Australian Government

Department of Infrastructure, Transport, Regional Development, Communications and the Arts

Western Sydney International (Nancy-Bird Walton) Airport – Airspace and flight path design

Draft Environmental Impact Statement

Technical paper 4: Hazard and risk

September 2023

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Terms and abbreviations

Term/abbreviation	Definition
ABS	Australian Bureau of Statistics
ACP	Airspace Change Proposal (Airservices Australia)
ALARP	As low as reasonably practicable
ANSP	Air Navigation Service Provider (Airservices Australia)
ATS	Air Traffic Services
ATSAS	Automated Thunderstorm Alert Service
ATSB	Australian Transport Safety Bureau
BoM	Bureau of Meteorology (Australia)
CASA	Civil Aviation Safety Authority (Australia)
CASR	Civil Aviation Safety Regulations (Cth, 1998)
Cth	Commonwealth of Australia
DEOH	Defence Establishment Orchard Hills
DfT	Department for Transport (United Kingdom)
DITRDCA	Department of Infrastructure, Transport, Regional Development, Communications and the Arts (Australian Government)
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPBC Act	Environment Protection and Biodiversity Conservation (Cth, 1999)
FAA	Federal Aviation Administration (United States)
FAR	Federal Aviation Regulation (United States)
FN	Frequency of events leading to N Fatalities
GA	General Aviation
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
KPA	Key Performance Area
LGA	Local Government Area
LIDAR	Light detection and ranging
MATS	Manual of Air Traffic Services
MOS	Manual of Standards (CASA (Aerodromes) Part 139)
MSA	Minimum safe altitude

Term/abbreviation	Definition
MTOW	Maximum take-off weight
MTOWA	Maximum take-off weight allowed
NASF	National Airports Safeguarding Framework
NATS	Air navigation service provider, United Kingdom
NM	Nautical mile (equivalent of 1.852 kilometres)
NSW	New South Wales (State of the Commonwealth of Australia)
NTSB	National Transportation Safety Board (United States of America)
PAAM	Plan for Aviation Airspace Management
PDF	Probability Distribution Function
PRA	Prohibited Restricted Area
PSA	Public Safety Area
PSZ	Public Safety Zone
RAAF	Royal Australian Air Force
RMO	Runway mode of operation
ROI HSA	Republic of Ireland Health and Safety Authority
RPT	Regular Public Transport (air service)
RRO	Reciprocal Runway Operations
SARPs	Standards and Recommended Practices (ICAO)
SFAISRP	So far as is reasonably practicable
SID	Standard Instrument Departure
SMS	Safety Management System
SRI	Scaled Risk Integral
STAR	Standard Instrument Arrival
TLS	Target level of safety
UK DfT	United Kingdom Department for Transport
UK HSE	United Kingdom Health and Safety Executive
VFR	Visual Flight Rules
WHMC	Wildlife Hazard and Management Committee
WSI	Western Sydney International (Nancy-Bird Walton) Airport

Executive summary

Badgerys Creek has been selected as the location of Western Sydney International (Nancy-Bird Walton) Airport (WSI). The development of this greenfield airport requires changes to the current Sydney Basin flight path network and airspace classification. Given their scale, an Environmental Impact Statement (EIS) for the proposed flight path changes is required. This technical paper sets out the findings of the assessment of hazards and risks to support that EIS.

A wide range of legislation, policy and associated guidance covering 3 distinct regulatory issues is relevant to the current review and assessment of hazards and risks; regulatory requirements specific to aviation operations; regulations relating to impacts on the environment, including natural ecosystems, people and heritage assets; broader regulations relating to the management of hazards and risks to people. The key requirements of the legislation are that risks should be as low as reasonably practicable (ALARP) and meet appropriate levels of safety.

The existing baseline is defined by the established airports, heliports, military aviation facilities, and associated flight paths in the Sydney Basin, covering the following: Sydney (Kingsford Smith) Airport, located approximately 43 kilometres (km) east of WSI; Bankstown Airport, located approximately 26 km east of WSI; Camden Airport, located approximately 17 km south of WSI, Westmead Hospital Helipads, located approximately 27 km east-northeast of WSI; Royal Australian Air Force (RAAF) Base Richmond, located approximately 31 km north of WSI, Holsworthy Military Airport, located approximately 23 km east-south-east of WSI, and The Defence Establishment Orchard Hills (DEOH) restricted area to the north of WSI. There are also enroute flight paths that cross the Sydney Basin within the existing baseline.

The assessment of hazards and risks that supports the airspace design process follows a well-established risk assessment methodology including the following key steps: hazard identification; risk characterization, including likelihood and consequence assessment; risk evaluation by reference to objective criteria; and identification of mitigation options. The relevant hazards are varied, covering causal factors and specific incident scenarios as follows: airspace conflicts; off-airport aircraft crash risks to people and critical infrastructure; aircraft fuel jettisoning; objects falling from aircraft; aircraft wake vortex strikes; local meteorological hazards, and; bird and bat strike hazards.

Main findings

Facilitated changes

Airspace changes will be required prior to the opening of WSI in 2026 to support the implementation of the preliminary airspace design. These changes are not the primary subject of the approval currently under consideration, but the EIS is required to assess the significance of their potential impacts. Hazards and risks associated with them are addressed by the risk assessment and management activities that apply generally, as described further in the following section on airspace conflicts and system operability. The facilitated changes can therefore be expected to meet the key goals of operational safety risks being ALARP and achieving an acceptable level of safety.

Airspace conflicts and system operability

The operation of WSI will introduce new flights into a busy and already complex Sydney Basin airspace structure. The design process that has been followed can be expected to provide a revised airspace design that meets operational needs and Safety by Design principles, as well as the key goals of being ALARP and achieving an acceptable level of safety, due to the following key features: the design is delivered within a regulatory framework in which the safety of air navigation is regarded as the most important consideration and management systems are in place to ensure that such a commitment is met; the design is underpinned by defined goals established at the outset that all risks will be managed to be ALARP and that any residual risk will be acceptable; the design is further underpinned by 2 design principles supporting inherent safety: systemic separation of aircraft and air traffic controller workload minimisation; the selection of the preferred concept option has followed a rigorous process which can be expected to deliver an optimum solution within the inherent constraints of the existing operational requirements that is safer by design; continued attention to hazard identification and risk mitigation during the remainder of the design process and ongoing safety performance monitoring post-implementation should provide further mitigation of any residual risks.

Third party and infrastructure risk impacts assessment

Quantitative risk assessment using an empirical crash risk model informed by the historical accident record demonstrates that the risks associated with single runway (05/23) operations at WSI as it approaches capacity in 2055 can be expected to be low and within acceptable levels. For the most part, residential and other properties are subject to individual risks that are below the level of a one in a million per annum fatality risk that is normally considered to be negligible in the context of the regulation of public safety. These generally low levels of risk reflect the siting of the single runway (05/23) and associated flight paths within the proposed airspace design which limits the extent to which areas of development are overflown. A few properties are estimated to be subject to individual fatality risks in excess of 1 in 1,000,000 per annum. On that basis, the risks cannot be considered to be entirely trivial but they are nevertheless identified as “slight” and, given the constraints associated with runway and flight path siting, these risk levels can be considered to be ALARP. Similar conclusions are reached on the basis of the societal risk estimates. The scope for further mitigation of this risk, for example by choice of the future runway mode of operation, is found to be limited.

