access

Potential road and rail access into the site is from the west, north or north-east. All options show roadways entering the site at the one point on the northern boundary.

Emergency evacuation from the construction site in the event of a bush fire would be along roads used for construction access. Therefore, these roads must be maintained in good condition, to facilitate quick evacuation of staff from the site. These roads would also be the main access for fire fighting equipment, during the construction period since the existing main access trail that currently dissects the Holsworthy Military Area from north to south would be lost in the construction of the airport.

Access for fighting fires outside the airport boundary which have potential to affect the site would be severely hampered in the airport periphery areas due to steep slopes, inaccessible terrain and the presence of unexploded ordnance. This would cause problems for fire fighting capability because no effective fire fighting platform would be available for safe firefighting operations and regular fuel management operations.

The existing fire trail that links Moorebank Avenue in the north with Nat Bull (near Giles Junction) immediately south of the south-west corner of the proposed boundary would also be affected. Extensive works in the head waters of Kalibucca Creek where they extend close to the proposed airport site would be required to reconstruct this trail link.

Fire trail access to the north-west sector is on lands external to the proposed airport site. While there is an opportunity to increase fire trails in this area there is limited opportunity to create a new fire trail within the airport site due to the steep terrain in the north-west.

Existing fire trails located in the land to the north of the proposed airport boundary are sufficient in their number and their range. However they would not be in the control of the airport authority under the current boundary proposal.

Therefore access trails could be constructed (on both sides) along the main entry road to the airport (from the north). This is particularly so if the landscape in that area remains as bushland (as opposed to development of light industry).

As some of the main road options into the airport would also have a parallel rail line and fuel supply line the provision of appropriate fire trails is a high priority. This would enable all roads and infrastructure to be surrounded by strategic fire breaks and safe fire fighting platforms.

Existing fire trails to the east of the airport boundary are limited to a single trail between Lucas Heights and Giles Junction. This trail has several other minor trails that tack off to the east into the rugged terrain of Wild Cat Ridge and Wallaby Ridge. Only the Eckersley Ridge Trail links externally into Heathcote National Park at Eckersley Ford. This trail would be lost in the development of the southern runway. However there is an opportunity to reconstruct this trail on the southern edge of the runway.

There are no existing fire trails that provide access to the lands south of Giles Junction and or east of the southern runway.

Adequate planning for the provision of safe refuge areas and evacuation routes will need to be considered in detail.

Thus there is no other way of guaranteeing the reduction or elimination of intense smoke plumes other than by reducing the potential for intense fires to occur. This means either being vigilant for ongoing fuel management and or suppressing each and every fire immediately. The suppression of all fires requires a superior fire trail network with off shoots to each ridge and/or spur.

In order to estimate the rate of fire spread, the potential fire intensity and the potential extent of smoke pluming it would be necessary to carry out fire behaviour modelling and smoke modelling.

Existing fire trails that link Engineers Bridge with Nat Bull allow access to the Campbelltown side of the Georges River at Freres Crossing. These two main fire trails are roughly parallel and are 2,200 metres apart at the widest point. They act as strategic fire trails. The land between these trails is fire prone and is likely to be an ongoing fire risk affecting the airport site.

The main access routes to the airport site are exposed to fires in that zone. In the case of evacuations from the construction zone this main link will require constant surveillance during periods of high to extreme fire danger so that its capability to provide safe and permanent egress remains intact.

The response time for the Campbelltown fire brigades to travel from Kentlyn Station to Old Coach Road has been estimated to be 45 minutes. Therefore the length and condition of fire trails will have a significant impact upon fire fighting capability.

Fire Fighting

During construction, safe fire fighting operations can only be achieved through the provision of effective fire fighting equipment, trained and experienced personnel, reasonable and timely access and the provision of adequate water supplies. Without these constituents a fire is likely to spread and gain intensity.

While there is a capability for fighting fires outside the boundary from within the airport site, fires could be significant in size well before they reach the airport boundary. This would necessitate a major fire suppression operation to extinguish the fire. Therefore adequate fire trails outside the airport boundary are a critical element for fire fighting. Aerial fire fighting methods may be necessary where access is difficult or time consuming.

Fire Prevention

Within the airport construction zone, potential sources of ignition should be managed effectively to reduce the potential for fires. This may include storing flammable liquids, fuels and other materials in cleared areas, mowing or otherwise keeping grasses under control and ensuring that fire extinguishers are used when "hot work", such as welding or metal cutting is being undertaken.

All airport vehicles should carry fire extinguishers to control small fires, and staff should be trained in how to fight small fires, and when to summon assistance.

Management of fuels and bush fire hazard outside the airport boundaries will not be within the powers of the airport operator.

This means that agreements may need to be made with adjoining land holders to carry out fuel management measures.

6.2.2 HOLSWORTHY OPTION A - OPERATIONS

Emergency Evacuation and Fire Fighting Access

As part of the construction phase, fire trails should be provided on each side of the main arterial road. This would require a 40 to 60 metre fuel free zone, which would provide a safe distance between the vegetative combustible fuels and the roadway in cases where cars are stranded and occupants are exposed to momentary fire and smoke. This would provide suitable room for a fire trail close to the main road and 30 to 50 metres of fuel free area. A combination of a fuel free zone and a regularly managed fuel reduced landscape could be used instead of a large fuel free area.

Fire Fighting

Planning for the fire fighting capability of the airport should be based on a potential major fire event or a series of events. It is possible that several fires may be burning simultaneously over a wide area west or south of the proposed boundary. In this case it may not be prudent to put fire fighters into the area to suppress the fires due to unsafe conditions associated with the steep terrain and the presence of unexploded ordnance.

Fires that break out west of O'Hares Creek can be suppressed due to good access and availability of fire brigade services. The existing Holsworthy Military Area boundary crosses into this developed area with a ragged boundary edge. Nonetheless the provision of the existing trails allows effective access to suppress fire outbreaks.

In the zone between O'Hares Creek and the airport site, the steep terrain does not allow fire fighting to occur from the ground. The boundary of the airport site is very close to the runways and does not provide for new fire trail access on the periphery. This will need to be addressed.

Fire fighting in this zone is difficult due to the slow access time to get on scene. Access is only available from Old Coach Road and through the operational zone thereby connecting with Old Illawarra Road two kilometres south of the south-east boundary of the proposed airport boundary. The time required to arrive on scene would be significant (greater than 60 minutes by fire fighting tanker). In this time the fire could have moved between 500 metres and 5,000 metres.

Where the land form is such that difficult terrain (for example, over the gorge) eliminates these options the alternative design for protection measures will require a parallel fire trail and regular fuel management on each side of the main access roadway(s).

There are difficulties associated with carrying out fire fighting over the large area of lands that currently constitutes the Holsworthy Military Area will require the assistance of medium size helicopters (for example, Bell 212) to enable water bombing of all small fires.

Use of fixed wing aircraft will not be effective when working in and around an operational airport facility. Helicopters are able to manoeuvre effectively and transport fire fighting personnel.

Smoke from fires in the Holsworthy Military Area could adversely affect aircraft engines as well as air conditioning at the airport facilities.

The only method to reduce the incidence of high particulate matter in the smoke plume is to suppress all fires in the first instance. Whilst reducing the amount of fuel on the ground limits the capability for intense fires to occur, it does not limit the outbreak and spread of fires.

All road access and egress will be affected by the presence of drifting smoke plumes. The movement of dense smoke plumes during nighttime fire operations usually occurs under milder conditions, however it will still potentially cause visibility problems for inbound aircraft as the visibility of tarmac lights will be affected.

Effective rapid suppression of fire should occur to reduce the potential for high intensity fires in areas of moderate to high fuel loads. Fuel management prescriptions could be designed to manage this situation but some of the surrounding land is likely to be controlled by NSW state agencies and the remaining areas remain as part of the Holsworthy Military Area. Fuel management outside the airport boundaries would require co-operation of adjacent land holders.

Where fires are occurring across the airport landscape it is likely that air conditioning systems at the airport would be required to be shut down, due to smoke pollution.

The need to reduce the potential smoke plumes of dark, dense smoke can only be achieved by extinguishing the fire in as small an area as possible. This can only be achieved by provision of good access and effective surveillance during periods of high fire danger. The proposed boundary of Option A does not reflect the need to manage larger areas of bushland for integrated fire management.

Fire Prevention

In the event that an airport goes ahead at one of the Holsworthy sites, an integrated approach to all future management issues must be implemented.

Fire management of the site must adhere to a detailed and well documented agreement that has the support of enabling legislation or some instrument of authority. There are situations on the New South Wales-Victorian border where state border committees develop integral relationships that do not rely on legislative impositions.

However these are generally developed between peers working in close quarters. If the airport becomes a private enterprise arrangement the need for a legislative approach must be considered as a way of stabilizing operational planning in the same way as regulations and a regulatory body manages and creates aircraft standards and procedures.

Fire fighting and prevention on private, Army, National Parks, Water Board, Crown Land, Sutherland Council, Liverpool Council and Campbelltown Council lands requires co-ordination and co-operation so that effective and harmonious operations occur. The current situation is less than satisfactory.

The existing situation of different training standards, different expertise, different fire fighting equipment, different communications systems, different budgets and different individual legislation prevents effective fire management occurring over the Holsworthy Military Area.

The urban expansion of Sydney to the west and particularly south of Campbelltown will increase the incidence of fire/s in that region. Fires resulting from historical arson type activities in the Appin are also likely to increase.

Measures will be required to suppress this activity otherwise an increase of deliberately lit fires will affect airport operations and surrounding areas.

It is possible that several fires may be burning at the one time in a wide area west of the proposed boundary. In this case it may not be prudent to put fire fighters into the area to suppress the fires due to a potential for unsafe conditions. In this case there could be a period when the airport will need to shut down so that fire fighting can proceed in a safe manner.

These occasions can be modelled by fire behaviour software to estimate the extent of fire spread in "real time". Modelling will provide a basis of determining the most appropriate strategy under a variety of scenarios. The results of the modelling will require empirical assessment from local fire management practitioners to ensure accuracy.

A number of options are available to resolve the conflicts of fire management on the peripheral lands. Modern fire fighting techniques and use of technology along with incident management and communication/s planning tools are able to be developed for the integrated management of the airport and its peripheral lands fire management.

The airport boundary as proposed does not allow for bushland management in practical terms. The existing perimeter and security fence does not allow for fuel management regimes that are required to protect the airport. Similarly it does not allow for problems created by smoke plumes associated with fires on land surrounding the airport.

6.2.3 HOLSWORTHY OPTION B - CONSTRUCTION

Emergency Evacuation and Fire Fighting Access

The Master Plans indicate that road and rail links may feed into the site from the north and possibly from the west via the Campbelltown area. A second road option is proposed to link from the north east and enter on the south-eastern flank. This route follows steep contours and crosses deep ravines but is generally close to existing residential developed areas within Campbelltown/ Wedderburn area. There is no alternative road access or egress to the site from the south. Other utility services are proposed to enter from the west and south-west.

The existing fire trail (Old Coach Road) that is accessed from the south is affected by the development of the airport operational zone. There is scope to re-route the trail on the western fringe of the operational zone of the airport. However the steep terrain would mean that the trail would be under the main access road/highway into the site.

The main eastern fire trail (Old Illawarra Road) would not be affected and would remain close to the eastern boundary of the airport operational zone.

Plans of the main western road to the site do not show fire trails on the flanks of the roadway approaches leading to the bridge. The plans refer to a 10 metre clearance outside the proposed fence line. This would be sufficient during construction in tandem with a fire trail on each side of the road.

Access from Wedderburn is not available. The only southern access is via fire trail No.108 that leads off the Bulli-Appin road. The time required to arrive on scene would be significant (greater than 60 minutes by fire fighting tanker).

The opportunity to develop a better fire trail network in the southern zone requires detailed investigation. Many trails can be developed in the zone.

Fire Fighting

Aerial suppression of fires would be required to ensure airport operations are not affected due to the long time period required to attend fires south of O'Hares Creek.

Fire Prevention

The existing Holsworthy Military Area boundary limits the capability to control the fuels in the west and south-west zones due to ownership by other agencies. Hazardous fuels within the airport boundary and external to that boundary should be identified for regular fuel management prior to construction beginning.

Qualified and trained staff will be required to manage the airport fire management issues on a daily basis. Such staff will be required to make the necessary decisions on fire strategies to be applied.

The response to the fire should be commensurate with the potential. Modelling of fire spread in "real time" can assist in the process of determining in advance the likelihood of a range of potential fire incidents. This will then enable human and mechanical resource requirements to be assessed.

Fuel management planning is a complex process involving the development of land management objectives and the refinement of how plant communities and habitat can be best maintained whilst at the same time be modified so that the potential fire intensity and rate of spread is lessened. This is usually achieved by designing prescriptive burns.

These prescriptive burns are "prescribed" on the basis of the needs of the plants and animals that live in or frequent, that habitat. The development of fuel management plans therefore require an ecological understanding of the likely impact upon species, communities and habitats. The process of environmental assessment which is currently used by the NSW National Parks and Wildlife Service in the preparation of fire management plans is an effective but developing model.

Impacts on flora and fauna are beyond the scope of this report.

As the remaining part of the Holsworthy Military Area will remain on the immediate periphery of the airport site, the management of the hazardous fuels within these lands will come under Commonwealth government legislation.

The difficulty in carrying out fuel management over the large area of lands that currently constitutes the Holsworthy Military Area will require the assistance of medium size helicopters (for example, Bell 212) to enable water bombing of all small fires. Use of fixed wing aircraft will not be effective when working in and around an operational airport facility. Helicopters are able to manoeuvre effectively and carry out fire fighting personnel transport.

Due to the type and distribution of vegetation on the Holsworthy and the conservation reserves adjoining the Military Area, fuel management of the landscape would require detailed fire management plans to be prepared.

6.2.4 HOLSWORTHY OPTION B - OPERATIONS

Emergency Evacuation and Fire Fighting Access

Comments relating to the construction period (refer *Section 6.2.3*) are also relevant for airport operations.

Fire Fighting

Fire fighting methods outlined for the construction period (refer *Section 6.2.3*) are also relevant here.

Fire Prevention

Fire prevention measures discussed for the construction period (refer *Section 6.2.3*) are also relevant here.

PART E: SUMMARY OF IMPACTS

CHAPTER 7 SUMMARY OF BUSHFIRE IMPACTS

7.1 BADGERYS CREEK OPTIONS

Badgerys Creek does not present a significant bush fire threat. Fuel management planning and ongoing grass maintenance works should provide an economical approach to fire protection at the sites of the airport options.

Potential problems at Badgerys Creek would be limited to smoke 'laying' across the runways if fire fighting suppression operations were not able to be mustered in time to extinguish any potential grass blazes. In any event these fires are likely to be small. In time, this issue may be eliminated due to a change of land use from farming to urban/industrial.

7.2 HOLSWORTHY OPTIONS

Holsworthy requires significant fire management to be applied both in the short term and in the long term.

The proposed use of part of the Holsworthy Military Area as the Second Sydney Airport will change the existing fire regimes on the landscape.

During construction, significant attention to access and development of safety planning regimes will be required.

The bushland that will remain around both of the airport options covers a significant landscape. Due to the conservation status of those lands and the presence of unexploded ordnance, the lands will be likely to remain as bushland and will therefore pose an ongoing bush fire threat to airport construction and operations.

Operational management of Holsworthy will require significant human and financial resources to manage fire and smoke. A total extinguishment policy will be appropriate for most fires.

As most bushfires occur in the mid to late part of the day, the effects of smoke or fire could seriously impede airline operations as well as the safety of people, including fire fighters. Closure of the airport may be necessary to enable fire fighting to be undertaken safely.

In terms of fire fighting, the primary objective would be the suppression of wild fires, threatening the airport site. However, the same commitment will be required to protect the other built facilities that service the airport, for example, rail lines, fuel lines, communications systems and road corridors. The use of helicopters as a first attack offensive operation would be the only option available to guarantee success of initial suppression operations. Ground troops would be supplementary and be conditional upon the location of unexploded ordnance.