Various scenarios for aircraft crashes into infrastructure have been identified, for example involving transport links, hospitals, DEOH, the Warragamba dam, Lake Burragorang and Prospect Reservoir. The typical event frequencies and scale of fatalities associated with these events are consistent with risks that would be considered acceptable when assessed against the societal risk criteria that have been employed more generally to evaluate the significance of third-party fatality risks.

Fuel jettisoning (dumping)

Fuel jettisoning (dumping) is an uncommon requirement that has no impacts at ground level if carried out in accordance with appropriate procedures (specifically the Manual of Air Traffic Services (MATS) Section 4.2.11 – Fuel Dumping), as has always been the case historically in Australia. There are limited occurrences only of impacts at ground level associated with fuel jettisoning in the wider international incident record, confirming that this is a very small risk indeed, including for future WSI operations, provided that established procedures are followed.

Objects falling from aircraft

Occurrences involving objects falling from aircraft are uncommon and typically involve small objects with limited hazard potential. Taking account of the relative size of the objects concerned and frequency of these occurrences compared with aircraft crashes, it may readily be concluded that the risks to people and sites on the ground are very small compared with the risks associated with aircraft crashes and hence can similarly be considered to be low and acceptable.

Wake vortex damage impacts

Vortex damage incidents are confined to a relatively small area close to approach paths near the ends of landing runways used by large aircraft. Damage is generally confined to the lifting of small-format roofing elements, such as tiles and slates. The number of properties located in areas where vortex damage may occur is very limited indeed. Accordingly, risks of wake vortex damage due to operations at WSI in practice are determined to be negligible and will be adequately mitigated by the compensation scheme operated by Airservices Australia.

Meteorological hazards

The most significant weather-related near-airport meteorological hazard is identified as turbulence and windshear. The severity of the consequences of these occurrences is normally relatively limited since the aircraft types operating at WSI can normally be expected to be resilient to this hazard which can be further mitigated by improved forecasting. It has been recommended that an Automated Thunderstorm Alert Service (ATSAS) should be implemented to provide improved thunderstorm forecasting and that consideration should be given to implementation of a Doppler LIDAR to support the identification of turbulence and wind shear, subject to the conclusions of an appropriate cost-benefit study.

Wildlife hazards

The general and WSI site-specific characteristics of wildlife hazards to aircraft operations have been comprehensively described in Technical paper 5: Wildlife strike risk. That study concluded that wildlife strike risk mitigation for WSI providing an acceptable level of safety is achievable, provided that an appropriate site-specific wildlife management program is implemented.

Facilitated impacts

Operating the new airport will require changes to the current Sydney Basin airspace through the introduction of a new controlled airspace volume and flight paths. Additional routes and flights will be introduced into what is already busy airspace serving the Sydney Basin with potential impacts on the existing operations. The process that has been described above in relation to airspace conflicts seeks to implement the required changes in a manner that ensures that an appropriate level of safety is achieved throughout the revised airspace.

Cumulative impacts

There are no significant cumulative impacts. Baseline risks, such as third-party risks that are of more particular potential concern, are generally focused in the vicinity of existing aviation facilities and associated flight paths and airspace and can be considered acceptable. Additional risks associated with WSI operations are focused elsewhere in its more immediate vicinity. Overall, the project will introduce new potentially significantly elevated crash risks only into areas that are currently subject to entirely negligible risk from existing operations. It will introduce no more than a trivial additional crash risk into areas that are currently subject to potentially significant risk from existing operations. The cumulative risk impacts can therefore be regarded to be trivial and acceptable.

Mitigations

In general, risks are mitigated by established operational measures supporting safe air traffic control and the design process that is expected to deliver an inherently safe design. Third party risks are effectively mitigated by the location of the runway and associated flightpaths which limits exposure to these risks and is further mitigated by the mode of operation. Local meteorological hazards and local bird and bat strike hazards will be mitigated by the specific measures identified above.

Conclusion

Operations at WSI and the associated airspace in the Sydney Basin are being introduced within a well-established regulatory and management framework that places the utmost importance on safety, underpinned by key requirements that risks should be ALARP and meet appropriate levels of safety. Assessment of the residual risks associated with WSI operations indicate that those key requirements will be met.

Chapter 1 Introduction

This chapter provides an overview of the proposed airspace and flight path design for the Western Sydney International (Nancy-Bird Walton) Airport (WSI). This includes the background to WSI and its accompanying airspace and flight path design (the project) which impacts on the existing Sydney Basin airspace. It describes the key features and objectives of the project and identifies the purpose and structure of this this technical paper.

1.1 Western Sydney International (Nancy-Bird Walton) Airport

1.1.1 Background

In 2016, the then Australian Minister for Urban Infrastructure approved development for a new airport for Western Sydney, now known as the Western Sydney International (Nancy-Bird Walton) Airport (WSI), under the *Airports Act 1996* (Commonwealth). The site of the new airport (the Airport Site) covers approximately 1,780 hectares (ha) at Badgerys Creek, as shown in Figure 1.1. The Airport Site is located within the Liverpool local government area (LGA).

Following the finalisation of the *Western Sydney Airport – Environmental Impact Statement* (2016 EIS), the Western Sydney Airport – Airport Plan (Airport Plan) was approved in December 2016. The Airport Plan authorised the construction and operation of the Stage 1 Development. It also set the requirements for the further development and assessment of the preliminary airspace design for WSI. The Australian Government has committed to developing and delivering WSI by the end of 2026.

The 2016 approval provided for the on-ground development of Stage 1 Development of WSI (a single runway and terminal facility capable of initially handling up to 10 million passengers per year) utilising indicative 'proof of concept' flight paths. These flight paths, presented in the 2016 EIS demonstrated that WSI could operate safely and efficiently in the Sydney Basin. WSI will be a 24-hour international airport and will:

- cater for ongoing growth in demand for air travel, particularly in the rapidly expanding Western Sydney region, as well as providing additional aviation capacity in the Sydney region more broadly
- provide a more accessible and convenient international and domestic airport facility for the large and growing population of Western Sydney
- provide long term economic and employment opportunities in the surrounding area
- accelerate the development of critical infrastructure and urban development.

The Australian Government has committed to developing and delivering WSI by the end of 2026.

The design and assessment process for the next phase of the airspace design (referred to as the preliminary airspace design) was set by Condition 16 of the Airport Plan. This included the future airspace design principles and the establishment of an Expert Steering Group. Key to these design principles was the need to minimise the impact on the community and other airspace users while maximising safety, efficiency and capacity of WSI and the Sydney Basin airspace. The airspace design must also meet the requirements of Airservices Australia and civil aviation safety regulatory standards.

Led by the Australian Government Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA), the Expert Steering Group has developed the preliminary flight paths and airspace arrangements for WSI (the project). The preliminary airspace design is the subject of the Draft EIS and this assessment on the impacts to human health.

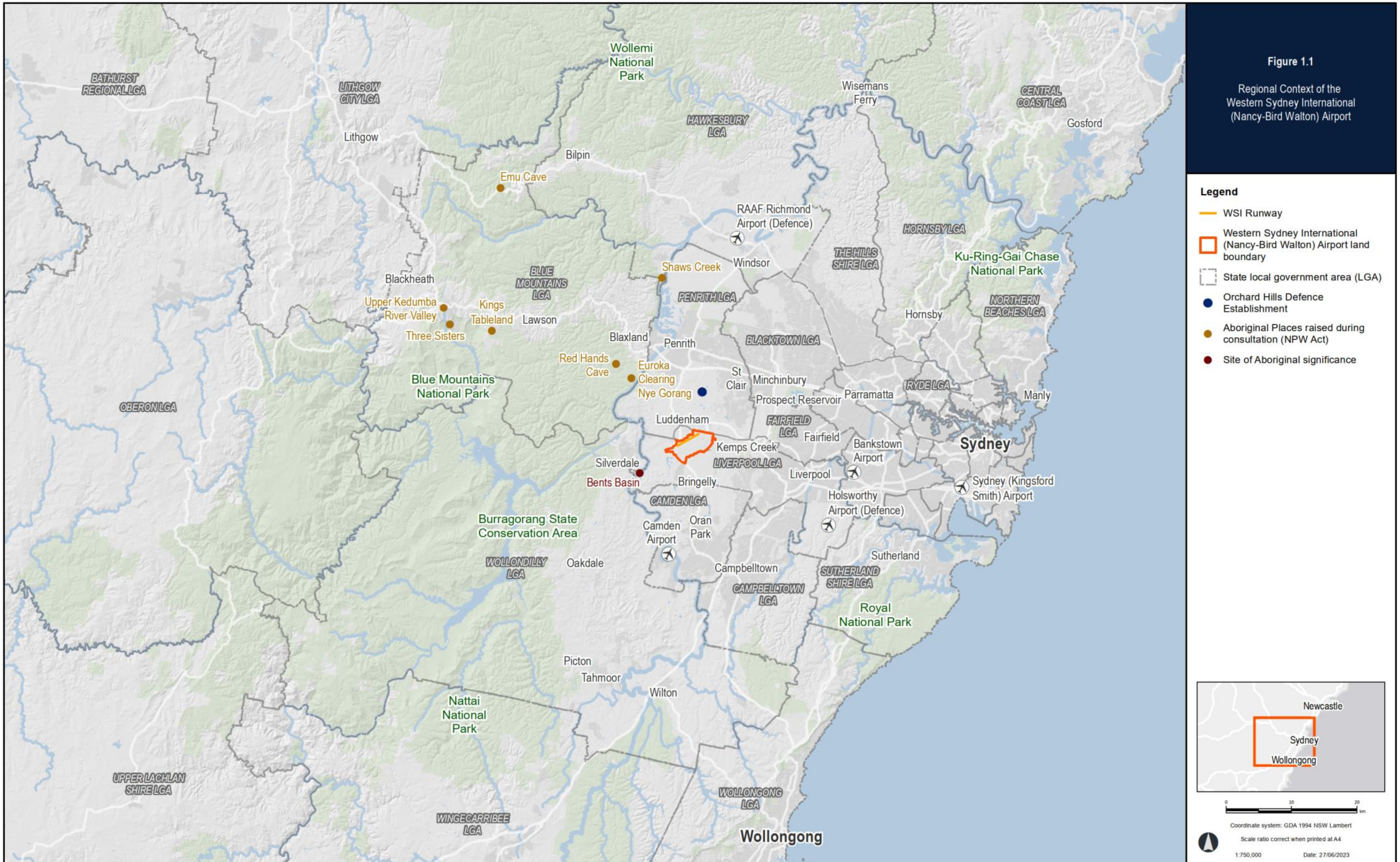


Figure 1.1

Regional Context of the Western Sydney International (Nancy-Bird Walton) Airport

Data sources: - DITRDC, DCS, Geoscience Australia
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Airbus,USGS,NGA,NASA,CGIAR,NCEAS,NLS,OS,NMA,Geodatastyrelsen,GSA,GSI and the GIS User Community

1.1.2 The Airport

1.1.2.1 Stage 1 Development

The Stage 1 Development of WSI has been approved and is limited to single runway operations. It will handle up to 10 million annual passengers and around 81,000 air traffic movements per year by 2033 including freight operations (a movement being a single aircraft arrival or departure). Single runway operations are expected to reach capacity at around 37 million annual passengers and around 226,000 air traffic movements per year in 2055.

The approval provides for the construction of the aerodrome (including the single runway), terminal and landside layout and facilities, and ground infrastructure such as the instrument landing systems and high intensity approach lighting arrays. Construction of the Stage 1 Development commenced in 2018. Figure 1.2 shows location of the single runway within the Airport Site.

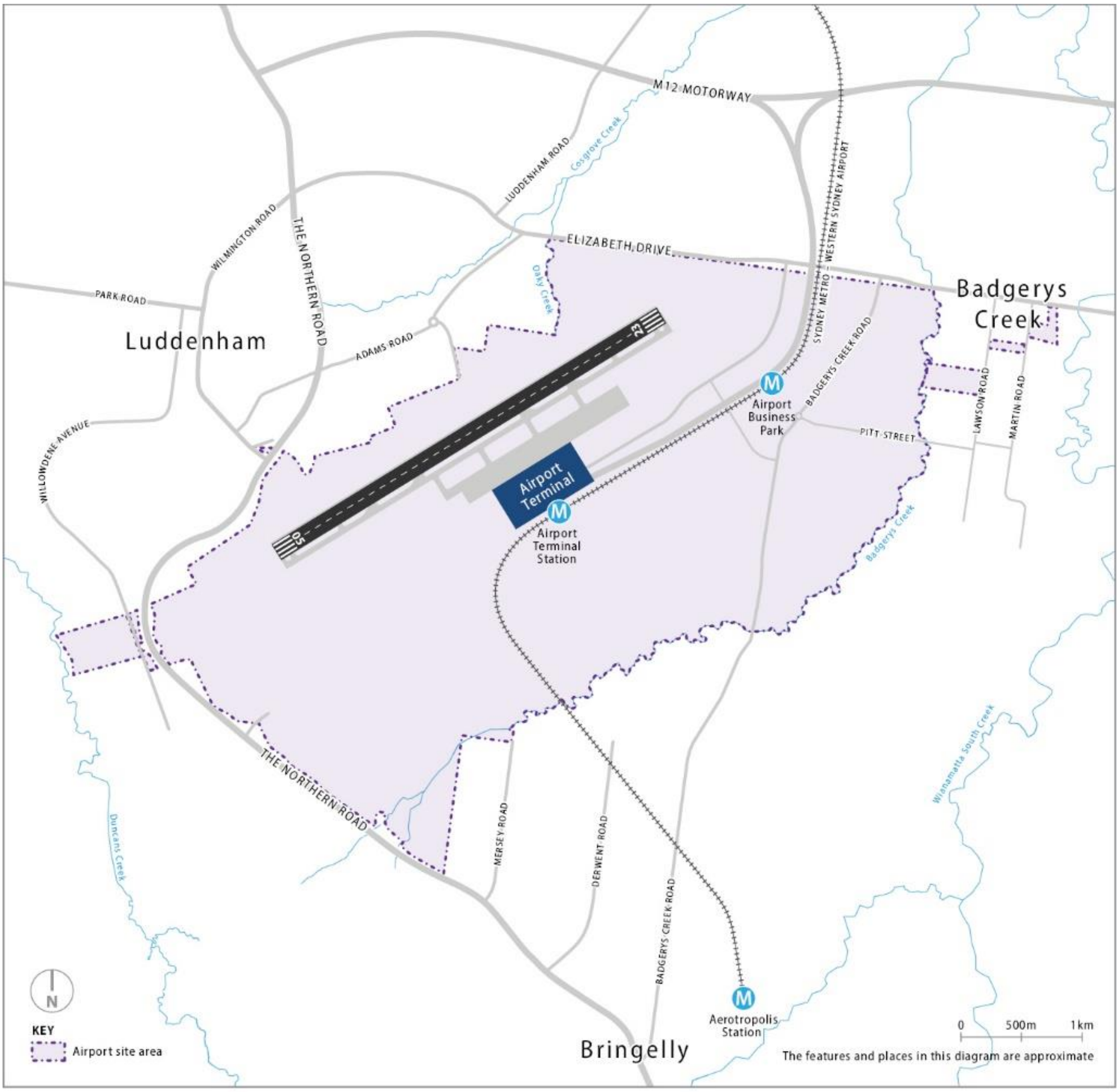


Figure 1.2 Western Sydney International Stage 1 Development

1.2 The project

The project consists of the development and implementation of proposed flight paths and a new controlled airspace volume for single runway operations at WSI. The project also includes the associated air traffic control and noise abatement procedures for eventual use by civil, commercial passenger and freight aircraft. The airspace and flight paths would be managed by the Air Navigation Services Provider (ANSP), Airservices Australia.