The layout of airport facilities will require some form of perimeter access so that permanent management regimes for the bushland fuels can be implemented.

Overall the Holsworthy options both have a high probability of the following events from bush fires occurring on the external lands to the proposed airport boundary:

- air-conditioning shutdown;
- loss of external electrical supply;
- vehicular accidents and or chokes on main arteries;
- personal health problems, for example, asthma, and or other respiratory problems;
- major evacuation or incident management events required to cater for airport operational breakdown; and
- airport closure.

Due to the large number of agencies managing bushland surrounding Holsworthy Military Area, conflicts may arise in the management of fuel loads and in the coordination of fire fighting activities. An integrated management approach will be required to coordinate the various agencies. This may involve using a single agency to manage all bushland areas surrounding Holsworthy, or creating a management committee with representatives from the relevant agency. Potential conflicts may also be avoided by preparing a bushland management plan for residential areas in proximity to the proposed Holsworthy airport sites. The NSW model should be central to any agreements.

REFERENCES

Barclay (1993), Research Report 38 of 1993 prepared by G Barclay, Conservation and Natural Resources (Victoria).

Bureau of Meteorology, (1993), Weather Records.

Benson, and Howell, J. (1995). *Taken for Granted. The Bushland of Sydney and its Suburbs*. Kangaroo Press.

Department of Bush Fire Services (1991). *Planning for Bush Fire Protection - A Guide for Land Use Planners, Home Owners, Planners and Fire Authorities.* Edited by Tony Gates. Department of Bush Fire Services.

Department of Bush Fire Services (1992). *Fire Coordination Manual - Model S41A Plan Guidelines.*

Department of Bush Fire Services (1996). *Draft. Planning for Bush Fire Protection - A Guide for Land Use Planners, Home Owners, Planners and Fire Authorities.* Edited by Tony Gates.

Department of Planning (1984). *Building in Fire Prone Areas.* Circular C10.

Department of Planning (1984). *Planning in Bush fire Prone Areas.* G20 Direction - Ministerial 117 Direction.

Draft Rural Fires Bill, 1997; Exposure Draft Bill and Regulations. (dated 21.3.97).

House of Representatives Standing Committee on Environment and Conservation (1984). *Bush Fires and The Australian Environment.* Aust Gov. Publishing Service Canberra 1984.

McArthur, AG (1967). *Leaflet 107 Fire Behaviour in Eucalypt Forest AG McArthur, Canberra. Commonwealth of Australia Department of National Development. Forestry and Timber Bureau (and reprinted later by) CSIRO Div. Forestry - Bush Fire Research Unit.1967.*

National Parks and Wildlife Service (1990). *Fire Management Manual.* NSW National Parks and Wildlife Service. NSW.

Second Sydney Airport Planners (1997a), *Planning and Design Report*, March 1997.

Senate Standing Committee (1994), *Disaster Management*, Senate Standing Committee - Parliament of Commonwealth of Australia, Canberra, 1988.

Sydney Water and NSW National Parks and Wildlife Service (1997). *Special Areas Draft Plan of Management - Woronora, O'Hares Creek and Metropolitan.*

Travers, J (1990). *The Use of Siro-Plan in Fire Management Planning.* Unpublished report.

Travers, J (1994). *Hazard and Threat Assessment Training Module.*

Walker, J. (1984). *Fuel Dynamics in Australian Vegetation.* In "Fire and the Australian Biota" Australian Academy of Science.

Wilson A.A.G (1984). *Assessing the Bush fire Hazard of Houses; A Quantitative Approach.* Rural Fire Research Centre. Technical Paper Number 6.

Appendix 1

Definitions and Terms

Definitions and Terms

Advantage	is an active or passive measure that protects a value or asset from the onslaught and spread of fire. They can be passive design criteria such as effective building design, fire trail or active features such as sprinklers or the availability of fire services.
Fire Danger	is the influence of weather on potential fire behaviour
Fuel Management	all activities associated with the prevention, control and use of fire in bushland for the protection of life, property, (heritage values and the maintenance of biodiversity).
Fire Prone	is a bushland landscape with a history of regular fires
Fire Protection Zone	is the area e.g. between the residential dwelling and the bushland that is recommended as being an area creating a buffer zone between the high intensity fires and any structure, thereby reducing heat radiation and direct flame contact Secondly, providing an area where airborne embers can fall with minimal opportunity to create further outbreaks.
Fuel Reduced Zone	is primarily free of surface fuels such as twigs bark and leaves and small shrubs. It comprises an area that is designed to aid in reducing the carriage and spread of fire and thus potential intensity or heat radiation from the flames.
Fuel Free Zone	is primarily almost free of combustible fuels and a significant reduction in the presence of trees. It is often designed to be grassy areas, car parks, roads, concrete areas, track or trails.
Hazard	is the availability of combustible fuel.
Airport Operational Zone	the lands that will used by the airport
Airport Non Operational Zone	the lands that will be external to the Airport Operational Zone and within the Airport external boundary. They would generally be lands on steep slopes and inaccessible.
Radiation Zone	was the term used in Circular C10 (formerly Circular 74) for what was to be renamed a fire protection zone. It referred to the zone ahead of a fire where radiated heat from that fire was likely to have an affect on buildings or their occupants
Fire Regime	the frequency, intensity and season of a fire recurrence.

Risk	is the chance of a fire starting, and spreading.
Setback	is the distance between a facility and the bushland. It also referred to the distance between the residential building and the boundary of allotment.
Threat	is the 'measure of potential' to cause an impact such as an injury or some form of damage to an asset or an impact on biodiversity.

Source: Department of Bush Fire Services; Co-ordinating Committee Policy Statement; NSW National Parks and Wildlife Service and John Travers & Associates.

Appendix F

Hazard and Risk Assessment for Defence Establishment Orchard Hills

Second Sydney Airport Environmental Impact Statement - Hazard and Risk Assessment for Defence Establishment Orchard Hills

---

Department of Transport and Regional Development

Prepared by
Four Elements

Edited by

PPK Environment & Infrastructure Pty Ltd

9 Blaxland Road
Rhodes NSW 2138
PO Box 248
Concord West NSW 2138
Australia

Telephone (61 2) 9743 0333
Facsimile: (61 2) 9736 1568

A NATA Certified Quality Company

25 August, 1997
58H233A PR_1346

CONTENTS

		Page Number
1	INTRODUCTION	1-1
2	OBJECTIVES AND SCOPE OF WORK	2-1
2.1	OBJECTIVES	2-1
2.2	SCOPE OF WORK	2-1
2.2.1	AIRPORT OPTIONS	2-1
2.2.2	SCENARIOS CONSIDERED	2-1
2.2.3	AIRPORT OPERATING MODES CONSIDERED	2-2
2.2.4	STRUCTURE OF THE REPORT	2-3
3	INFORMATION SOURCES	3-1
4	DESCRIPTION OF FACILITIES	4-1
4.1.1	EXPLOSIVE STORAGE	4-1
4.1.2	SITE ACTIVITIES	4-1
5	AIRSPACE CONSTRAINTS	5-1
5.1	CURRENT RESTRICTIONS	5-1
5.2	FUTURE IMPLICATIONS	5-1
5.3	VIEWS OF AUTHORITIES	5-1
5.3.1	CIVIL AVIATION SAFETY AUTHORITY	5-1
5.3.2	AUSTRALIAN ORDNANCE COUNCIL	5-1
6	IMPACT ASSESSMENT - BADGERYS CREEK OPTION A	6-1
6.1	PROPOSED FLIGHT PATHS	6-1
6.2	PROPOSED NUMBER OF AIRCRAFT MOVEMENTS	6-1
6.3	INDICATIVE RANGE OF AIRCRAFT ALTITUDE ABOVE DEFENCE ESTABLISHMENT ORCHARD HILLS	6-2

6.4 Hazards and Risks Identified 6-3

6.4.1 Distraction 6-3
6.4.2 Electromagnetic radiation 6-3
6.4.3 Airborne lasers 6-4
6.4.4 Aircraft Crashes 6-4
6.4.5 Hazards to aircraft 6-4

6.5 Consequences of Aircraft Crashes 6-5

6.5.1 Direct Consequences 6-5
6.5.2 Secondary Consequences 6-6

6.6 Aircraft Crash Probability Analysis 6-8

6.6.1 Frequency of Crashes 6-8
6.6.2 Acceptability of Risk to Explosives 6-9

6.7 Hazards to Aircraft 6-10

6.7.1 Planned Explosions 6-10
6.7.2 accidental explosions 6-10
6.7.3 Consequence Analysis 6-10
6.7.4 Probability Analysis 6-12
6.7.5 Acceptability of Risk 6-13

7 Impact Assessment - Badgerys Creek Option B 7-1

7.1 Proposed Flight Paths 7-1
7.2 Proposed Number of Aircraft Movements 7-1
7.3 Indicative Range of Aircraft Altitude Above Defence Establishment Orchard Hills 7-3
7.4 Hazard and Risk Assessment 7-4

7.4.1 Distraction 7-4
7.4.2 Electromagnetic radiation 7-5
7.4.3 Airborne lasers 7-5
7.4.4 Aircraft Crashes 7-6
7.4.5 Hazards to aircraft 7-6

7.5 Consequences of Aircraft Crashes 7-6

7.5.1 Direct Consequences 7-6
7.5.2 Secondary Consequences 7-7

7.6 Aircraft Crash Probability Analysis 7-9

7.6.1 Frequency of Crashes 7-9
7.6.2 Acceptability of Risk to Explosives 7-10

7.7 Hazards to Aircraft 7-11

7.7.1 Planned explosions 7-11
7.7.2 Accidental Explosions 7-11
7.7.3 Consequence Analysis 7-12
7.7.4 Probability Analysis 7-14
7.7.5 Acceptability of Risk 7-15

8 Impact Assessment - Badgerys Creek Option C 8-1

8.1 Proposed Flight Paths 8-1
8.2 Proposed Number of Aircraft Movements 8-1
8.3 Indicative Range of Aircraft Altitude Above Defence Establishment Orchard Hills 8-3
8.4 Hazard and Risks Identified 8-5

8.4.1 Distraction 8-5
8.4.2 Electromagnetic radiation 8-5
8.4.3 Airborne lasers 8-6
8.4.4 Aircraft Crashes 8-6
8.4.5 Hazards to aircraft 8-6

8.5 Consequences of Aircraft Crashes 8-6

8.5.1 Direct Consequences 8-6
8.5.2 Secondary Consequences 8-7

8.6 Aircraft Crash Probability Analysis 8-9

8.6.1 Frequency of Crashes 8-9
8.6.2 Acceptability of Risk to Explosives 8-10

8.7 HAZARDS TO AIRCRAFT 8-11

8.7.1 PLANNED EXPLOSIONS 8-11
8.7.2 ACCIDENTAL EXPLOSIONS 8-11
8.7.3 CONSEQUENCE ANALYSIS 8-12
8.7.4 PROBABILITY ANALYSIS 8-14
8.7.5 ACCEPTABILITY OF RISK 8-15

9 SUMMARY OF OPTIONS 9-1

1 INTRODUCTION

Four Elements, part of the ERM Mitchell McCotter Consulting Group, was engaged by PPK Environment & Infrastructure to undertake a quantitative risk assessment study on potential impacts of aircraft overflights for the Defence Establishment Orchard Hills.

This was because concerns had been expressed by the Department of Defence about the possibility of establishing permanent flight paths through currently restricted airspace above the Defence Establishment.

The findings of this study have been summarised in *Technical Paper No. 10 - Hazards and Risks*, and in the Draft EIS.

2 OBJECTIVES AND SCOPE OF WORK

2.1 OBJECTIVES

The Defence Establishment Orchard Hills is located to the north of Badgerys Creek Options A, B and C. The aim of this part of the study is to examine the risk and safety implications of flight establishing permanent flight paths over the Defence Establishment Orchard Hills, including potential implications for existing airspace restrictions.

2.2 SCOPE OF WORK

2.2.1 AIRPORT OPTIONS

The three Badgerys Creek Airport options are located in approximately the same general area, however the implications of flight paths over the Defence Establishment Orchard Hills are different for each option. Therefore specific impact assessments have been undertaken for each option.

2.2.2 SCENARIOS CONSIDERED

The role of the Second Sydney Airport in meeting the overall airport needs within the Sydney basin has not been decided at this stage. Therefore the risk assessment process will consider three possible scenarios. These are as follows:

Air Traffic Forecast 1

This scenario allows for 10 percent of all Sydney basin traffic move to the Second Sydney Airport in the year 2006. After 2006, all growth in the Sydney basin is accommodated at the Second Sydney Airport.

Air Traffic Forecast 2

This scenario allows for 10 million passengers from the Sydney basin to be accommodated at Second Sydney Airport in the year 2006. After 2006, all growth in the Sydney basin is accommodated at the Second Sydney Airport.

Air Traffic Forecast 3

This scenario allows for the majority of the wide body aircraft to be located at the Second Sydney Airport from 2006. After 2006, all growth in the Sydney basin is accommodated at the Second Sydney Airport.

The risk of aircraft accidents depends upon a range of factors, one of which is the number of traffic movements per year. Risk levels in year 2016 would be higher than risk levels in year 2006 on account of higher traffic levels in year 2016. On this basis, risk assessments have been undertaken for year 2016 scenarios, rather than 2006 scenarios, since they represent "worse-case" impacts.

A preliminary analysis of all three scenarios, for the year 2016, is outlined in the Aircraft Crash Risk Assessment Report, contained in *Appendix* A of *Technical Paper No. 10 - Hazards and* Risks. This analysis has indicated that the Additional Noise Scenario presents a relatively higher risk impact than the other two scenarios. Therefore detailed quantitative risk assessments have been undertaken for the Additional Noise Scenario, in year 2016 only.

2.2.3 AIRPORT OPERATING MODES CONSIDERED

The likely pattern of runway usage at the airport, in terms of operating modes and preferred runways, has not been decided at this stage. Therefore, for the year 2016, risks associated with three possible operating modes have been investigated:

Airport Operation 1

This operating mode allows for aircraft movements to occur on the parallel runways in one specified direction (arbitrarily chosen to be the direction closer to north), unless this is impossible due to meteorological conditions. Under this operating mode, aircraft takeoff predominantly to the north and land from the south. Second priority is given to operations in the other direction, on the parallel runways. Operation of the cross runway occurs only if necessitated by meteorological conditions.

Airport Operation 2

As for the mode outlined above, but with the preferred direction of movements on the parallel runways reversed.

Airport Operation 3

This operating mode allows for a deliberate implementation of a "noise sharing" policy under which a certain number of movements are directed to occur on the cross runway (with equal numbers in each direction), with the remainder distributed equally between the two parallel runway directions. Airservices Australia indicated that the maximum number of movements which is likely to occur on the cross runway is seven percent of the total traffic. Analysis of meteorological data indicated that such a scenario would be within the allowed meteorological parameters for all airport sites.

For the Badgerys Creek Option A, only the Southerly modes were considered, since no cross runway exists.

2.2.4 STRUCTURE OF THE REPORT

- *Section 4* describes the Defence Establishment Orchard Hills;
- *Section 5* discusses existing airspace restrictions above the Defence Establishment Orchard Hills, the implications for existing airspace restrictions and the views of authorities (Civil Aviation Safety Authority and the Australian Ordnance Council);
- *Section 6* describes the proposed use of airspace above the Defence Establishment Orchard Hills for operations at Badgerys Creek Option A and resultant hazards and risks;
- *Section 7* describes the proposed use of airspace above the Defence Establishment Orchard Hills for operations at Badgerys Creek Option B and resultant hazards and risks;
- *Section 8* describes the proposed use of airspace above the Defence Establishment Orchard Hills for operations at Badgerys Creek Option C and resultant hazards and risks; and
- *Section 9* provides a comparison of hazards and risks for the Badgerys Creek options.

While *Sections 6, 7* and *8* stand alone as descriptions of the likely hazards and risks, some repetition of material common to the three options occurs.