The project involves flight paths for all-weather operations on Runway 05 and Runway 23 during the day (5:30 am to 11 pm) and night (11 pm to 5:30 am), as well as head-to-head Reciprocal Runway Operations (RRO) during night-time periods (when meteorological conditions and low flight demand permit) to minimise the number of residences subjected to potential noise disturbance.

The flight paths differ during the day and night. Flight paths at night differ to take advantage of the additional airspace capacity offered when the curfew for Sydney (Kingsford Smith) Airport is in force. The proposed flight paths are depicted in Figure 1.3 to Figure 1.7.

The project does not include any physical infrastructure or construction work.

1.2.1 Objectives of the project

The overall objectives for WSI are to:

- improve access to aviation services for Western Sydney
- resolve the long-term aviation capacity constraints in the Sydney Basin
- maximise the economic benefit for Australia by maximising the value of the Airport as a national asset
- optimise the benefit of WSI for employment and investment in Western Sydney
- deliver sound financial, environmental and social outcomes for the Australian community.

The project will assist in achieving these overall objectives as it would enable single runway operations to commence at WSI through the introduction of new flight paths and a new controlled airspace volume.

The Western Sydney Airport Plan sets out 12 airspace design principles that the design process is required to follow. The principles were informed by and reflect community and industry feedback on the 2016 EIS. The principles seek to maximise safety, efficiency and capacity, while minimising impacts on the community and the environment. For further information on the airspace design principles refer to Chapter 6 (Project development and alternatives) of the Draft EIS.

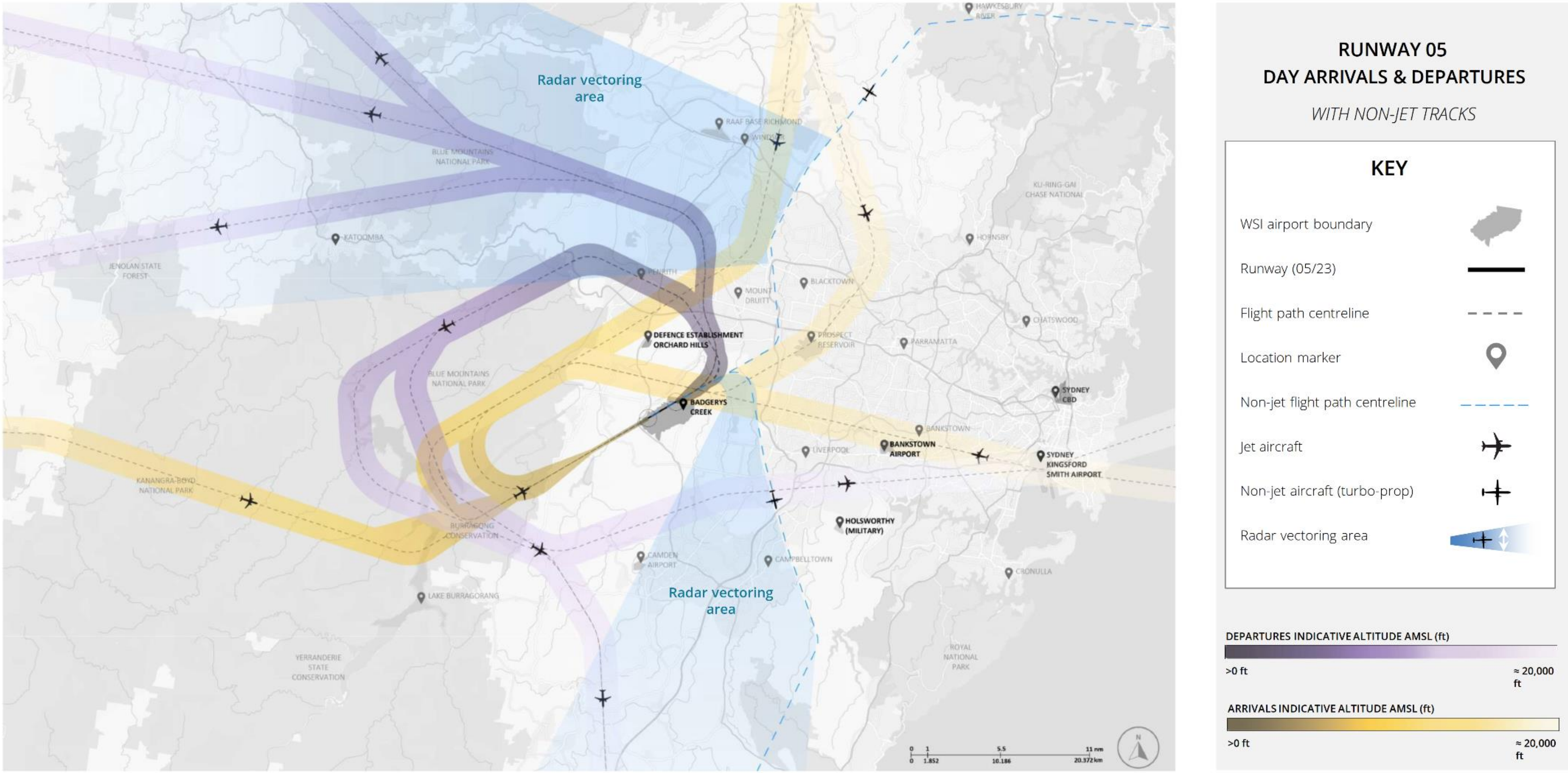


Figure 1.3 Proposed flight paths for Runway 05 (day)