3 INFORMATION SOURCES

Information on explosive storage, handling and demolition activities at the Defence Establishment Orchard Hills was provided by the Royal Australian Navy (Navy) and the Royal Australia Air Force (Air Force).

Information on proposed flight paths and annual number of aircraft overflying the facility was collated as part of the Aircraft Crash Risk Assessment Report, which is contained in *Appendix* A of *Technical Paper No. 10 - Hazards and Risks.*

The Australian Ordnance Council's Guidelines for Control of Airspace Above Explosives Facilities and Sites of Planned Detonation (Australian Ordnance Council, 1992) and the Defence Operations Manual OPSMAN 3 Defence Explosives Safety Manual (Department of Defence, 1994) provided other relevant information.

The Civil Aviation Safety Authority was consulted to provide guidelines for flights over explosives facilities, or acceptable risk criteria for such flights.

A meeting was held with the Australian Ordnance Council to discuss issues related to establishing permanent flight paths over the Orchard Hills site.

A site inspection was undertaken by Four Elements and PPK Environment & Infrastructure, prior to preparation of this report, and discussions were held with Department of Defence staff at this time.

4 DESCRIPTION OF FACILITIES

The Defence Establishment Orchard Hills includes Explosive Ordnance storage and maintenance facilities for both the Navy and Air Force.

The site could be considered to be divided into four distinct areas as follows:

- administration area along the western boundary;
- weapon maintenance (Navy) towards the south-west;
- Explosive Ordnance maintenance (Air Force) and Explosive Ordnance storage buildings (Navy and Air Force) generally in the middle of the site; and
- demolition area towards the east.

Buffer zones (vacant land) within the Defence Establishment Orchard Hills area surround the Explosive Ordnance storage and demolition areas. The site area is estimated to be approximately 15 square kilometres.

4.1.1 EXPLOSIVE STORAGE

The Defence Establishment Orchard Hills area contains approximately 150 purpose built buildings that are licensed to store Explosive Ordnance. The aggregate licence quantity for all Explosive Ordnance storage buildings in the Navy area, known as RANAD Kingswood, is 200 tonnes Net Explosive Quantity of ammunition. However this quantity of Explosive Ordnance is not present at all times. For example, at the time of the study about 100 tonnes Net Explosive Quantity of ammunition was held.

The types of Explosive Ordnance stored includes all types of Explosive Ordnance used by the Australian Defence Forces, for example, guided weapons, gun ammunition, demolition and pyrotechnic stores, and small arms ammunition.

Some buildings are traversed, for example, are surrounded by a mound, while others are not. The roofs of these buildings are of lightweight construction and are designed to vent the effects of an explosion upwards instead of outwards.

4.1.2 SITE ACTIVITIES

While no explosives are manufactured on the site, Explosive Ordnance is assembled, repaired, inspected and proof-tested. Certain operations require the removal of electro-explosive devices from their packaging. During this time these devices may be susceptible to electromagnetic radiation.

Testing of the initiating devices of guided weapons is undertaken in special buildings on the site. The weapons are placed in a horizontal position, facing towards a particular direction before these tests are started. This is to ensure that if a weapon were to accidentally fire, it would most likely pass through a lightweight door, before impinging on a solid wall directly opposite the building entrance. These walls are designed to take the full brunt of the impact and prevent damage to adjacent buildings, by directing the weapon upwards after the impact.

The demolition range at 1CAMD was not being used at the time of the site inspection as no emergency disposals were necessary at the time. The range remains active and is licensed to dispose of a high explosive bomb with a Net Explosive Quantity of 87.1 kilograms. The rifle range on site was only operating between 10am and 5pm, three days a week for similar reasons.

5 AIRSPACE CONSTRAINTS

5.1 CURRENT RESTRICTIONS

There are no existing permanent flight paths over the Defence Establishment Orchard Hills. Airspace between 0-1,500 feet within one nautical mile radius of the Kingswood/Orchard Hill Defence Facilities is permanently restricted from Monday to Friday during daylight hours. Airspace between 0-4,500 feet within 1 nautical mile radius of the facility is permanently restricted from Monday to Friday between 10am-12 noon and 3-5pm. Both of these restrictions are based upon demolition activities on site, rather than storage of Explosive Ordnance.

5.2 FUTURE IMPLICATIONS

Airservices Australia has stated that if the current permanent airspace restrictions over the facilities remain, the operation of a Second Sydney Airport at Badgerys Creek could be severely constrained.

The Department of Defence has indicated that permanent restrictions relating to account of site demolition activities could possible be removed. However, as there is an ongoing need to demolish small quantities of Explosive Ordnance from time to time, the Department of Defence and Airservices Australia have discussed the possibility of such demolition activities being undertaken with temporary airspace restrictions.

5.3 VIEWS OF AUTHORITIES

5.3.1 CIVIL AVIATION SAFETY AUTHORITY

The Civil Aviation Safety Authority has indicated that all airspace restrictions must be observed. However, if current permanent airspace restrictions were to be removed, the Civil Aviation Safety Authority would have no further requirements regarding flight paths over the Defence Establishment Orchard Hills.

5.3.2 AUSTRALIAN ORDNANCE COUNCIL

The flight of an aircraft over an explosives storage facility is a potentially a hazard to both the explosives and to the aircraft. It is Defence policy to protect the utility of a licensed facility from the adverse effects of developments outside Defence-controlled property. The process used to provide the required protection is known as safeguarding. The Australian Ordnance Council has developed guidelines on the Control of Airspace above Explosives Facilities and Sites of Planned Detonation. This is commonly known as Australian Ordnance Council Pillar Proceeding 205.92 (Australian Ordnance Council, 1992). This document provides guidance on calculating relevant safeguarding heights.

Australian Ordnance Council recommends that:

- flights over explosives facilities should be restricted to essential transit;
- where flights over explosives facilities cannot be avoided, they should not normally be permitted at heights lower than the minimum heights already stipulated for the surrounding urban or rural areas (1,000 feet or 500 feet respectively);
- restrictions should apply for flights over planned detonations. Safety heights should be calculated as shown in Pillar Proceeding 205.92.

In separate communications, Australian Ordnance Council has provided further guidance, as follows:

- permanent flight paths associated with the operation of a major airport are not considered to be essential transit;
- if it is necessary to have flight paths, holding patterns, or approach or departure routes passing over the Defence Establishment Orchard Hills at heights less than those calculated by applying formulae in the guidelines, a full hazard and risk analysis would need to be conducted.

Australian Ordnance Council's main concern is the risk of an aircraft crash on Explosive Ordnance storage buildings and the possible consequences of such an incident.

6 IMPACT ASSESSMENT - BADGERYS CREEK OPTION A

6.1 PROPOSED FLIGHT PATHS

The parallel runways for Badgerys Creek area Option A are not in direct line with the Defence Establishment Orchard Hills. Arrival and departure tracks have not been finalised at this stage, however, a set of arrival and departure tracks were defined for each airport option in discussion with Airservices Australia to enable noise impact studies to be undertaken.

Two out of the fifteen assumed departure flight tracks (D01 and D06) for this option, pass over parts of the Facilities area.

D01 crosses the north-east corner of the Facilities area, and applies to aircraft departing from Runway 05L and heading north-west. D06 passes along the northern boundary, and applies to aircraft departing from Runway 23R and heading east. No arrival tracks pass over the Facilities.

It should be noted that the flight tracks over the Facilities area used for analysis are preliminary and have not been finalised. Actual flight tracks may differ from these. Moreover, for any flight track, a certain amount of lateral deviation from the centreline is expected. This deviation increases as a function of the distance along the track. For risk analysis, it has been assumed that aircraft could deviate by up to 9 degrees on either side of the centerline.

6.2 PROPOSED NUMBER OF AIRCRAFT MOVEMENTS

To simplify analysis, only the worst-case scenario (year 2016 with larger aircraft at the new airport - Airport Forecast 3) has been considered in this risk assessment.

Two airport operating modes (Airport Operation 1 and Airport Operation 2) have been investigated. The absence of a cross runway means that a 'Share the Noise' scenario will not occur. The annual number of aircraft on D01 and D06 tracks for the two operating modes, classified according to risk categories are shown in *Tables 6.1* and *Table 6.2*.

TABLE 6.1 ANNUAL AIRCRAFT MOVEMENTS OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 1

Aircraft Category	Flight Tracks	
	D01	D06
Low Capacity	577	6
High Capacity - Small	1,100	42
High Capacity - Medium	1,369	243
High Capacity - Large	3,350	1,324
High Capacity - Large- Increased Fuel Load	3,799	710
General Aviation	774	32
Total	**10,969**	**2,357**

TABLE 6.2 ANNUAL AIRCRAFT MOVEMENTS OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 2

Aircraft Category	Flight Tracks	
	D01	D06
Low Capacity	201	14
High Capacity - Small	360	107
High Capacity - Medium	462	635
High Capacity - Large	1,053	3,417
High Capacity - Large- Increased Fuel Load	1,211	1,869
General Aviation	261	84
Total	**3,548**	**6,126**

The description, and the rationale for the definition of risk categories is provided in *Appendix* A of *Technical Paper No. 10 - Hazards and Risks.*

6.3 INDICATIVE RANGE OF AIRCRAFT ALTITUDE ABOVE DEFENCE ESTABLISHMENT ORCHARD HILLS

The curvilinear distance of the projection of the flight track on the ground from the runway end to the boundary of the facility is approximately 11 kilometres for D01 and 22.5 kilometres for flight track D06. Indicative ranges of altitude at these distances during takeoff for representative aircraft within these categories are shown in *Table 6.3*.

TABLE 6.3 INDICATIVE RANGE OF ALTITUDE ABOVE THE DEFENCE ESTABLISHMENT ORCHARD HILLS

Aircraft Category	Altitude at 11 kilometres (D01)	Altitude at 22.5 kilometres (D06)
Low Capacity	600 metres - 1,400 metres	1,300 metres - 2,900 metres
High Capacity - Small	600 metres - 1,400 metres	1,300 metres - 2,900 metres
High Capacity - Medium	1,200 metres - 1,900 metres	3,000 metres
High Capacity - Large	1,200 metres - 1,700 metres	2,800 metres - 3,000 metres
High Capacity - Large-Increased Fuel Load	800 metres - 900 metres	1,600 metres - 2,400 metres
General Aviation	600 metres - 1,400 metres	1,300 metres - 2,900 metres

Notes: 1. Source: Calculated from INM profiles for typical aircraft within each category.

The actual height above the Defence area will differ, depending upon the type of aircraft and on operating conditions. However, aircraft would generally be higher than 1,000 feet above the Facilities area.

6.4 HAZARDS AND RISKS IDENTIFIED

Hazards identified in Pillar Proceeding 205.92 are examined in this section.

6.4.1 DISTRACTION

Defence personnel working with explosives could potentially become distracted by noise, if aircraft pass overhead. This could increase the possibility of an accident.

It is understood that the majority, if not all of the activities involving the handling of explosives are carried out indoors. Therefore it would be feasible to reduce noise levels inside sensitive buildings by noise insulation, if required. This could possibly reduce or eliminate this hazard.

6.4.2 ELECTROMAGNETIC RADIATION

Electromagnetic radiation could accidentally detonate electrically initiated explosive devices, leading to an explosion. Radio and radar transmissions from aircraft can affect electro-explosive devices. There is normally little risk to electro-explosive devices Installed in weapons because of the shielding provided by the casing. However electro-explosive devices removed from weapons during maintenance are susceptible for the short time they remain outside a protective shield. Removal of electro explosive devices is carried out within buildings which provide some level of protection, although they are not designed to provide complete protection.

A review by the Electrical Explosives Hazards Committee of the Australian Ordnance Council showed that even the most sensitive electro-explosive device in service is not at risk from direct exposure to the most powerful airborne emitters in civilian and military uses over the frequency spectrum from 3 megahertz to 20 gigahertz, at distances of greater than 300 feet. No allowance was made for any shielding of the electro explosive devices in these calculations (Australian Ordnance Council, 1992).

During an inspection of the Defence Establishment Orchard Hills, site personnel indicated that the human body and other objects in the vicinity can act as antennae during the handling of exposed electro explosive devices and could potentially amplify transmissions. This phenomenon has not been examined in this risk assessment.

Other fixed sources of transmissions exist at airports. These include Terminal Area Radar and other communication systems. Potential hazards to explosives from such fixed sources have not been examined in this risk assessment.

Considering the short time that electro-explosive devices remain outside their protective shield, the height of the aircraft above the facility, the location of flight tracks in relation to maintenance areas, and the Electrical Explosives Hazards Committee test results, the risks to electro explosive devices from aircraft operations from Badgerys Creek Option A appear to quite be low. Such risks could be reduced by additional engineering and procedural controls.

6.4.3 AIRBORNE LASERS

Airborne lasers may be a hazard to explosives devices, however aircraft operations at the Second Sydney Airport would not present such hazards.

6.4.4 AIRCRAFT CRASHES

The assessment of risks on explosion storage areas associated with aircraft crashes requires a consideration of both the consequences and the likelihood of aircraft crashes. This is discussed in *Sections* 6.5 *and* 6.6.

6.4.5 HAZARDS TO AIRCRAFT

Hazards to aircraft overflying Defence Establishment Orchard Hills are discussed in *Section 6.7*.

6.5 CONSEQUENCES OF AIRCRAFT CRASHES

6.5.1 DIRECT CONSEQUENCES

The consequences of an aircraft crash at any location depend on a number of variables at the time of the accident, the most relevant of which include:

- aircraft parameters such as the size and fuel load;
- crash characteristics, such as angle of impact (steep or shallow); and
- characteristics of the crash location such as the construction of buildings and the density of buildings in the area.

Different combinations of the above factors result in different crash consequences. The consequences of aircraft crashes on general built-up areas are discussed in *Appendix* A of *Technical Paper No. 10 - Hazards and* Risks.

Scaled impact areas for arriving and departing aircraft, where the equivalent probability of fatality is 100 percent, are summarised in *Table 6.4*. A scaled impact area is the mathematical equivalent of a larger impact area (approximately 3.33 times the scaled area for the large aircraft category) over which the average probability of fatality is about 0.3. Calculations of scaled impact areas are based on direct consequences of aircraft crash (including impact and post impact fire), but do not take into account hazards present on the ground.

TABLE 6.4: SCALED IMPACT AREAS - DEPARTING AND ARRIVING AIRCRAFT

	Departing Aircraft		Arriving Aircraft	
Aircraft Category	**Steep Angle Scaled Impact Area (m^2)**	**Shallow Angle Scaled Impact Area (m^2)**	**Steep Angle Scaled Impact Area (m^2)**	**Shallow Angle Scaled Impact Area (m^2)**
Low Capacity	2,100	3,700	2,000	2,600
High Capacity - Small	2,100	3,700	2,000	2,600
High Capacity - medium	6,600	7,800	5,900	6,900
High Capacity - Large	16,700	28,100	16,500	25,800
High Capacity - Large- Increased Fuel Load	21,000	48,400	16,500	25,800
General Aviation	2,100	3,700	2,000	2,600

Departing aircraft generally do not crash at shallow angles at distances greater than 1 kilometre from an airport. Therefore, for the Defence Establishment Orchard Hills, steep angle scaled impact areas rather than shallow angle scaled impact areas would apply. Also, in the case of Badgerys Creek Option A, no arriving aircraft movements are anticipated over the Facilities area.

An important feature of many Explosive Ordnance storage buildings is the traverse, or mound around the building. This feature may provide a barrier to aircraft crash trajectories, and so limit the crash impact area.

6.5.2 SECONDARY CONSEQUENCES

Explosive Ordnance present in many buildings on site could escalate the consequences of an aircraft crash. The quantity of Explosive Ordnance kept within maintenance buildings is relatively small, therefore the secondary consequences of an aircraft crash on a maintenance building would most likely be within the scale of the direct consequences.

Many storage buildings contain Explosive Ordnance of Hazard Division 1.1. This particular Explosive Ordnance is susceptible to ground shock, blast, flame and high velocity projectiles. It is prone to mass explosion, which means that the entire stored amount can explode virtually instantaneously. This can give rise to a blast and high and low velocity projectiles.