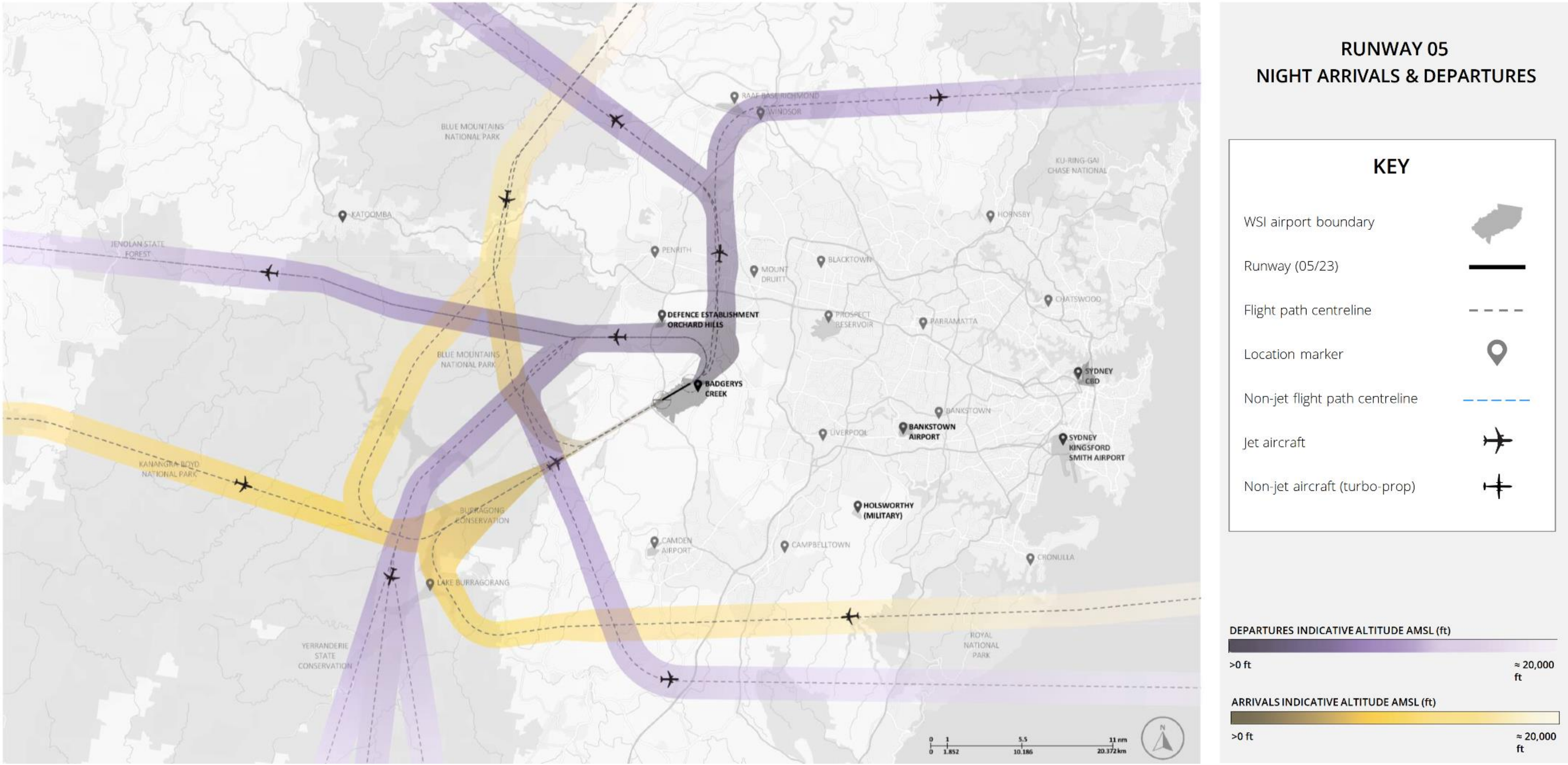


Figure 1.4 Proposed flight paths for Runway 05 (night)

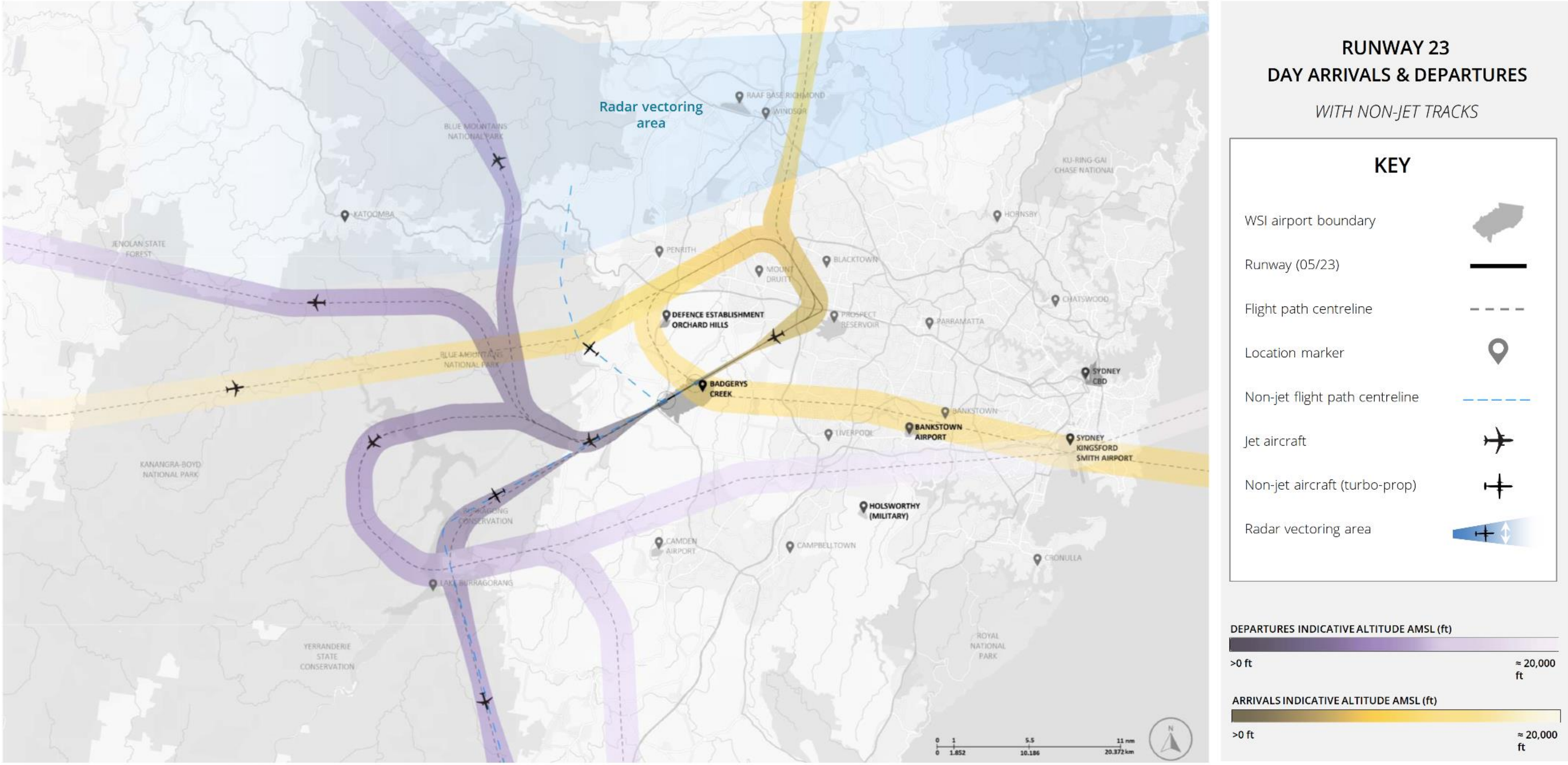


Figure 1.5 Proposed flight paths for Runway 23 (day)

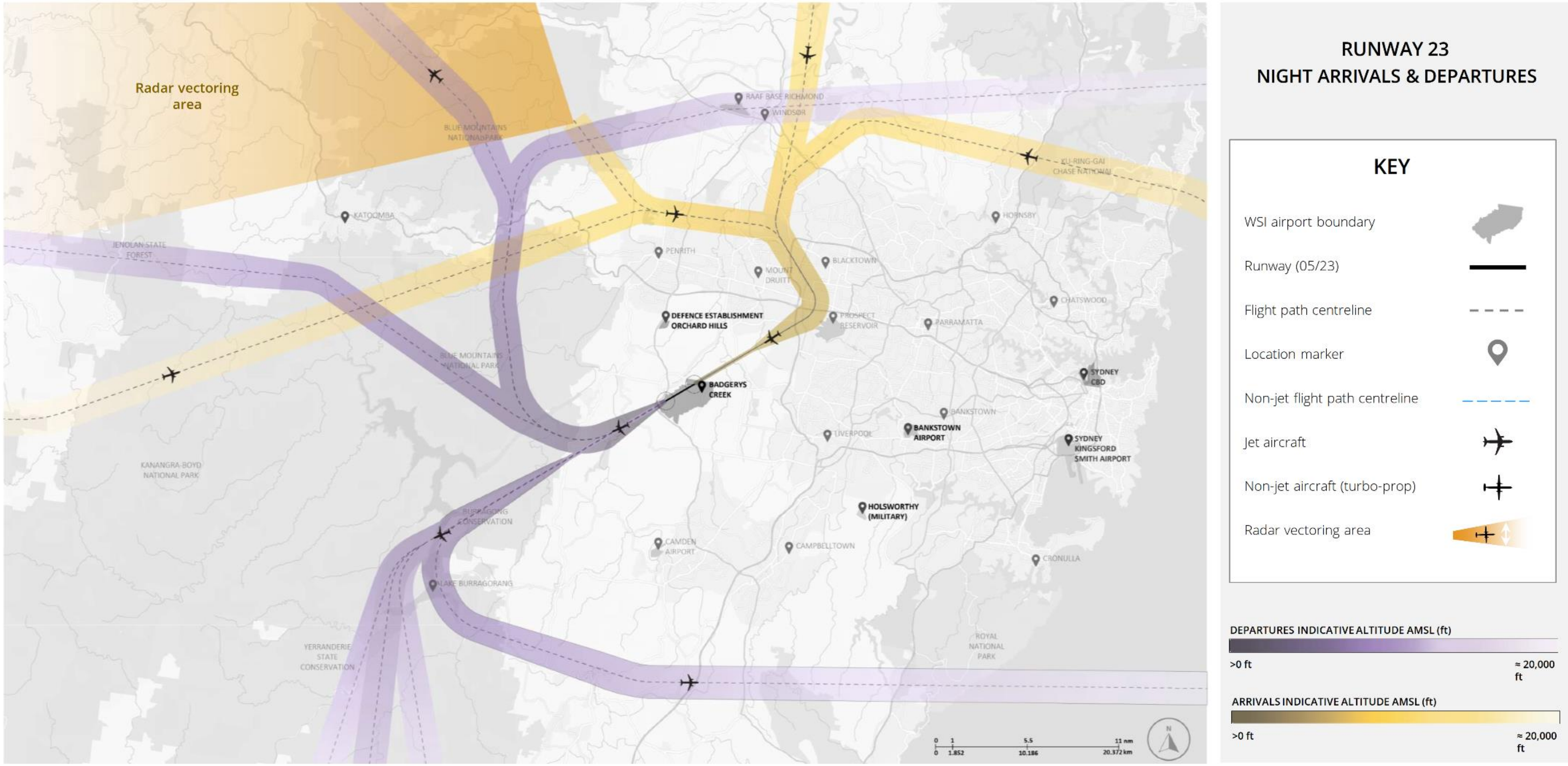


Figure 1.6 Proposed flight paths for Runway 23 (night)

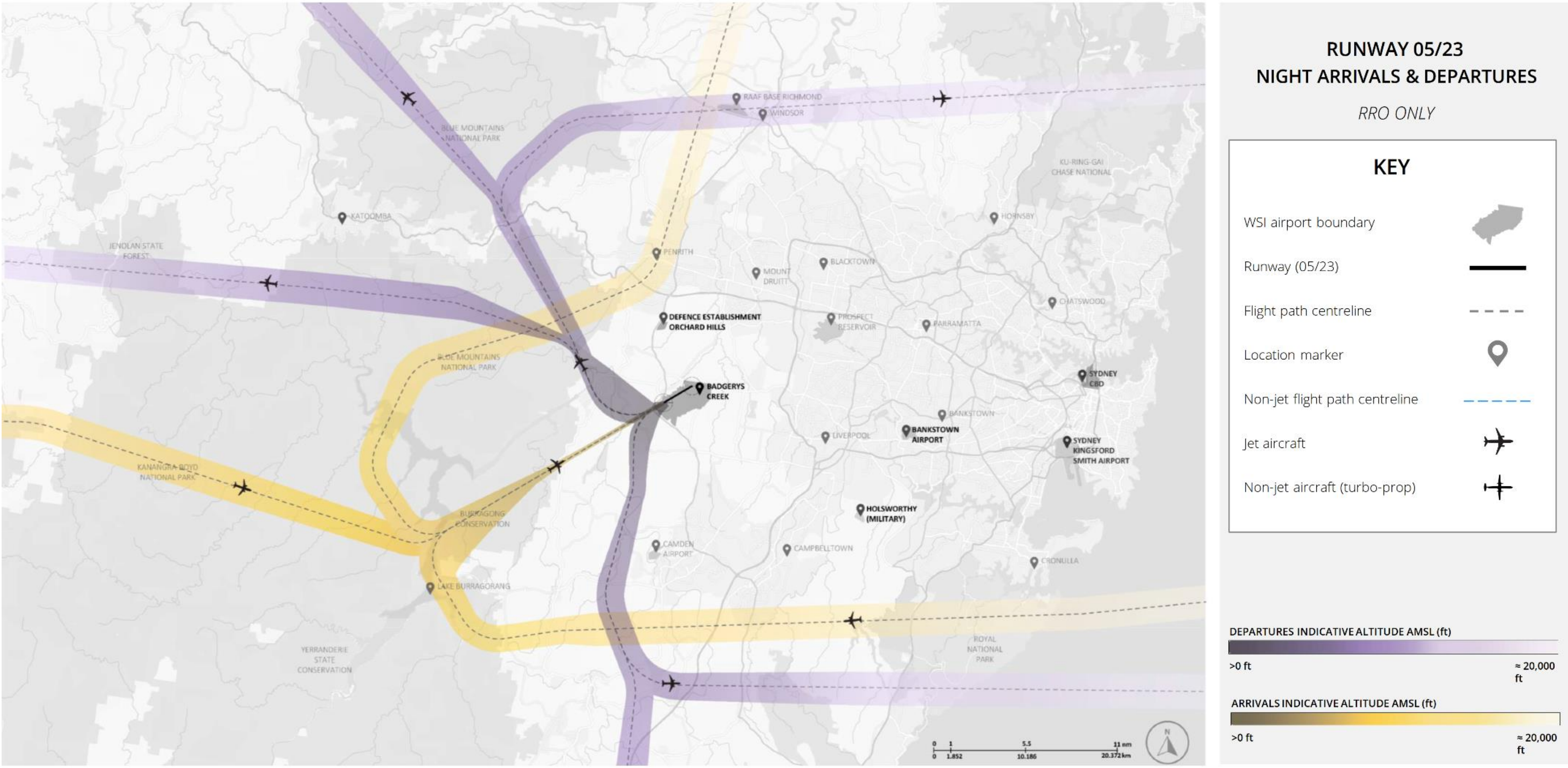


Figure 1.7 Proposed flight paths for Runway 05/23 (night)

1.3 Purpose of this technical paper

This aircraft hazard and risk assessment has been prepared as part of the Draft EIS to document the process for and outcomes of the consideration of its hazard and risk impacts. Its purpose is to demonstrate that the proposed airspace to support the operation of WSI achieves an acceptable level of safety when it first becomes operational in late 2026. In this context, achievement of an acceptable level of safety means that any risks that may be associated with airspace operation have been minimised, so far as is reasonably practicable (SFAIRP), and that any residual risks are sufficiently small to be considered acceptable in return for the benefits associated with the activities giving rise to them. The term 'so far as is reasonably practicable' is used in defining an obligation under the relevant safety legislation, whereas in related guidance and in the practical implementation of this legislation reference is often made to a requirement that risks are managed to be 'as low as reasonably practicable'. In general, the terms 'so far as reasonably practicable' and 'as low as reasonably practicable' are synonymous, and the latter term was employed in the remainder of this chapter, pursuant to its use in safety documentation supporting the design process.