Explosive Ordnance of other Hazard Divisions may also be present in storage buildings. Explosive Ordnance of Hazard Division 1.2 is susceptible to blast, flame and projectiles. It causes a projection hazard but not a mass explosion hazard. That means it may explode, but the explosion would involve a few items at a time, rather than the entire stored amount.

Explosive Ordnance of Hazard Division 1.3, which can also be stored on the site, is a mass fire hazard.

Therefore direct consequences of an aircraft crashing into Explosive Ordnance storage areas include ground shocks, high velocity projectiles, and fire. The exposure of Explosive Ordnance to such effects could result in a series of explosions involving Hazard Division 1.1 and 1.2 Explosive Ordnance, consequent blasts and projectile generation, and mass fire.

The size of the direct impact areas illustrated in *Table 6.4*, shows that a number of Explosive Ordnance storage buildings could be affected by a single aircraft crash.

The severity of any explosion depends on the quantity of explosives involved. Since Hazard Division 1.1 is the only hazard division which has the potential for mass explosion, the most severe single explosion that could occur would require the entire quantity of Hazard Division 1.1 Explosive Ordnance present in the building to explode.

The maximum quantity of Hazard Division 1.1 Explosive Ordnance that is licensed to be stored in any single building on site is approximately 50,000 kilograms (TNT equivalent). Away from the direct blast area, the consequences of an explosion are determined by the overpressure wave generated. This is a pressure wave which travels away from the centre of the explosion and decreases in intensity with increasing distance. *Table 6.5* gives an indication of the potential effects of explosion overpressures.

TABLE 6.5: EFFECTS OF EXPLOSION OVERPRESSURE

Overpressure kPa	Effect
3.5	90 percent glass breakage. No fatality and very low probability of injury.
7	Damage to internal partitions and joinery 10 percent probability of injury. No fatality.
14	House inhabitable.
21	Reinforced structures distort. 20 percent probability of fatality to a person in the building.
35	Threshold of eardrum damage. 50 percent probability of fatality to a person in building and 15 percent probability of fatality for a person in the open.
70	Complete demolition of houses. 100 percent chance of fatality to a person in a building or in the open.

Explosion overpressures resulting from explosions of different quantities of explosives, calculated using the TNT equivalent method, are shown in *Table 6.6*.

TABLE 6.6: EXPLOSION OVERPRESSURE DISTANCES

TNT Equivalent	Distance (in metres) to Overpressure values of				
Quantity (kg)	35 kPa Distance	21 kPa Distance	14 kPa Distance	7 kPa Distance	3.5 kPa Distance
1,000	55	76	98	151	233
5,000	95	130	168	259	399
10,000	119	164	211	326	502
20,000	150	207	266	410	633
30,000	172	236	305	470	725
40,000	189	260	335	517	797
50,000	204	280	361	557	859

Comparison of the direct consequence areas shown in *Table 6.4* with the explosion overpressure distances shown in *Table 6.6* indicates that the secondary consequences of an aircraft on an Explosive Ordnance storage building are likely to be more severe than the direct consequences of the crash. However, considering the location of Explosive Ordinance storage facilities in relation to the site boundaries, injuries or fatalities outside the site boundary of the Defence Establishment Orchard Hills would not be expected.

6.6 AIRCRAFT CRASH PROBABILITY ANALYSIS

6.6.1 FREQUENCY OF CRASHES

Figures 3.2 in *Appendix* A of the Technical Paper shows contours for the frequency of aircraft crash per square kilometre per year for Preferred Northerly (Airport Operation 1) modes of operation. No part of the Defence Establishment Orchard Hills area is enclosed within the 1×10^{-3} or 1×10^{-4} crashes per square kilometre per year contours. The north-east corner of the site is within the 1×10^{-5} crashes per square kilometre per year contour, and almost fifty percent of the site is contained within the 1×10^{-6} crashes per square kilometre per year contour.

If it is assumed that a 1 kilometre per square area located within the 1×10^{-5} crashes per square kilometre per year contour is exposed to an average frequency level of 5×10^{-5} crashes per square kilometre per year, then the average frequency of aircraft crashes in that area would be 5×10^{-5} per year. Similarly, the average frequency of aircraft crashes on a 1 square kilometre area located between the 1×10^{-5} and 1×10^{-6} crashes per square kilometre per year contours would be 5×10^{-6} per year.

The approximate area of the Defence Establishment Orchard Hills is contained within different frequency zones for the two operating modes is shown in *Table 6.7*

TABLE 6.7 AREAS OF DEFENCE ESTABLISHMENT ORCHARD HILLS WITHIN DIFFERENT AIRCRAFT CRASH FREQUENCY ZONES

Frequency (crashes per square kilometre per year) Zone	**Approximate area of the Defence Establishment Orchard Hills within the Zone (square kilometres)**	
	Airport Operation 1	**Airport Operation 2**
$> 1 \times 10^{-3}$	0	0
$1 \times 10^{-3} > x > 1 \times 10^{-4}$	0	0
$1 \times 10^{-4} > x > 1 \times 10^{-5}$	3	0.5
$1 \times 10^{-5} > x > 1 \times 10^{-6}$	4.5	6.5

The frequencies shown in *Table 6.7* relate to all sizes of aircraft. The proportion of different aircraft sizes which make up this total frequency is calculated by taking into account the crash rate per departure movement for each risk category and the actual number of aircraft departures on tracks, and by grouping the aircraft categories according to aircraft size. The results are shown in *Table 6.8*.

TABLE 6.8: DEFENCE ESTABLISHMENT ORCHARD HILLS CRASH FREQUENCY DISTRIBUTION

Aircraft Size	Proportion of Total Frequency of Aircraft Crash	
	Airport Operation 1	Airport Operation 2
Small	67%	68%
Medium	5%	5%
Large	13%	12%
Large - Increased Fuel Load	15%	15%

This shows that small aircraft are more than four times more likely to crash into the Defence Establishment Orchard Hills than larger aircraft. However a crash of a larger aircraft would have a greater impact, in that more buildings could be destroyed by the direct impact and secondary effects could be greater.

6.6.2 ACCEPTABILITY OF RISK TO EXPLOSIVES

In major industrial areas, situations occur where accidents on one installation cause damage to the neighbouring installation and hence initiate further hazardous incidents - the so-called 'domino effect'. Damage can occur due to exposure to heat or explosion overpressure. For example, steel structures exposed to 23 kilowatts per square metre of heat radiation for a prolonged period can suffer thermal stresses that may cause structural failure. Similarly, a conventional building exposed to 14 kilo pascals of explosion overpressure would probably suffer serious structural damage. Thus, each type of exposure can trigger a hazardous incident.

In NSW, the criteria for risk at neighbouring property or land from a hazardous installation are that the frequency of exposure to 23 kilowatts per square metre heat radiation should not exceed 50×10^{-6} (5×10^{-5}) per year, and the frequency of exposure to 14 kilo pascals of explosion overpressure level should not exceed 50×10^{-6} (5×10^{-5}) per year.

Exposure to 23 kilowatts per square metre of heat radiation and 14 kilo pascals explosion overpressure at a total frequency of 1×10^{-4} per year is considered acceptable, provided that each component of exposure is within the 5×10^{-5} per year limit.

The above mentioned criteria are outlined here to provide information on the levels of risk that are considered acceptable in an industrial situation. Although these criteria are not strictly applicable to the situation at the Defence Establishment Orchard Hills, they provide a reference point to assist in making judgements about the acceptability of risks relating to aircraft crashes.

6.7 HAZARDS TO AIRCRAFT

6.7.1 PLANNED EXPLOSIONS

Demolition activities were suspended at the Defence Establishment Orchard Hills at the time when this report was prepared. It is understood that if such activities are resumed, only minor quantities of Explosive Ordnance (approximately 5 kilograms at a time) would be demolished, and this would only occur infrequently. Temporary airspace restrictions have been discussed between with Airservices Australia and the Department of Defence. These restrictions would be determined using the methodology recommended in Pillar Proceeding 205.92 (AOC, 92), which takes into account both the fragment and the blast hazard to aircraft. In view of these arrangements, risks to overflying aircraft would be low.

6.7.2 ACCIDENTAL EXPLOSIONS

Aircraft flying over, or in the vicinity of an accidental explosion at the site could be affected by blast, fragments or both. Two types of assessments are relevant in this situation. The first is an assessment of risk to an aircraft each time it flies over, or is in the vicinity of the Defence Establishment Orchard Hills, while the second is the assessment of total risk to all aircraft that fly over, or are in the vicinity of the Defence Establishment Orchard Hills.

Risk assessment requires a consideration of both the consequences of accidental explosions and the likelihood of harm to aircraft. These are discussed in *Sections 6.7.3 and 6.7.4.*

6.7.3 CONSEQUENCE ANALYSIS

The consequences of an explosion on ground for an aircraft flying overhead depend on a number of factors, including the quantity of explosives involved in the explosion and the separation between the centre of explosion and the aircraft, at the time of the explosion.

The quantity of explosives involved in an accidental explosion on site would be limited to the licensed quantity of Hazard Division 1.1 Explosive Ordnance for each particular building. Licence capability varies from building to building, with a maximum of 50,000 kilograms (TNT equivalent).

Defence trials show that occasional buffeting of aircraft is experienced at pressures exceeding 1 kilo pascals (Australian Ordnance Council, 1992). Distance in metres to tolerable occasional buffeting are calculated from the formula 112 $Q^{1/3}$, where Q is the TNT equivalent mass of explosives (in kilograms) involved in the explosion.

The minimum separation distances (D13) between explosives storage facilities and inhabited buildings are specified in OPSMAN 3 (Department of Defence, 1994). The distances in metres equal 22.2 $Q^{1/3}$, where Q is the net explosives quantity (in kilograms) of the total explosives involved in the explosion, which corresponds to a peak side-on overpressure of 5 kilo pascals.

D13 distances are also the recommended minimum separation between Explosive Ordnance storage facilities and major public transport routes. The effect on aircraft at D13 distances is not known, but effects would have to be more severe than distances of 112 $Q^{1/3}$, the distance to tolerable occasional buffeting.

Table 6.9 illustrates the distances to tolerable occasional buffeting (112 $Q^{1/3}$), and D13 distances for Hazard Division 1.1 (22.2 $Q^{1/3}$) for the range of accidental explosions at Defence Establishment Orchard Hills.

TABLE 6.9: CONSEQUENCE DISTANCE FOR EXPLOSIONS

Explosives Quantity (kilograms TNT Equivalent)[1,2]	Distances in metres to	
	Tolerable Occasional Buffeting	Inhabited Buildings
1,000	1,120	270
2,000	1,420	280
5,000	1,920	380
10,000	2,420	480
20,000	3,040	610
30,000	3,480	690
40,000	3,830	760
50,000	4,130	820

Notes: 1. TNT equivalent quantity in the case of 'Occasional Tolerable Buffeting'.
2. Net Explosives Quantity in the case of 'Inhabited Building' distance.

Thus, aircraft at distances greater than approximately 4 kilometres from the centre of the worst case explosion on site would only experience tolerable occasional buffeting. However, consequences for aircraft within 4 kilometres of the worst-case explosion on site could be greater than tolerable occasional buffeting, and could even include sub-lethal or lethal effects, depending upon the separation between the centre of the explosion and the aircraft at the time of explosion.

Fragments could also be projected from explosions on the ground, but fragment effects at a particular distance are somewhat different from blast wave effects. Although fragments may travel great distances, they have to hit the 'target' (aircraft in this case) for them to have an effect, unlike a blast wave which will 'hit' everything in its path. While there is a chance that a fragment may hit an aircraft, there is conversely a much greater chance that it may not hit the target. However it is difficult to determine the probability of a 'hit'.

In view of the uncertainty in both the blast and fragment effects on aircraft, a conservative approach has been adopted for this risk assessment. The preliminary analysis undertaken assumes that all explosions at the Defence Establishment Orchard Hills involve the worst-case explosives quantity of 50,000 kilograms and that aircraft within four kilometres of the centre of the Defence Establishment Orchard Hills at the time of explosion would crash. If this analysis shows that the level of risk is unacceptable, then more detailed analysis may be justified.

6.7.4 PROBABILITY ANALYSIS

Since a blast wave travels in all directions, the space within 4 kilometres of the worst-case explosion on site would be a hemispheric shape of 4 kilometre radius, centred around the explosion site.

The flight time of a particular aircraft within the 4 kilometres radius hemisphere will depend upon flight parameters such as airspeed, altitude, and its flight path relative to this hemisphere. The worst-case (longest) flight time inside this space could be calculated by assuming the worst set of parameters, ie., the slowest airspeed, the lowest altitude, and the longest travel in a straight line within this hemisphere. At the slowest airspeed of 160 kilometres per hour, travelling a distance of 8 kilometres, the maximum time an aircraft would spend inside the space would be 3 minutes. The following paragraphs discuss the probability of an explosion on ground during a 3 minute period.

Accidental detonation of the contents of explosives storehouses, or of explosives in other facilities, are very uncommon (Australian Ordnance Council, 1992). None of the Department of Defence staff consulted as part of this study could recall an explosion in a Department of Defence explosives storage building in Australia although a recent case in the USA was mentioned. While the frequency of such accidents is low, such an accident could occur at any storage facility, including at the Defence Establishment Orchard Hills.

An examination by Menz (Menz, 1984) concluded that civilian storage magazines explode with a frequency of between 1×10^{-4} and 1×10^{-6} per year. Other estimates have placed the figure nearer to 2.5×10^{-4} per annum. The actual mechanisms which caused such detonations are not recorded by Menz or other analysts.

The relevance and applicability of these frequencies to Defence Explosive Ordnance storage buildings is not clear. For the purpose of preliminary analysis, a frequency of 1×10^{-5} per year will be assumed. On this basis, considering that there are about 150 Explosive Ordnance storage buildings on site, the total frequency of accidental explosions at the Defence Establishment Orchard Hills would be 1.5×10^{-3} per year.

If the total frequency of accidental explosions at the Defence Establishment Orchard Hills is 1.5×10^{-3} per year, the frequency over any 3 minute period would be 8.6×10^{-9}.

Thus, in the worst-case, the risk of crash per flight over the Defence Establishment Orchard Hills due to an accidental explosion at the facilities would be 8.6×10^{-9}. This does not affect flights that do not pass directly over or within 4 kilometres of the facility.

The estimated annual number of aircraft movements over the Defence Establishment Orchard Hills in each operating mode is shown on *Table 6.10.*

TABLE 6.10: ANNUAL AIRCRAFT MOVEMENTS OVER THE DEFENCE ESTABLISHMENT ORCHARD HILLS

Flight Category	Airport Operation 1	Airport Operation 2
Low Capacity	583	215
High Capacity	11,937	9,114
General Aviation	806	345
Total	**13,326**	**9,674**

It should be noted that the probability of more than one aircraft being present within the four kilometre radius effect zone of the Defence Establishment Orchard Hills worst-case explosion at the same time has not been evaluated in this risk assessment.

6.7.5 ACCEPTABILITY OF RISK

The acceptability of crash risk per flight from accidental explosions at the Defence Establishment Orchard Hills could be judged by comparing the additional risk in the worst-case with the risk of crashing from all other causes (obtained from *Appendix A* of *Technical Paper No. 10 - Hazards and Risks*. *Table 6.11* provides such a comparison.

TABLE 6.11: CRASH RISK PER MOVEMENT

Flight Category	Crash risk per arrival (other causes)	Crash risk per departure (other causes)	Worst-case additional crash risk per flight)	Percentage increase in risk
Low Capacity	6.36×10^{-7}	9.54×10^{-7}	8.6×10^{-9}	0.9- 1.3%
High Capacity	9.64×10^{-8}	1.07×10^{-7}	8.6×10^{-9}	8-9%
General Aviation	3.95×10^{-6}	3.95×10^{-6}	8.6×10^{-9}	0.2%

The additional crash risk per year from explosions at the Defence Establishment Orchard Hills can be calculated by multiplying the worst case additional crash risk per flight (*Table 6.11*) by the number of flights per year (*Table 6.10*) for each mode of operation. *Table 6.12* provides a comparison of this worst-case additional risk, with the risk of crashing from all other causes.

TABLE 6.12: CRASH RISK PER YEAR

		Airport Operation 1		Airport Operation 2	
Flight Operation Category	**Total risk per year**	**Worst-case additional risk per year (Defence Establishment Orchard Hills)**	**Percentage increase**	**Worst-case additional risk per year (Defence Establishment Orchard Hills)**	**Percentage increase**
Low Capacity	0.0263	5.01×10^{-6}	0.02	1.85×10^{-6}	0.01
High Capacity	0.0199	1.03×10^{-4}	0.51	7.84×10^{-5}	0.39
General Aviation	0.0614	6.93×10^{-6}	0.01	2.97×10^{-6}	0.00
Total	**0.108**	**1.15×10^{-4}**	**0.11**	**8.32×10^{-5}**	**0.08**

This analysis shows that the increase in crash risk for aircraft overflying the Defence Establishment Orchard Hills is insignificant for Badgerys Creek Option A.

7 IMPACT ASSESSMENT - BADGERYS CREEK OPTION B

7.1 PROPOSED FLIGHT PATHS

The parallel runways for Badgerys Creek Option B are not in direct line with the Defence Establishment Orchard Hills. However, the cross runway is in line with the south-west corner of the site. Arrival and departure tracks have not been finalised at this stage, however, a set of arrival and departure tracks were defined for each airport option in discussion with Airservices Australia, to enable noise impact studies to be undertaken.

Two assumed departure flight tracks from the parallel runways (D01 and D06) pass over parts of the facility. In addition, around four departure tracks (D18, D37, D19 and D38), and three arrival tracks (A30, A31 and A32) for the cross runway pass over the Defence Establishment Orchard Hills.

It should be noted that the flight tracks over the Defence area are preliminary and have not been finalised. Actual flight tracks may differ from these. Moreover, for any flight track, a certain amount of lateral deviation from the centerline is expected. This deviation increases as a function of the distance along the track. For risk analysis, it has been assumed that departing aircraft could deviate by up to nine degrees on either side of the centerline. For arrival, a dispersion of three degrees on either side of the centreline was assumed.

7.2 PROPOSED NUMBER OF AIRCRAFT MOVEMENTS

Three operating modes at the airport were investigated. The cross runway is used only in Airport Operation 3, therefore tracks D18, D19, D37 D38, A30, A31, and A32 do not have any aircraft movements for the other two operating modes.

The annual number of aircraft on D01 and D06 tracks for the three operating modes classified according to risk categories are shown in *Tables 7.1 to 7.3*

TABLE 7.1 ANNUAL AIRCRAFT MOVEMENTS OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 1

Aircraft Category	D01	D06
Low Capacity	577	6
High Capacity - Small	1,100	42
High Capacity - Medium	1,369	243
High Capacity - Large	3,350	1,324
High Capacity - Large- Increased Fuel Load	3,799	710
General Aviation	774	32
Total	**10,969**	**2,357**

TABLE 7.2 ANNUAL AIRCRAFT MOVEMENTS OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 2

Aircraft Category	D01	D06
Low Capacity	201	14
High Capacity - Small	360	107
High Capacity - Medium	462	635
High Capacity - Large	1,053	3,417
High Capacity - Large- Increased Fuel Load	1,211	1,869
General Aviation	261	84
Total	**3,548**	**6,126**

TABLE 7.3 ANNUAL AIRCRAFT DEPARTURES OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 3

Aircraft Category	D01	D06	D18	D19	D37	D38
Low Capacity	380	9	223	29	9	1
High Capacity - Small	729	27	158	55	5	10
High Capacity - Medium	905	372	421	68	17	56
High Capacity - Large	2,227	2,066	288	168	19	311
High Capacity - Large-Increased Fuel Load	2,523	1,075	0	190	10	162
General Aviation	512	49	108	39	4	7
Total	**7,276**	**3,637**	**1,199**	**548**	**64**	**548**

TABLE 7.4 ANNUAL AIRCRAFT ARRIVALS OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 3

Aircraft Category	A31	A32	A33
Low Capacity	417	84	77
High Capacity - Small	291	4	60
High Capacity - Medium	848	119	176
High Capacity - Large	1,535	196	204
High Capacity - Large-Increased Fuel Load	0	0	0
General Aviation	214	22	36
Total	**3,306**	**424**	**553**

The description, and the rationale for the definition of risk categories is provided in *Appendix A* of *Technical Paper No. 10 - Hazards and Risks.*

7.3 INDICATIVE RANGE OF AIRCRAFT ALTITUDE ABOVE DEFENCE ESTABLISHMENT ORCHARD HILLS

The curvilinear distance of the projection of the flight track on the ground from the runway end to the boundary of the facility is shown on *Table 7.5.*

TABLE 7.5 FLIGHT DISTANCE FROM RUNWAY END TO DEFENCE ESTABLISHMENT ORCHARD HILLS BOUNDARY

Track Name	Runway End	Flight Distance along track (kilometres)
D01	Parallel North 05 L	11
D06	Parallel South 23 R	25.5
D18	Cross West 33 C	7
D19	Cross West 33 C	7
D37	Cross West 33 C	7
D38	Cross West 33 C	8
A30	Cross East 15 C	7
A31	Cross East 15 C	7
A32	Cross East 15 C	7

Indicative ranges of altitudes at these distances during take-off, for representative aircraft within these categories, are shown in *Table* 7.6.

TABLE 7.6 INDICATIVE ALTITUDE ABOVE DEFENCE ESTABLISHMENT ORCHARD HILLS FOR DEPARTING AIRCRAFT

Aircraft Category	Altitude at 7 kilometres (D18, D19, D37, D38)	Altitude at 11 kilometres (D01)	Altitude at 25.5 kilometres (D06)
Low Capacity	450 metres -1,050 metres	600 metres - 1,400 metres	1,300 metres - 2,900 metres
High Capacity - Small	450 metres -1,050 metres	600 metres - 1,400 metres	1,300 metres - 2,900 metres
High Capacity - Medium	850 - 1,150 metres	1,200 metres - 1,900 metres	3,000 metres
High Capacity - Large	800 metres - 1,100 metres	1,200 metres - 1,700 metres	2,800 metres - 3,000 metres
High Capacity - Large-Increased Fuel Load	650 metres - 750 metres	800 metres - 900 metres	1,600 metres - 2,400 metres
General Aviation	450 metres -1,050 metres	600 metres - 1,400 metres	1,300 metres - 2,900 m

Source: Calculated from INM profiles for representative aircraft within each category

At the normal glide-slope of three degrees, aircraft on arrival tracks A30, A31 and A32 would be at a height of about 367 metres.

The actual height above the facility will differ depending on the type of aircraft and on operating conditions. Aircraft would generally be more than 1,000 feet above the facility for Airport Operation 1 and 2. However, for Airport Operation 3 the altitude of arriving aircraft would generally not be much greater than 1,000 feet.

7.4 HAZARD AND RISK ASSESSMENT

Hazards identified in Pillar Proceeding 205.92 are examined in this Section.

7.4.1 DISTRACTION

Defence personnel working with explosives could potentially become distracted by noise, if aircraft pass overhead. This could increase the possibility of an accident.

It is understood that the majority, if not all of the activities involving the handling of explosives are carried out indoors. Therefore it would be feasible to reduce noise levels inside sensitive buildings by noise insulation, if required. This could possibly reduce or eliminate this hazard.

7.4.2 ELECTROMAGNETIC RADIATION

Electromagnetic radiation could accidentally detonate electrically initiated explosive devices, leading to an explosion. Radio and radar transmissions from aircraft can affect electro-explosive devices. There is normally little risk to electro-explosive devices Installed in weapons because of the shielding provided by the casing. However electro-explosive devices removed from weapons during maintenance are susceptible for the short time they remain outside a protective shield. Removal of electro explosive devices is carried out within buildings which provide some level of protection, although they are not designed to provide complete protection.

A review by the Electrical Explosives Hazards Committee of the Australian Ordnance Council showed that even the most sensitive electro-explosive device in service is not at risk from direct exposure to the most powerful airborne emitters in civilian and military uses over the frequency spectrum from 3 megahertz to 20 gigahertz, at distances of greater than 300 feet. No allowance was made for any shielding of the electro explosive devices in these calculations (Australian Ordnance Council, 1992).

During an inspection of the Defence Establishment Orchard Hills, site personnel indicated that the human body and other objects in the vicinity can act as antennae during the handling of exposed electro explosive devices and could potentially amplify transmissions. This phenomenon has not been examined in this risk assessment.

Other fixed sources of transmissions exist at airports. These include Terminal Area Radar and other communication systems. Potential hazards to explosives from such fixed sources have not been examined in this risk assessment.

Considering the short time that electro-explosive devices remain outside their protective shield, the height of the aircraft above the facility, the location of flight tracks in relation to maintenance areas, and the Electrical Explosives Hazards Committee test results, the risks to electro explosive devices from aircraft operations from Badgerys Creek Option B appear to quite be low, for Airport Operations 1 and 2.

However, for Airport Operation 3, arrival and departure tracks related to the cross runway are positioned generally over the guided weapon maintenance area, and the height of the aircraft is relatively lower. Therefore, this operating mode presents relatively higher risk of accidental initiation of electro-explosive devices. Such risks could be reduced by additional engineering and procedural controls.

7.4.3 AIRBORNE LASERS

Airborne lasers may be a hazard to explosives devices, however aircraft operations at the Second Sydney Airport would not present such hazards.

7.4.4 AIRCRAFT CRASHES

The assessment of risks on explosion storage areas associated with aircraft crashes requires a consideration of both the consequences and the likelihood of aircraft crashes. This is discussed in *Sections 7.5 and 7.6.*

7.4.5 HAZARDS TO AIRCRAFT

Hazards to aircraft overflying Defence Establishment Orchard Hills are discussed in *Section 7.7.*

7.5 CONSEQUENCES OF AIRCRAFT CRASHES

7.5.1 DIRECT CONSEQUENCES

The consequences of an aircraft crash at any location depends on a number of variables at the time of the accident, the most relevant of which include:

- aircraft parameters such as the size and fuel load;
- crash characteristics, such as angle of impact (steep or shallow); and
- characteristics of the crash location such as the construction of buildings and the density of buildings in the area.

Different combinations of the above factors result in different crash consequences. The consequences of aircraft crashes on general built-up areas are discussed in *Appendix A* of *Technical Paper No. 10 - Hazards and Risks.*

Scaled impact areas for arriving and departing aircraft, where the equivalent probability of fatality is 100 percent, are summarised in *Table 7.7*. A scaled impact area is the mathematical equivalent of a larger impact area (approximately 3.33 times the scaled area for the large aircraft category) over which the average probability of fatality is about 0.3. Calculations of scaled impact areas are based on direct consequences of aircraft crash (including impact and post impact fire), but do not take into account hazards present on the ground.

TABLE 7.7 SCALED IMPACT AREAS - DEPARTING AND ARRIVING AIRCRAFT

Aircraft Category	Departing Aircraft		Arriving Aircraft	
	Steep Angle Scaled Impact Area (m^2)	**Shallow Angle Scaled Impact Area (m^2)**	**Steep Angle Scaled Impact Area (m^2)**	**Shallow Angle Scaled Impact Area (m^2)**
Low Capacity	2,100	3,700	2,000	2,600
High Capacity - Small	2,100	3,700	2,000	2,600
High Capacity - Medium	6,600	7,800	5,900	6,900
High Capacity - Large	16,700	28,100	16,500	25,800
High Capacity - Large- Increased Fuel Load	21,000	48,400	16,500	25,800
General Aviation	2,100	3,700	2,000	2,600

Departing aircraft generally do not crash at shallow angles at distances greater than one kilometre from the airport. Therefore, for the Defence Establishment Orchard Hills, the steep angle scaled impact areas would apply to departing aircraft.

An important feature of many explosive ordnance storage buildings is the traverse, or the mound around the building. This feature may provide a barrier to aircraft crash trajectories, and so limit the crash impact area.

7.5.2 SECONDARY CONSEQUENCES

Explosive ordnance present in many buildings on site could escalate the consequences of aircraft crash. The quantity of explosive ordnance within maintenance buildings is relatively small, therefore the secondary consequences of an aircraft crash would most likely be within the scale of the direct consequences.

Many storage buildings contain Explosive Ordnance of Hazard Division 1.1. This particular Explosive Ordnance is susceptible to ground shock, blast, flame and high velocity projectiles. It is prone to mass explosion, which means that the entire stored amount can explode virtually instantaneously. This can give rise to a blast and high and low velocity projectiles.

Explosive Ordnance of other Hazard Divisions may also be present in storage buildings. Explosive Ordnance of Hazard Division 1.2 is susceptible to blast, flame and projectiles. It causes a projection hazard but not a mass explosion hazard. That means it may explode, but the explosion would involve a few items at a time, rather than the entire stored amount.

Explosive Ordnance of Hazard Division 1.3, which can also be stored on the site, is a mass fire hazard.

Therefore direct consequences of an aircraft crashing into Explosive Ordnance storage areas include ground shocks, high velocity projectiles, and fire. The exposure of Explosive Ordnance to such effects could result in a series of explosions involving Hazard Division 1.1 and 1.2 Explosive Ordnance, consequent blasts and projectile generation, and mass fire.

The size of the direct impact areas illustrated in *Table 7.7*, shows that a number of Explosive Ordnance storage buildings could be affected by a single aircraft crash.

The severity of any explosion depends on the quantity of explosives involved. Since Hazard Division 1.1 is the only hazard division which has the potential for mass explosion, the most severe single explosion that could occur would require the entire quantity of Hazard Division 1.1 Explosive Ordnance present in the building to explode.

The maximum quantity of Hazard Division 1.1 Explosive Ordnance that is licensed to be stored in any single building on site is approximately 50,000 kilograms (TNT equivalent). Away from the direct blast area, the consequences of an explosion are determined by the overpressure wave generated. This is a pressure wave which travels away from the centre of the explosion and decreases in intensity with increasing distance. *Table 7.8* gives an indication of the potential effects of explosion overpressures.

TABLE 7.8 EFFECTS OF EXPLOSION OVERPRESSURE

Overpressure kPa	Effect
3.5	90 percent glass breakage No fatality and very low probability of injury
7	Damage to internal partitions and joinery 10 percent probability of injury. No fatality
14	House inhabitable
21	Reinforced structures distort 20 percent probability of fatality to a person in a building
35	Threshold of eardrum damage 50 percent probability of fatality to a person in a building and 15 percent probability of fatality for a person in the open
70	Complete demolition of houses 100 percent chance of fatality to a person in a building or in the open

Explosion overpressures resulting from explosions of different quantities of explosives, calculated using the TNT equivalent method, are shown in *Table 7.9*.

TABLE 7.9 OVERPRESSURE DISTANCES

TNT Equivalent	Distance (in metres) to Overpressure values of				
Quantity (kg)	35 kPa	21 kPa	14 kPa	7 kPa	3.5 kPa
1,000	55	76	98	151	233
5,000	95	130	168	259	399
10,000	119	164	211	326	502
20,000	150	207	266	410	633
30,000	172	236	305	470	725
40,000	189	260	335	517	797
50,000	204	280	361	557	859

Comparison of the direct consequence areas shown in *Table 7.7* with the explosion overpressure distances shown in *Table 7.9* indicates that the secondary consequences of an aircraft on an Explosive Ordnance storage building are likely to be more severe than the direct consequences of the crash. However, considering the location of Explosive Ordinance storage facilities in relation to the site boundaries, injuries or fatalities outside the site boundary of the Defence Establishment Orchard Hills would not be expected.