First and foremost, the assessment seeks to provide an account of how ”Safety by Design” principles have been considered in the development of the proposed airspace arrangements and flight paths to ensure that the above ALARP requirements have been met. Notwithstanding the implementation of those principles, some residual risks will arise. Drawing on the extensive hazard and risk identification exercises and assessments have been undertaken to support previous studies of the risk impacts of WSI and wider experience a comprehensive and varied list of relevant hazard issues that merit attention has been identified, comprising several causal factors for potential hazards and specific incident scenarios (e.g., bat and bird strike and mid-air collision with other aircraft) and potential event consequences associated with aircraft accidents across the wider environment, including in particular risk to third parties in the vicinity of WSI and its associated airspace. These varied risk factors and scenarios have been systematically assessed to demonstrate that any residual risks are small and can be considered acceptable in return for the benefits arising from the future operation of WSI.

There is a requirement to address hazards and risks as part of the EIS. Many activities supporting modern society carry some level of risk and these risks cannot be eliminated entirely by any amount of attention to safety. These risks may be tolerated in return for the benefits associated with them. Striking an appropriate balance between risks and benefits is the subject of considerable regulatory attention which seeks to ensure that risks are managed to be ALARP and that any residual risk will be small and justified by the level of benefits associated with the activity giving rise to the risk.

The above considerations apply to the aviation sector and, whilst aircraft accidents are relatively rare events, those that do occur take place predominantly during landing and take-off and are more concentrated along flight paths and close to both runway ends. It is therefore appropriate to give particular attention to these hazards and risks when considering the siting of new runway facilities and the associated flight paths. In that context, consideration of 2 distinct aspects of hazard and risk is now required:

1. Review of potential hazards associated with the site-specific environment within which the new facility is to be located and assurance that these are identified and appropriately managed, as far as practical by design.
2. Assessment of any residual risks to people and other components of the environment and assurance that these risks are acceptable, given the benefits associated with the proposed new runway facility.

An overall account of hazards and risks associated with the project has previously been provided in the 2016 EIS (Commonwealth of Australia 2016). That account and the consideration of hazards and risks during the earlier stages of the design process was supported by a detailed hazard and risk review (r2a Due Diligence Engineers 2016). This document builds on this previous work, focusing on hazards associated with airborne aircraft outside the airport boundary and having regard to the design of the proposed airspace supporting the proposed operation of WSI. It considers the following:

- airspace conflicts between aircraft and potential threats to safe inter-operability associated with the introduction of additional flight operations into the existing Sydney Basin airspace (Chapter 6)
- risks to people living, working or otherwise congregating in areas that may be subject to potential risks from aircraft crashes (third party risk) (Chapter 7)
- risks to critical infrastructure from aircraft crashes (Chapter 7)
- aircraft jettisoning of fuel and potential contamination events (Section 8.1)
- objects falling from aircraft (Section 8.2)
- aircraft wake vortex strikes (Section 8.3)
- local meteorological hazards (Section 8.4).

Given the overall context of this assessment, safe inter-operability of the Sydney Basin airspace is of primary importance and so is considered first. Given the potential scale of the consequences of an aircraft crash, this hazard is seen as being of primary importance and is therefore considered next. The treatment of these 2 primary issues is followed by the assessment of various secondary hazard and risk issues, comprising a mixture of potential adverse impacts and casual factors that may contribute to the level of risk.

1.3.1 Assessment requirements

The project was referred to the Minister for the Environment (EPBC 2022/9143) in accordance with Section 161 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Cth) and Condition 16 of the Airport Plan. In response, the delegate for the Minister for the Environment determined that an EIS would be required and the EIS Guidelines were issued on 26 April 2022 (EIS Guidelines).

This technical paper has been prepared to address the requirements related to aircraft hazard and risk outlined in Table 1.1.

Table 1.1 Summary of Minister's EIS Guidelines (EPBC 2022/9143)

EIS Guidelines reference	Information required	Location in this technical paper
6.0 – Description of the environment	The EIS must include a description of the environment, land uses and character of the proposal site and the surrounding areas that may be affected by the action.	Section 1.4 and Chapter 4
7.1 – Describe and assess relevant Impacts	The EIS must include a description of all the relevant impacts of the action (including direct, indirect, facilitated and cumulative), including the magnitude, duration and frequency of the impacts.	Chapters 6, 7 and 8
7.4 – People and communities	Detailed assessment of impacts that the proposed action may facilitate on people and communities. Including, but not limited to: • an assessment of any identified risks to people and communities associated with the proposed action.	Chapter 7 and Section 8.2
8.0 – Proposed safeguards and mitigation measures	The EIS must provide information on proposed safeguards and mitigation measures to deal with the relevant impacts of the action.	Chapter 11

1.4 Study area

The existing baseline is defined primarily by the various established airports, heliports, military aviation facilities, and associated flight paths in the Sydney Basin. This baseline comprises the following facilities:

- **Sydney (Kingsford Smith) Airport**, located approximately 43 kilometres (km) east of WSI, handling predominantly scheduled Regular Public Transport (RPT) and some air freight transport services with more than 345,000 movements per annum reported in 2019 (BITRE Air Traffic Data).
- **Bankstown Airport,** located approximately 26 km east of WSI, handling a range of general aviation (GA), charter and flying training services with around 250,000 movements per annum. Aircraft flight operations primarily involve single-engine and twin-engine piston aircraft (circa. 80 per cent), some helicopter aircraft (circa. 15 per cent) and a smaller number of turbo-prop and jet aircraft (circa. 5 per cent).
- **Camden Airport,** a relatively busy GA facility, located approximately 17 km south of WSI, handling just over 100,000 movements per annum. Aircraft flight operations involve recreational gliders, powered fixed-wing, and helicopter aircraft.
- **Westmead Hospital Helipads,** located approximately 27 km east-north-east of WSI, comprising 3 separate roof top helipads and a ground support base landing site.
- **Royal Australian Air Force (RAAF) Base Richmond**, located approximately 31 km north of WSI, from which C-130 Hercules medium transport aircraft operate.
- **Holsworthy Military Airport**, located approximately 23 km east-south-east of WSI.
- **Defence Establishment Orchard Hills** restricted area to the north of WSI.

In addition to flight operations to and from these facilities, there are enroute flight paths that cross the Sydney Basin and a few restricted areas and danger areas over which flying is restricted within the Sydney Basin. These operations set the overall current baseline risk to people and other environmental components from an aircraft crash or other incidents in the Sydney Basin airspace. It may be noted that the civilian facilities are located relatively close to areas of urban development. Flight paths associated with the earlier phases of climb during departure and the latter stages of approach to landing pass above some areas of relatively dense urban development at distances that are relatively close to each runway end. In contrast, the vicinity of the Badgerys Creek site is more sparsely developed and areas beneath runway-aligned flight paths employed earlier during departure and later in the approach are generally devoid of any development out to distances of several kilometres from each runway end. The implications of the proximity of existing flight paths to urban development for the current risk profile of operations across the Sydney Basin is considered further in Chapter 10 in the context of cumulative impacts.