7.6 AIRCRAFT CRASH PROBABILITY ANALYSIS

7.6.1 FREQUENCY OF CRASHES

Figure 3.3 in *Appendix A* of *Technical Paper No. 10 - Hazards and Risks* shows contours for the frequency of aircraft crash per square kilometre per year for Airport Operation 3. No part of the Defence Establishment Orchard Hills area is enclosed within the 1 x 10^{-3} or 1 x 10^{-4} crashes per square kilometre per year contours. The north-east corner of the site is within the 1 x 10^{-5} crashes per square kilometre per year contour, and almost fifty percent of the site is contained within the 1 x 10^{-6} crashes per square kilometre per year contour.

If it is assumed that a 1 kilometre per square area located within the 1 x 10^{-5} crashes per square kilometre per year contour is exposed to an average frequency level of 5 x 10^{-5} crashes per square kilometre per year, then the average frequency of aircraft crashes in that area would be 5 x 10^{-5} per year. Similarly, the average frequency of aircraft crashes on a 1 square kilometre area located between the 1 x 10^{-5} and 1 x 10^{-6} crashes per square kilometre per year contours would be 5 x 10^{-6} per year.

The approximate area of the Defence Establishment Orchard Hills that is contained within different frequency zones for the three operating modes is shown in *Table 7.10.*

TABLE 7.10 AREAS OF DEFENCE ESTABLISHMENT ORCHARD HILLS WITHIN DIFFERENT FREQUENCY ZONES

Frequency (crashes per square kilometre per year) Zone	Approximate Area of the Defence Establishment Orchard Hills within the Zone (square kilometres)		
	Airport Operation 1	Airport Operation 2	Airport Operation 3
$> 1 \times 10^{-3}$	0	0	0
$1 \times 10^{-3} > x > 1 \times 10^{-4}$	0	0	0
$1 \times 10^{-4} > x > 1 \times 10^{-5}$	3	0.5	6
$1 \times 10^{-5} > x > 1 \times 10^{-6}$	4.5	6.5	9

The frequencies shown in *Table 7.10* relate to all sizes of aircraft. The proportion of different aircraft sizes which make up this total frequency is calculated by taking into account the crash rate per departure movement for each risk category and the actual number of aircraft departures on tracks, and by grouping the aircraft categories according to aircraft size. The results are shown in *Table 7.11.*

TABLE 7.11 DEFENCE ESTABLISHMENT ORCHARD HILLS CRASH FREQUENCY DISTRIBUTION

Aircraft Size	Proportion of Total Frequency of Aircraft Crash in Operating Mode		
	Airport Operation 1	Airport Operation 2	Airport Operation 3
Small	67%	68%	82%
Medium	5%	5%	5%
Large	13%	12%	8%
Large - Increased Fuel Load	15%	15%	5%

7.6.2 ACCEPTABILITY OF RISK TO EXPLOSIVES

In major industrial areas, situations occur where accidents on one installation cause damage to the neighbouring installation and hence initiate further hazardous incidents - the so-called 'domino effect'. Damage can occur due to exposure to heat or explosion overpressure. For example, steel structures exposed to 23 kilowatts per square metre of heat radiation for a prolonged period can suffer thermal stresses that may cause structural failure.

Similarly, a conventional building exposed to 14 kilo pascals of explosion overpressure would probably suffer serious structural damage. Thus, each type of exposure can trigger a hazardous incident.

In NSW, the criteria for risk at neighbouring property or land from a hazardous installation are that the frequency of exposure to 23 kilowatts per square metre heat radiation should not exceed 50×10^{-6} (5×10^{-5}) per year, and the frequency of exposure to 14 kilo pascals of explosion overpressure level should not exceed 50×10^{-6} (5×10^{-5}) per year.

Exposure to 23 kilowatts per square metre of heat radiation and 14 kilo pascals explosion overpressure at a total frequency of 1×10^{-4} per year is considered acceptable, provided that each component of exposure is within the 5×10^{-5} per year limit.

The above mentioned criteria are outlined here to provide information on the levels of risk that are considered acceptable in an industrial situation. Although these criteria are not strictly applicable to the situation at the Defence Establishment Orchard Hills, they provide a reference point to assist in making judgements about the acceptability of risks relating to aircraft crashes.

7.7 HAZARDS TO AIRCRAFT

7.7.1 PLANNED EXPLOSIONS

Demolition activities were suspended at the Defence Establishment Orchard Hills at the time when this report was prepared. It is understood that if such activities are resumed, only minor quantities of Explosive Ordnance (approximately five kilograms at a time) would be demolished, and this would only occur infrequently. Temporary airspace restrictions have been discussed between with Airservices Australia and the Department of Defence. These restrictions would be determined using the methodology recommended in Pillar Proceeding 205.92 (Australian Ordnance Council, 1992), which takes into account both the fragment and the blast hazard to aircraft. In view of these arrangements, risks to overflying aircraft would be low.

7.7.2 ACCIDENTAL EXPLOSIONS

Aircraft flying over, or in the vicinity of an accidental explosion at the site could be affected by blast, fragments or both. Two types of assessments are relevant in this situation. The first is an assessment of risk to an aircraft each time it flies over, or is in the vicinity of the Defence Establishment Orchard Hills, while the second is the assessment of total risk to all aircraft that fly over, or are in the vicinity of the Defence Establishment Orchard Hills.

Risk assessment requires a consideration of both the consequences of accidental explosions and the likelihood of harm to aircraft. These are discussed in *Sections 7.7.3 and 7.7.4.*

7.7.3 CONSEQUENCE ANALYSIS

The consequences of an explosion on ground for an aircraft flying overhead depend on a number of factors, including the quantity of explosives involved in the explosion and the separation between the centre of explosion and the aircraft, at the time of the explosion.

The quantity of explosives involved in an accidental explosion on site would be limited to the licensed quantity of Hazard Division 1.1 Explosive Ordnance for each particular building. Licence capability varies from building to building, with a maximum of 50,000 kilograms (TNT equivalent).

Defence trials show that occasional buffeting of aircraft is experienced at pressures exceeding 1 kilo pascals (Australian Ordnance Council, 1992). Distance in metres to tolerable occasional buffeting are calculated from the formula 112 $Q^{1/3}$, where Q is the TNT equivalent mass of explosives (in kilograms) involved in the explosion.

The minimum separation distances (D13) between explosives storage facilities and inhabited buildings are specified in OPSMAN 3 (Department of Defence, 1994). The distances in metres equal 22.2 $Q^{1/3}$, where Q is the net explosives quantity (in kilograms) of the total explosives involved in the explosion, which corresponds to a peak side-on overpressure of 5 kilo pascals.

D13 distances are also the recommended minimum separation between Explosive Ordnance storage facilities and major public transport routes. The effect on aircraft at D13 distances is not known, but effects would have to be more severe than distances of 112 $Q^{1/3}$, the distance to tolerable occasional buffeting.

Table 7.12 illustrates the distances to tolerable occasional buffeting (112 $Q^{1/3}$), and D13 distances for Hazard Division 1.1 (22.2 $Q^{1/3}$) for the range of accidental explosions at Defence Establishment Orchard Hills.

TABLE 7.12 CONSEQUENCE DISTANCES FOR EXPLOSIONS

Explosives Quantity (kg)[1,2]	Distances in metres to	
	Tolerable Occasional Buffeting	Inhabited Buildings
1,000	1,120	270
2,000	1,420	280
5,000	1,920	380
10,000	2,420	480
20,000	3,040	610
30,000	3,480	690
40,000	3,830	760
50,000	4,130	820

Notes: 1. TNT equivalent quantity in the case of 'Occasional Tolerable Buffeting'.
2. Net Explosives Quantity in the case of 'Inhabited Building' distance.

Thus, aircraft at distances greater than approximately 4 kilometres from the centre of the worst case explosion on site would only experience tolerable occasional buffeting. However, consequences for aircraft within four kilometres of the worst-case explosion on site could be greater than tolerable occasional buffeting, and could even include sub-lethal or lethal effects, depending upon the separation between the centre of the explosion and the aircraft at the time of explosion.

Fragments could also be projected from explosions on the ground, but fragment effects at a particular distance are somewhat different from blast wave effects. Although fragments may travel great distances, they have to hit the 'target' (aircraft in this case) for them to have an effect, unlike a blast wave which will 'hit' everything in its path. While there is a chance that a fragment may hit an aircraft, there is conversely a much greater chance that it may not hit the target. However it is difficult to determine the probability of a 'hit'.

In view of the uncertainty in both the blast and fragment effects on aircraft, a conservative approach has been adopted for this risk assessment. The preliminary analysis undertaken assumes that all explosions at the Defence Establishment Orchard Hills involve the worst-case explosives quantity of 50,000 kilograms and that aircraft within four kilometres of the centre of the Defence Establishment Orchard Hills at the time of explosion would crash. If this analysis shows that the level of risk is unacceptable, then more detailed analysis maybe justified.

7.7.4 PROBABILITY ANALYSIS

Since a blast wave travels in all directions, the space within 4 kilometres of the worst-case explosion on site would be a hemispheric shape of 4 kilometre radius, centred around the explosion site.

The flight time of a particular aircraft within the 4 kilometres radius hemisphere will depend upon flight parameters such as airspeed, altitude, and its flight path relative to this hemisphere. The worst-case (longest) flight time inside this space could be calculated by assuming the worst set of parameters, ie., the slowest airspeed, the lowest altitude, and the longest travel in a straight line within this hemisphere. At the slowest airspeed of 160 kilometres per hour, travelling a distance of 8 kilometres, the maximum time an aircraft would spend inside the space would be 3 minutes. The following paragraphs discuss the probability of an explosion on ground during a three minute period.

Accidental detonation of the contents of explosives storehouses, or of explosives in other facilities, are very uncommon (Australian Ordnance Council, 1992). None of the Department of Defence staff consulted as part of this study could recall an explosion in a Department of Defence explosives storage building in Australia although a recent case in the USA was mentioned. While the frequency of such accidents is low, such an accident could occur at any storage facility, including at the Defence Establishment Orchard Hills.

An examination by Menz (Menz, 1984) concluded that civilian storage magazines explode with a frequency of between 1×10^{-4} and 1×10^{-6} per year. Other estimates have placed the figure nearer to 2.5×10^{-4} per annum. The actual mechanisms which caused such detonations are not recorded by Menz or other analysts.

The relevance and applicability of these frequencies to Defence Explosive Ordnance storage buildings is not clear. For the purpose of preliminary analysis, a frequency of 1×10^{-5} per year will be assumed. On this basis, considering that there are about 150 Explosive Ordnance storage buildings on site, the total frequency of accidental explosions at the Defence Establishment Orchard Hills would be 1.5×10^{-3} per year.

If the total frequency of accidental explosions at the Defence Establishment Orchard Hills is 1.5×10^{-3} per year, the frequency over any 3 minute period would be 8.6×10^{-9}.

Thus, in the worst-case, the risk of crash per flight over the Defence Establishment Orchard Hills due to an accidental explosion at the facilities would be 8.6×10^{-9}. This does not affect flights that do not pass directly over or within four kilometres of the facility.

The estimated annual number of aircraft movements over the Defence Establishment Orchard Hills in each operating mode is shown on *Table 6.10*.

TABLE 7.13 ANNUAL AIRCRAFT MOVEMENTS OVER THE DEFENCE ESTABLISHMENT ORCHARD HILLS

Flight Category	Airport Operation 1	Airport Operation 2	Airport Operation 3
Low Capacity	583	215	1,229
High Capacity	11,937	9,114	15,335
General Aviation	806	345	991
Total	**13,326**	**9,674**	**17,554**

It should be noted that the probability of more than one aircraft being present within the four kilometre radius effect zone of the Defence Establishment Orchard Hills worst-case explosion at the same time has not been evaluated in this risk assessment.

7.7.5 ACCEPTABILITY OF RISK

The acceptability of crash risk per flight from accidental explosions at the Defence Establishment Orchard Hills could be judged by comparing the additional risk in the worst-case with the risk of crashing from all other causes (obtained from *Appendix A* of *Technical Paper No. 10 - Hazards and Risks*). *Table 7.14* provides such a comparison.

TABLE 7.14 CRASH RISK PER MOVEMENT

Flight Category	Crash risk per arrival	Crash risk per departure	Worst-case additional risk per flight (Defence Establishment Orchard Hills)	Percent increase
Low Capacity	6.36×10^{-7}	9.54×10^{-7}	8.6×10^{-9}	0.9- 1.3%
High Capacity	9.64×10^{-8}	1.07×10^{-7}	8.6×10^{-9}	8-9%
General Aviation	3.95×10^{-6}	3.95×10^{-6}	8.6×10^{-9}	0.2%

The additional crash risk per year from explosions at the Defence Establishment Orchard Hills can be calculated by multiplying the worst case additional crash risk per flight (*Table 7.14*) by the number of flights per year (*Table 7.13*) for each mode of operation. *Table 7.15* provides a comparison of this worst-case additional risk, with the risk of crashing from all other causes.

TABLE 7.15 CRASH RISK PER YEAR

Flight Operation Category	Total Risk per year	Airport Operation 1		Airport Operation 2		Airport Operation 3	
		Worst-case additional risk per year (OHDF)	% increase	Worst-case additional risk per year (OHDF)	% increase	Worst-case additional risk per year (OHDF)	% increase
Low Capacity	0.0263	5.01×10^{-6}	0.02	1.85×10^{-6}	0.01	1.06×10^{-5}	0.04
High Capacity	0.0199	1.03×10^{-4}	0.51	7.84×10^{-5}	0.39	1.32×10^{-4}	0.66
General Aviation	0.0614	6.93×10^{-6}	0.01	2.97×10^{-6}	0.00	8.52×10^{-6}	0.01
Total	**0.108**	**1.15×10^{-4}**	**0.11**	**8.32×10^{-5}**	**0.08**	**1.51×10^{-5}**	**0.14**

This analysis shows that the increase in crash risk for aircraft overflying the Defence Establishment Orchard Hills is insignificant for Badgerys Creek Option B.

8 IMPACT ASSESSMENT - BADGERYS CREEK OPTION C

8.1 PROPOSED FLIGHT PATHS

One of the parallel runways for Badgerys Creek Option C is in direct line with the south-east part of the Defence Establishment Orchard Hills area. Arrival and departure tracks have not been decided at this stage, however, a set of arrival and departure tracks were defined for each airport option in discussion with Airservices Australia to enable noise impact studies to be undertaken. The arrival and departure tracks associated with one of the parallel runways, and some departure tracks associated with the cross runway, pass over the Defence Establishment Orchard Hills.

It should be noted that the flight tracks over the Defence Establishment Orchard Hills are preliminary and have not been finalised. Actual flight tracks may differ from these. Moreover, for any flight track, a certain amount of lateral deviation from the centerline is expected. This deviation increases as a function of the distance along the track. For risk analysis, it has been assumed that aircraft could deviate by up to nine degrees on either side of the centerline. For arrival, a dispersion of three degrees on either side of the centreline was assumed.

8.2 PROPOSED NUMBER OF AIRCRAFT MOVEMENTS

Three operating modes at the airport were investigated. The cross runway is used only in Airport Operation 3, therefore, tracks D10 and D13 do not have any aircraft movements in the other two operating modes.

The annual number of aircraft movements on various tracks for the three operating modes, classified according to risk categories are shown in *Tables 8.1 to 8.3*.

TABLE 8.1 ANNUAL AIRCRAFT OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 1

Aircraft Category	D02	D03	D04	D36
Low Capacity	579	3,331	3,069	106
High Capacity - Small	1,109	162	2,388	56
High Capacity - Medium	1,377	4,716	7,007	199
High Capacity - Large	3,389	2,121	8,121	208
High Capacity - Large- Increased Fuel Load	3,838	5,676	0	145
General Aviation	779	859	1,437	47
Total	**11,071**	**16,864**	**22,021**	**761**

TABLE 8.2 ANNUAL AIRCRAFT ARRIVALS OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 1

Aircraft Category	A21	A22	A23	A24
Low Capacity	2,397	121	696	640
High Capacity - Small	1,434	231	34	499
High Capacity - Medium	4,527	287	988	1,469
High Capacity - Large	6,066	1,510	1,641	1,700
High Capacity - Large- Increased Fuel Load	0	0	0	0
General Aviation	1,107	162	181	304
Total	**15,531**	**2,312**	**3,540**	**4,611**

TABLE 8.3 ANNUAL AIRCRAFT DEPARTURES OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 2

Aircraft Category	D02	D03	D04	D36
Low Capacity	138	731	708	24
High Capacity - Small	250	19	523	12
High Capacity - Medium	319	964	1,399	41
High Capacity - Large	736	364	1,714	43
High Capacity - Large- Increased Fuel Load	844	1,042	0	29
General Aviation	180	149	226	8
Total	**2,467**	**3,270**	**4,570**	**157**

TABLE 8.4 ANNUAL AIRCRAFT ARRIVALS OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 2

Aircraft Category	A21	A22	A23	A24
Low Capacity	6,915	345	2,015	1,838
High Capacity - Small	4,163	668	107	1,446
High Capacity - Medium	13,240	824	2,892	4,316
High Capacity - Large	17,725	4,377	4,885	4,952
High Capacity - Large- Increased Fuel Load	0	0	0	0
General Aviation	3,301	467	541	918
Total	**45,344**	**6,679**	**10,440**	**13,470**

TABLE 8.5 ANNUAL AIRCRAFT DEPARTURES OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 3

Aircraft Category	D02	D03	D04	D36	D10	D13
Low Capacity	380	2,189	2,016	70	196	224
High Capacity - Small	729	107	1,569	37	64	168
High Capacity - Medium	905	3,102	4,609	131	306	477
High Capacity - Large	2,227	1,397	5,340	137	277	599
High Capacity - Large-Increased Fuel Load	2,523	3,736	0	95	478	162
General Aviation	512	565	947	31	82	115
Total	**7,276**	**11,096**	**14,481**	**500**	**1,404**	**1,746**

TABLE 8.6 ANNUAL AIRCRAFT ARRIVALS OVER DEFENCE ESTABLISHMENT ORCHARD HILLS - AIRPORT OPERATION 3

Aircraft Category	A21	A22	A23	A24
Low Capacity	3,831	193	1,111	1,023
High Capacity - Small	2,289	370	54	797
High Capacity - Medium	7,215	459	1,574	2,340
High Capacity - Large	9,669	2,411	2,606	2,711
High Capacity - Large- Increased Fuel Load	0	0	0	0
General Aviation	1757	260	287	481
Total	**24,760**	**3,693**	**5,633**	**7,351**

The description, and the rationale for the definition of risk categories is provided in *Appendix A* of *Technical Paper No. 10 - Hazards and Risks.*

8.3 INDICATIVE RANGE OF AIRCRAFT ALTITUDE ABOVE DEFENCE ESTABLISHMENT ORCHARD HILLS

The curvilinear distance of the projection of the flight track on the ground from the runway end to the boundary of the facility is shown on *Table 8.7*.

TABLE 8.7 FLIGHT DISTANCE FROM RUNWAY END TO DEFENCE ESTABLISHMENT ORCHARD HILLS BOUNDARY

Track Name	Runway End	Flight Distance along track (kilometres)
D02	Parallel North 36L	5.5
D03	Parallel North 36L	5.5
D04	Parallel North 36L	5.5
D36	Parallel North 36L	5.5
D10	Cross East 09C	15
D13	Cross West 27C	12.5
A21	Parallel South 18R	5.5
A22	Parallel South 18R	5.5
A23	Parallel South 18R	5.5
A24	Parallel South 18R	5.5

Indicative ranges of altitudes at these distances during take-off for representative aircraft within these categories are shown in *Table* 8.8.

TABLE 8.8 INDICATIVE ALTITUDE ABOVE DEFENCE ESTABLISHMENT ORCHARD HILLS FOR DEPARTING AIRCRAFT

Aircraft Category	Altitude at 5.5 kilometres (D02, D03, D04, D36)	Altitude at 12.5 kilometres (D10)	Altitude at 15 kilometres (D13)
Low Capacity	375 metres -900 metres	700 metres - 1,600 metres	900 metres - 1,800 metres
High Capacity - Small	375 metres - 900 metres	700 metres - 1,600 metres	900 metres - 1,800 metres
High Capacity - Medium	650 - 950 metres	1,400 - 2,200 metres	1,750 metres - 2,650 metres
High Capacity - Large	750 metres - 950 metres	1,400 metres - 1,900 metres	1,650 metres - 2,300 metres
High Capacity - Large-Increased Fuel Load	550 metres - 700 metres	850 metres - 1050 metres	900 metres - 1,250 metres
General Aviation	375 metres -900 metres	700 metres - 1,600 metres	900 metres - 1,800 metres

Source: Calculated from INM profiles.

At the normal glide-slope of three degrees, aircraft on arrival tracks A21, A22, A23 and A24 would be at a height of about 288 metres.

The actual height above the facilities area will differ, depending upon the type of aircraft and operating conditions. However, a significant proportion of aircraft would be at altitudes below 1,000 feet above the Facilities area.

8.4 HAZARD AND RISKS IDENTIFIED

Hazards identified in Pillar Proceeding 205.92 are examined in this section.

8.4.1 DISTRACTION

Defence personnel working with explosives could potentially become distracted by noise, if aircraft pass overhead. This could increase the possibility of an accident.

It is understood that the majority, if not all of the activities involving the handling of explosives are carried out indoors. Therefore it would be feasible to reduce noise levels inside sensitive buildings by noise insulation, if required. This could possibly reduce or eliminate this hazard.

8.4.2 ELECTROMAGNETIC RADIATION

Electromagnetic radiation could accidentally detonate electrically initiated explosive devices, leading to an explosion. Radio and radar transmissions from aircraft can affect electro-explosive devices. There is normally little risk to electro-explosive devices Installed in weapons because of the shielding provided by the casing. However electro-explosive devices removed from weapons during maintenance are susceptible for the short time they remain outside a protective shield. Removal of electro explosive devices is carried out within buildings which provide some level of protection, although they are not designed to provide complete protection.

A review by the Electrical Explosives Hazards Committee of the Australian Ordnance Council showed that even the most sensitive electro-explosive device in service is not at risk from direct exposure to the most powerful airborne emitters in civilian and military uses over the frequency spectrum from 3 megahertz to 20 gigahertz, at distances of greater than 300 feet. No allowance was made for any shielding of the electro explosive devices in these calculations (Australian Ordnance Council, 1992).

During an inspection of the Defence Establishment Orchard Hills, site personnel indicated that the human body and other objects in the vicinity can act as antennae during the handling of exposed electro explosive devices and could potentially amplify transmissions. This phenomenon has not been examined in this risk assessment.

Other fixed sources of transmissions exist at airports. These include Terminal Area Radar and other communication systems. Potential hazards to explosives from such fixed sources have not been examined in this risk assessment.

Considering the height of the aircraft above the facility, the location of flight tracks in relation to maintenance areas, and the number of aircraft movements, the risks to electro-explosive devices from aircraft operations from Badgerys Creek Option C could be significant. The risks could be reduced by instituting appropriate engineering and procedural controls.

8.4.3 AIRBORNE LASERS

Airborne lasers may be a hazard to explosives devices, however aircraft operations at the Second Sydney Airport would not present such hazards.

8.4.4 AIRCRAFT CRASHES

The assessment of risks on explosion storage areas associated with aircraft crashes requires a consideration of both the consequences and the likelihood of aircraft crashes. This is discussed in *Sections 8.5 and 8.6*.

8.4.5 HAZARDS TO AIRCRAFT

Hazards to aircraft overflying Defence Establishment Orchard Hills are discussed in *Section 8.7*.

8.5 CONSEQUENCES OF AIRCRAFT CRASHES

8.5.1 DIRECT CONSEQUENCES

The consequences of an aircraft crash at any location depend on a number of variables at the time of the accident, the most relevant of which include:

- aircraft parameters such as the size and fuel load;
- crash characteristics, such as angle of impact (steep or shallow); and
- characteristics of the crash location such as the construction of buildings and the density of buildings in the area.

Different combinations of the above factors result in different crash consequences. The consequences of aircraft crashes on general built-up areas are discussed in the Quantitative Risk Assessment Section of the main report.

Scaled impact areas for arriving and departing aircraft, where the equivalent probability of fatality is 100 percent, are summarised in *Table 8.9*. A scaled impact area is the mathematical equivalent of a larger impact area (approximately 3.33 times the scaled area for the large aircraft category) over which the average probability of fatality is about 0.3. Calculations of scaled impact areas are based on direct consequences of aircraft crash (including impact and post impact fire), but do not take into account hazards present on the ground.

TABLE 8.9 SCALED IMPACT AREAS - DEPARTING AND ARRIVING AIRCRAFT

Aircraft Category	Departing Aircraft		Arriving Aircraft	
	Steep Angle Scaled Impact Area (m^2)	Shallow Angle Scaled Impact Area (m^2)	Steep Angle Scaled Impact Area (m^2)	Shallow Angle Scaled Impact Area (m^2)
Low Capacity	2,100	3,700	2,000	2,600
High Capacity - Small	2,100	3,700	2,000	2,600
High Capacity - Medium	6,600	7,800	5,900	6,900
High Capacity - Large	16,700	28,100	16,500	25,800
High Capacity - Large-Increased Fuel Load	21,000	48,400	16,500	25,800
General Aviation	2,100	3,700	2,000	2,600

Departing aircraft generally do not crash at shallow angles at distances greater than one kilometre from an airport. Therefore, for the Defence Establishment Orchard Hills, the steep angle scaled impact areas would apply to departing aircraft.

An important feature of many Explosive Ordnance storage buildings is the traverse, or the mound around the building. This feature may provide a barrier to aircraft crash trajectories, and limit the crash impact area.

8.5.2 SECONDARY CONSEQUENCES

Explosive Ordnance present in many buildings on site could escalate the consequences of aircraft crash. The quantity of Explosive Ordnance within maintenance buildings is relatively small, therefore the secondary consequences of an aircraft crash would most likely be within the scale of the direct consequences.

Many storage buildings contain Explosive Ordnance of Hazard Division 1.1. This particular Explosive Ordnance is susceptible to ground shock, blast, flame and high velocity projectiles. It is prone to mass explosion, which means that the entire stored amount can explode virtually instantaneously. This can give rise to a blast and high and low velocity projectiles.

Explosive Ordnance of other Hazard Divisions may also be present in storage buildings. Explosive Ordnance of Hazard Division 1.2 is susceptible to blast, flame and projectiles. It causes a projection hazard but not a mass explosion hazard. That means it may explode, but the explosion would involve a few items at a time, rather than the entire stored amount.

Explosive Ordnance of Hazard Division 1.3, which can also be stored on the site, is a mass fire hazard.

Therefore direct consequences of an aircraft crashing into Explosive Ordnance storage areas include ground shocks, high velocity projectiles, and fire. The exposure of Explosive Ordnance to such effects could result in a series of explosions involving Hazard Division 1.1 and 1.2 Explosive Ordnance, consequent blasts and projectile generation, and mass fire.

The size of the direct impact areas illustrated in *Table 8.9*, shows that a number of Explosive Ordnance storage buildings could be affected by a single aircraft crash.

The severity of any explosion depends on the quantity of explosives involved. Since Hazard Division 1.1 is the only hazard division which has the potential for mass explosion, the most severe single explosion that could occur would require the entire quantity of Hazard Division 1.1 Explosive Ordnance present in the building to explode.

The maximum quantity of Hazard Division 1.1 Explosive Ordnance that is licensed to be stored in any single building on site is approximately 50,000 kilograms (TNT equivalent). Away from the direct blast area, the consequences of an explosion are determined by the overpressure wave generated. This is a pressure wave which travels away from the centre of the explosion and decreases in intensity with increasing distance. *Table 8.10* gives an indication of the potential effects of explosion overpressures.

TABLE 8.10 EFFECTS OF EXPLOSION OVERPRESSURE

Overpressure kPa	Effect
3.5	90 percent glass breakage No fatality and very low probability of injury
7	Damage to internal partitions and joinery 10 percent probability of injury. No fatality
14	House inhabitable
21	Reinforced structures distort 20 percent probability of fatality to a person in a building
35	Threshold of eardrum damage 50 percent probability of fatality to a person in a building and 15 percent probability of fatality for a person in the open
70	Complete demolition of houses 100 percent chance of fatality to a person in a building or in the open

Explosion overpressures resulting from explosions of different quantities of explosives, calculated using the TNT equivalent method, are shown in *Table 8.11*.

TABLE 8.11 OVERPRESSURE DISTANCES

TNT Equivalent	**Distance (in metres) to Overpressure values of**				
Quantity (kg)	**35 kPa**	**21 kPa**	**14 kPa**	**7 kPa**	**3.5 kPa**
1,000	55	76	98	151	233
5,000	95	130	168	259	399
10,000	119	164	211	326	502
20,000	150	207	266	410	633
30,000	172	236	305	470	725
40,000	189	260	335	517	797
50,000	204	280	361	557	859

Comparison of the direct consequence areas shown in *Table 8.9* with the explosion overpressure distances shown in *Table 8.11* indicates that the secondary consequences of an aircraft on an Explosive Ordnance storage building are likely to be more severe than the direct consequences of the crash. However, considering the location of Explosive Ordinance storage facilities in relation to the site boundaries, injuries or fatalities outside the site boundary of the Defence Establishment Orchard Hills would not be expected.

8.6 AIRCRAFT CRASH PROBABILITY ANALYSIS

8.6.1 FREQUENCY OF CRASHES

Figure 3.4 from *Appendix A* of *Technical Paper No. 10 - Hazards and Risks* show contours for the frequency of aircraft crash per square kilometre per year for Airport Operation 2. An area along the south-east boundary of the Orchard Hills site is enclosed within the 1 x 10^{-3} crashes per square kilometre per year contours. A portion of the site is within the 1 x 10^{-4} crashes per square kilometre per year contours, and the rest of the site is enclosed within the 1 x 10^{-5} crashes per square kilometre per year contours.

If it is assumed that a 1 kilometre per square area located within the 1 x 10^{-5} crashes per square kilometre per year contour is exposed to an average frequency level of 5 x 10^{-5} crashes per square kilometre per year, then the average frequency of aircraft crashes in that area would be 5 x 10^{-5} per year. Similarly, the average frequency of aircraft crashes on a 1 square kilometre area located between the 1×10^{-5} and 1×10^{-6} crashes per square kilometre per year contours would be 5×10^{-6} per year.

The approximate area of the Defence Establishment Orchard Hills that is contained within different frequency zones for the three operating modes is shown in *Table 8.12*.

TABLE 8.12 DEFENCE ESTABLISHMENT ORCHARD HILLS AREA WITHIN DIFFERENT FREQUENCY ZONES

Frequency (crashes per square kilometre per year) Zone	Approximate area of the Defence Establishment Orchard Hills within the Zone (km^2)		
	Airport Operation 1	Airport Operation 2	Airport Operation 3
$> 1 \times 10^{-3}$	0	1.6	0
$1 \times 10^{-3} > x > 1 \times 10^{-4}$	9	5	7
$1 \times 10^{-4} > x > 1 \times 10^{-5}$	6	8.4	8
$1 \times 10^{-5} > x > 1 \times 10^{-6}$	n/a	n/a	n/a

The frequencies shown in *Table 8.12* relate to all sizes of aircraft. The proportion of different aircraft sizes which make up this total frequency is calculated by taking into account the crash rate per departure movement for each risk category and the actual number of aircraft departures on tracks, and by grouping the aircraft categories according to aircraft size. The results are shown in *Table 8.13*.

TABLE 8.13 DEFENCE ESTABLISHMENT ORCHARD HILLS CRASH FREQUENCY DISTRIBUTION

Aircraft Size	Proportion of Total Frequency of Aircraft Crash in Operating Mode		
	Airport Operation 1	Airport Operation 2	Airport Operation 3
Small	84%	84%	84%
Medium	6%	6%	6%
Large	7%	9%	8%
Large - Increased Fuel Load	3%	1%	2%

8.6.2 ACCEPTABILITY OF RISK TO EXPLOSIVES

In major industrial areas, situations occur where accidents on one installation cause damage to the neighbouring installation and hence initiate further hazardous incidents - the so-called 'domino effect'. Damage can occur due to exposure to heat or explosion overpressure. For example, steel structures exposed to 23 kilowatts per square metre of heat radiation for a prolonged period can suffer thermal stresses that may cause structural failure. Similarly, a conventional building exposed to 14 kilo pascals of explosion overpressure would probably suffer serious structural damage. Thus, each type of exposure can trigger a hazardous incident.

In NSW, the criteria for risk at neighbouring property or land from a hazardous installation are that the frequency of exposure to 23 kilowatts per square metre heat radiation should not exceed 50×10^{-6} (5×10^{-5}) per year, and the frequency of exposure to 14 kilo pascals of explosion overpressure level should not exceed 50×10^{-6} (5×10^{-5}) per year.

Exposure to 23 kilowatts per square metre of heat radiation and 14 kilo pascals explosion overpressure at a total frequency of 1×10^{-4} per year is considered acceptable, provided that each component of exposure is within the 5×10^{-5} per year limit.

The above mentioned criteria are outlined here to provide information on the levels of risk that are considered acceptable in an industrial situation. Although these criteria are not strictly applicable to the situation at the Defence Establishment Orchard Hills, they provide a reference point to assist in making judgements about the acceptability of risks relating to aircraft crashes.

8.7 HAZARDS TO AIRCRAFT

8.7.1 PLANNED EXPLOSIONS

Demolition activities were suspended at the Defence Establishment Orchard Hills at the time when this report was prepared. It is understood that if such activities are resumed, only minor quantities of Explosive Ordnance (approximately 5 kilograms at a time) would be demolished, and this would only occur infrequently.

Temporary airspace restrictions have been discussed between with Airservices Australia and the Department of Defence. These restrictions would be determined using the methodology recommended in Pillar Proceeding 205.92 (AOC, 92), which takes into account both the fragment and the blast hazard to aircraft. In view of these arrangements, risks to overflying aircraft would be low.

8.7.2 ACCIDENTAL EXPLOSIONS

Aircraft flying over, or in the vicinity of an accidental explosion at the site could be affected by blast, fragments or both. Two types of assessments are relevant in this situation. The first is an assessment of risk to an aircraft each time it flies over, or is in the vicinity of the Defence Establishment Orchard

Hills, while the second is the assessment of total risk to all aircraft that fly over, or are in the vicinity of the Defence Establishment Orchard Hills.

Risk assessment requires a consideration of both the consequences of accidental explosions and the likelihood of harm to aircraft. These are discussed in *Sections 8.7.3 and 8.7.4*.

8.7.3 CONSEQUENCE ANALYSIS

The consequences of an explosion on ground for an aircraft flying overhead depend on a number of factors, including the quantity of explosives involved in the explosion and the separation between the centre of explosion and the aircraft, at the time of the explosion.

The quantity of explosives involved in an accidental explosion on site would be limited to the licensed quantity of Hazard Division 1.1 Explosive Ordnance for each particular building. Licence capability varies from building to building, with a maximum of 50,000 kilograms (TNT equivalent).

Defence trials show that occasional buffeting of aircraft is experienced at pressures exceeding 1 kilo pascals (Australian Ordnance Council, 1992). Distance in metres to tolerable occasional buffeting are calculated from the formula 112 $Q^{1/3}$, where Q is the TNT equivalent mass of explosives (in kilograms) involved in the explosion.

The minimum separation distances (D13) between explosives storage facilities and inhabited buildings are specified in OPSMAN 3 (Department of Defence, 1994). The distances in metres equal 22.2 $Q^{1/3}$, where Q is the net explosives quantity (in kilograms) of the total explosives involved in the explosion, which corresponds to a peak side-on overpressure of 5 kilo pascals.

D13 distances are also the recommended minimum separation between Explosive Ordnance storage facilities and major public transport routes. The effect on aircraft at D13 distances is not known, but effects would have to be more severe than distances of 112 $Q^{1/3}$, the distance to tolerable occasional buffeting.

Table 8.14 illustrates the distances to tolerable occasional buffeting (112 $Q^{1/3}$), and D13 distances for Hazard Division 1.1 (22.2 $Q^{1/3}$) for the range of accidental explosions at Defence Establishment Orchard Hills.

TABLE 8.14 CONSEQUENCE DISTANCES FOR EXPLOSIONS

Explosives Quantity (kg)[1,2]	Distances in metres to	
	Tolerable Occasional Buffeting	Inhabited Buildings
1,000	1,120	270
2,000	1,420	280
5,000	1,920	380
10,000	2,420	480
20,000	3,040	610
30,000	3,480	690
40,000	3,830	760
50,000	4,130	820

Notes: 1. TNT equivalent quantity in the case of 'Occasional Tolerable Buffeting'.
2. Net Explosives Quantity in the case of 'Inhabited Building' distance.

Thus, aircraft at distances greater than approximately four kilometres from the centre of the worst case explosion on site would only experience tolerable occasional buffeting. However, consequences for aircraft within four kilometres of the worst-case explosion on site could be greater than tolerable occasional buffeting, and could even include sub-lethal or lethal effects, depending upon the separation between the centre of the explosion and the aircraft at the time of explosion.

Fragments could also be projected from explosions on the ground, but fragment effects at a particular distance are somewhat different from blast wave effects. Although fragments may travel great distances, they have to hit the 'target' (aircraft in this case) for them to have an effect, unlike a blast wave which will 'hit' everything in its path. While there is a chance that a fragment may hit an aircraft, there is conversely a much greater chance that it may not hit the target. However it is difficult to determine the probability of a 'hit'.

In view of the uncertainty in both the blast and fragment effects on aircraft, a conservative approach has been adopted for this risk assessment. The preliminary analysis undertaken assumes that all explosions at the Defence Establishment Orchard Hills involve the worst-case explosives quantity of 50,000 kilograms and that aircraft within four kilometres of the centre of the Defence Establishment Orchard Hills at the time of explosion would crash. If this analysis shows that the level of risk is unacceptable, then more detailed analysis maybe justified.

8.7.4 PROBABILITY ANALYSIS

Since a blast wave travels in all directions, the space within four kilometres of the worst-case explosion on site would be a hemispheric shape of four kilometre radius, centred around the explosion site.

The flight time of a particular aircraft within the four kilometres radius hemisphere will depend upon flight parameters such as airspeed, altitude, and its flight path relative to this hemisphere. The worst-case (longest) flight time inside this space could be calculated by assuming the worst set of parameters, ie., the slowest airspeed, the lowest altitude, and the longest travel in a straight line within this hemisphere. At the slowest airspeed of 160 kilometres per hour, travelling a distance of eight kilometres, the maximum time an aircraft would spend inside the space would be three minutes. The following paragraphs discuss the probability of an explosion on ground during a three minute period.

Accidental detonation of the contents of explosives storehouses, or of explosives in other facilities, are very uncommon (Australian Ordnance Council, 1992). None of the Department of Defence staff consulted as part of this study could recall an explosion in a Department of Defence explosives storage building in Australia although a recent case in the USA was mentioned. While the frequency of such accidents is low, such an accident could occur at any storage facility, including at the Defence Establishment Orchard Hills.

An examination by Menz (Menz, 1984) concluded that civilian storage magazines explode with a frequency of between 1×10^{-4} and 1×10^{-6} per year. Other estimates have placed the figure nearer to 2.5×10^{-4} per annum. The actual mechanisms which caused such detonations are not recorded by Menz or other analysts.

The relevance and applicability of these frequencies to Defence Explosive Ordnance storage buildings is not clear. For the purpose of preliminary analysis, a frequency of 1×10^{-5} per year will be assumed. On this basis, considering that there are about 150 Explosive Ordnance storage buildings on site, the total frequency of accidental explosions at the Defence Establishment Orchard Hills would be 1.5×10^{-3} per year.

If the total frequency of accidental explosions at the Defence Establishment Orchard Hills is 1.5×10^{-3} per year, the frequency over any 3 minute period would be 8.6×10^{-9}.

Thus, in the worst-case, the risk of crash per flight over the Defence Establishment Orchard Hills due to an accidental explosion at the facilities would be 8.6×10^{-9}. This does not affect flights that do not pass directly over or within four kilometres of the facility.

The estimated annual number of aircraft movements over the Defence Establishment Orchard Hills in each operating mode is shown on *Table 8.15*.

TABLE 8.15 ANNUAL AIRCRAFT MOVEMENTS OVER THE DEFENCE ESTABLISHMENT ORCHARD HILLS

Flight Category	Airport Operation 1	Airport Operation 2	Airport Operation 3
Low Capacity	10,939	12,714	11,234
High Capacity	60,897	67,892	61,669
General Aviation	4,875	5,791	5,037
Total	**76,711**	**86,397**	**77,941**

It should be noted that the probability of more than one aircraft being present within the four kilometre radius effect zone of the Defence Establishment Orchard Hills worst-case explosion at the same time has not been evaluated in this risk assessment.

8.7.5 ACCEPTABILITY OF RISK

The acceptability of crash risk per flight from accidental explosions at the Defence Establishment Orchard Hills could be judged by comparing the additional risk in the worst-case with the risk of crashing from all other causes (obtained from *Appendix A* of *Technical Paper No. 10 - Hazards and Risks*). *Table 8.16* provides such a comparison.

TABLE 8.16 CRASH RISK PER MOVEMENT

Flight Category	Crash risk per arrival	Crash risk per departure	Worst-case additional risk per flight (Defence Establishment Orchard Hills)	% increase
Low Capacity	6.36×10^{-7}	9.54×10^{-7}	8.6×10^{-9}	0.9- 1.3%
High Capacity	9.64×10^{-8}	1.07×10^{-7}	8.6×10^{-9}	8-9%
General Aviation	3.95×10^{-6}	3.95×10^{-6}	8.6×10^{-9}	0.2%

The additional crash risk per year from explosions at the Defence Establishment Orchard Hills can be calculated by multiplying the worst case additional crash risk per flight (*Table 8.16*) by the number of flights per year (*Table 8.15*) for each mode of operation. *Table 8.17* provides a comparison of this worst-case additional risk, with the risk of crashing from all other causes.

TABLE 8.17 CRASH RISK PER YEAR

Flight Operation Category	Total Risk per year	Airport Operation 1		Airport Operation 2		Airport Operation 3	
		Worst-case additional risk per year	**% increase**	**Worst-case additional risk per year**	**% increase**	**Worst-case additional risk per year**	**% increase**
Low Capacity	0.0263	9.41×10^{-5}	0.36	1.09×10^{-4}	0.42	9.66×10^{-5}	0.37
High Capacity	0.0199	5.24×10^{-4}	2.62	5.84×10^{-4}	2.93	5.3×10^{-4}	2.66
General Aviation	0.0614	4.19×10^{-5}	0.07	4.98×10^{-5}	0.08	4.33×10^{-5}	0.07
Total	**0.108**	**6.6×10^{-4}**	**0.61**	**7.43×10^{-4}**	**0.69**	**6.7×10^{-4}**	**0.62**

This analysis shows that the increase in crash risk for aircraft overflying the Defence Establishment Orchard Hills is insignificant for Badgerys Creek Option C.

9 SUMMARY OF OPTIONS

Table 9.1 provides a summary of the proposed use of airspace above the Defence Establishment Orchard Hills and the hazards and risks arising from the three Badgerys Creek options.

TABLE 9.1 COMPARISON OF OPTIONS

Issue	Badgerys Creek Option A	Badgerys Creek Option B	Badgerys Creek Option C
Parallel runway alignment	• not in line with the Defence Establishment Orchard Hills	• not in line with the Defence Establishment Orchard Hills	• one parallel runway in line with the Defence Establishment Orchard Hills
Cross runway alignment	• n/a	• in line with the SW corner of the Defence Establishment Orchard Hills	• not in line with the Defence Establishment Orchard Hills
Flight paths over the Defence Establishment Orchard Hills	• two indirect departure flight paths from a parallel runway	• two indirect departure flight paths from a parallel runway • all arrival and most of the departure tracks from one end of the cross runway	• all arrival and departure tracks on one end of a parallel runway • two indirect departure tracks from the cross runway
Annual number of movements over the Defence Establishment Orchard Hills	• 13,300 (Airport Operation 1) • 9,700 (Airport Operation 2)	• 13,300 (Airport Operation 1) • 9,700 (Airport Operation 2) • 17,600 (Airport Operation 3)	• 76,700 (Airport Operation 1) • 86,400 (Airport Operation 2) • 78,000 (Airport Operation 3)
Altitude above the Defence Establishment Orchard Hills	• generally more than 600 metres (Airport Operation 1, Airport Operation 2)	• generally more than 600 metres (Airport Operation 1) • about 360 m for arrivals (Airport Operation 2)	• arriving aircraft about 288 m (Airport Operation 1, Airport Operation 2) • low departing aircraft about 370m (Airport Operation 3)

Issue	Badgerys Creek Option A	Badgerys Creek Option B	Badgerys Creek Option C
Risk to electro-explosive devices from aircraft		• probably low (Airport Operation 1, Airport Operation 2) • higher (Airport Operation 3)	• could be significant
Consequences of a crash at the Defence Establishment Orchard Hills	• worst-case consequences could include impact on more than one EO storage building • the entire quantity of HD 1.1 explosives in an impacted building could explode • off-site injuries or fatalities not expected		
Probability of a crash at the Defence Establishment Orchard Hills	• no area within the 10^{-3} or 10^{-4} crash per square km per year contour • 1 to 3 square km site area (NE corner) within the 10^{-4} - 10^{-5} zone • 5 to 7 square km site area (NE half) within the 10^{-5} - 10^{-6} zone • 67% probability that the crash would be of a small aircraft	• no area within the 10^{-3} or 10^{-4} crash per square km per year contour • 3 to 6 square km site area (NE and SW corners) within the 10^{-4} - 10^{-5} zone • 5 to 9 square km site area within the 10^{-5} - 10^{-6} zone • 67-82% probability that the crash would be of a small aircraft	• no area within the 10^{-3} crash per square km per year contour (Airport Operation 1, Airport Operation 2) • about 2 square km site area (SE corner) within the 10^{-3} zone (Airport Operation 2) • 5 to 9 square km site area within the 10^{-3} - 10^{-4} zone • rest of site within the 10^{-5} - 10^{-6} zone • 84% probability that a crash would be of a small aircraft
Consequence of an explosion at the Defence Establishment Orchard Hills for an overflying aircraft	• aircraft within about 4 km could be affected • consequence would depend upon aircraft separation from the centre of explosion, and could be sub-lethal or lethal		

<table>
<tr><th>Issue</th><th>Badgerys Creek Option A</th><th>Badgerys Creek Option B</th><th>Badgerys Creek Option C</th></tr>
<tr><td>Crash risk per flight due to an explosion at the Defence Establishment Orchard Hills</td><td colspan="3">• crash risk per flight due to explosions at the Defence Establishment Orchard Hills is estimated to be less than 8.6 x 10^{-9}.
• in the worst-case, this would represent an increase of about 0.2% for general aviation, up to 1.3% for low capacity, and about 9% for high capacity flights</td></tr>
<tr><td>Crash risk per year due to an explosion at the Defence Establishment Orchard Hills</td><td>• estimated to be less than 1.15 x 10^{-4} per year
• this would represent an increase of less than 0.11% to the total crash risk per year</td><td>• estimated to be less than 1.51 x 10^{-4} per year
• this would represent an increase of less than 0.14% to the total crash risk per year</td><td>• estimated to be less than 7.43 x 10^{-4} per year
• this would represent an increase of less than 0.69% to the total crash risk per year</td></tr>
</table>

It should be recognised that for all three options, some risks have not been able to be investigated, namely:

- the effects of electronic emissions from aircraft on missile maintenance activities; and
- the risk to storage and maintenance facilities from falling aircraft debris.

Other issues such as the effect of aircraft noise on people employed on potentially hazardous activities are very difficult to quantify.

These issues may require further investigation if establishment of permanent flight paths over the Defence Establishment Orchard Hills is considered.