As well as defining the baseline risk to people and other potential receptors, the above facilities represent a set of constraints on the airspace design servicing WSI. Furthermore, the above facilities are relevant considerations in respect of inter-operability issues and potential threats to operational safety associated with conflicts between the current requirements and the new requirements associated with WSI for the aviation infrastructure in the Sydney Basin.

Chapter 2 Legislation and strategic context

This chapter provides an overview of the broader policies, legislation and strategies relevant to the project and considered in this technical paper.

2.1 Outline of relevant regulatory elements

Legislation and associated guidance covering 3 distinct regulatory issues is relevant to the current review and assessment:

- regulatory requirements specific to aviation
- regulations relating to impacts on the environment, including natural ecosystems, people and heritage assets, and
- broader regulations relating to the management of hazards and risks to people.

These relevant aspects of the legislation have already been outlined in the 2016 WSI EIS (Commonwealth of Australia 2016, r2a Due Diligence Engineers 2016) and all the detail is not repeated here. A summary of the main points of relevance to the airspace EIS is set out below, addressing the regulation of aviation, environmental protection and hazard and risk in turn. Consideration has then been given to the more specific prescriptions relating to risks to people living, working or otherwise present in locations potentially exposed to the aircraft crash hazard.

2.2 Aviation legislation

The primary legislation relating to aviation safety in Australia is set by the Australian Government and is overseen by the Civil Aviation Safety Authority (CASA). Requirements relating to the safety of all aspects of civil aviation are set out in the *Civil Aviation Safety Regulations 1998* (CASRs), made under the *Civil Aviation Act 1988* (Cth). The CASRs implement the standards and recommended practices (SARPs) of the International Civil Aviation Organization (ICAO), a specialised agency of the United Nations (UN), which regulates and supports international civil aviation worldwide and are closely aligned with the Federal Aviation Regulations (FAR) of the United States of America (USA).

As a contracting State under the 1944 Convention on International Civil Aviation (also known as the Chicago Convention), Australia has an obligation to adopt these ICAO standards. Licensing of aerodromes in accordance with these technical standards ensures that airports such as WSI provide safe environments for the operation of the types of aircraft that they are intended to serve. Further regulations apply to the operation of aircraft and to air traffic management services to ensure that all elements of the system provide for safe and efficient air transport.

The ICAO regulatory framework, as implemented in Australia, is largely dependent upon well-defined technical standards and guidance, for example including: detailed geometrical and other specifications for the physical characteristics of airports to provide a safe operating environment in their vicinity (ICAO 2018a, CASA 2020a); criteria for flight instrument design defining comprehensive vertical and lateral clearance margins supporting the design of safe operating procedures (ICAO 2018b, ICAO 2020); requirements for aircraft flight operations, covering performance operating limitations; aeroplane instruments, equipment and flight documents; aeroplane communication and navigation equipment; aeroplane maintenance; flight crew; etc (ICAO 2018c, CASA 2020b). Operating experience over many years demonstrates that these technical prescriptions provide high standards of aviation safety.

Over and above compliance with these prescriptive standards, there has been an increasing move over the past 25 years or so to supplement the technical prescriptions of the standards with the use of an objectives-based approach to the provision of aviation safety, underpinned by risk assessment and the ALARP principle that was initially developed across other industry sectors over a much longer period. For example, airport operators are subject to a licensing regime under which they are required to operate a safety management system (ICAO 2018a). Specifically, air traffic service providers are subject to a regulatory requirement (ICAO 2018d, CASA 2020c) that *"any significant safety-related change to the ATS [Air Traffic Services] … shall only be effected after a safety risk assessment has demonstrated that an acceptable level of safety will be met and users have been consulted."* It is not sufficient to rely on compliance with technical standards prescribed by the regulatory authorities alone. Those responsible for designing and operating the system, who should be best placed to address the individual, case-specific safety issues associated with it, must take steps to optimise safety. These broad requirements for the conduct of risk assessment to support the provision of aircraft safety in the context of safety management systems operated by air transport service providers are supported by more detailed guidance (ICAO 2018e, CASA 2014, CASA 2022) covering, hazard identification, the characterisation of risk in terms of likelihood and the severity of consequences, risk mitigation and the evaluation of risk significance and acceptability.

Whilst the safety framework identified above is intended primarily to provide for the safety of aircraft and their occupants, it will also support the safety of those living and working in the vicinity of airports by ensuring that aircraft crashes are very rare events. Nevertheless, as has already been noted above, although aircraft crashes are uncommon, the majority occur along flight paths and close to the runway ends where the crash risk is more concentrated, as demonstrated by the detailed technical analysis that underpins the models employed to support the assessment of crash risk described later in Section 3.1.3.

Whilst the ICAO technical specifications for the physical characteristics of aerodromes provide a safe operating environment for aircraft, they do not make any specific provisions for the protection of third parties or other valued components of the environment against potential incident and accident scenarios. Guidance in relation to airport planning supporting the implementation of the standards recognises that third-party risk is an important issue in decision-making on airport development but no specific aerodrome design prescriptions relating to this issue are provided in the international standards. However, the guidance advises that specific methodologies can be developed by ICAO contracting States and used to define dedicated land use policy controls.

2.3 Environmental protection legislation

The preliminary airspace design for WSI has been assessed with the findings presented in a Draft EIS as required under the EPBC Act (Cth). The EPBC Act (Cth) identifies requirements for the assessment of impacts of controlled actions, to provide information for decisions whether to approve the taking of the actions, including the preparation of a Draft EIS were considered appropriate, supported by guidance on the required content. In that context, the current consideration of hazards and risks has been informed by guidance issued in respect of the EIS Guidelines (EPBC 2022/9143). The legislation and associated guidance prescribe general requirements for the assessment of potential impacts on fauna, heritage, people and communities. In addition to these general requirements, the text of the guidance document makes specific reference to the following issues relevant to the aircraft hazard and risk topic:

- risks to people and communities
- risk of bird and bat strike
- contamination risk from aircraft fuel jettisoning.

Accordingly, this technical working paper considers these issues but is not limited to these topics. Aircraft hazard and risk in the context of the Draft EIS is considered to encompass any unintended or accidental event occurring beyond the limits of the normal operational envelope and the associated consequences and potential adverse impacts of such unwanted events. To that end, the assessment of hazards and risks is supported by a comprehensive review of potential hazards, as described in further detail in Chapter 3.

2.4 General risk and related land use planning policy

The *Work Health and Safety Act 2011*(Cth) and New South Wales (NSW) *Work Health and Safety Act 2011* place duties on persons responsible for facilities that may give rise to risks *"to eliminate risks to health and safety, so far as is reasonably practicable"*. In the acts, *"reasonably practicable, in relation to a duty to ensure health and safety, means that which is, or was at a particular time, reasonably able to be done in relation to ensuring health and safety, taking into account and weighing up all relevant matters including:*

(a) the likelihood of the hazard or the risk concerned occurring; and

(b) the degree of harm that might result from the hazard or the risk; and

(c) what the person concerned knows, or ought reasonably to know, about:

(i) the hazard or the risk; and

(ii) ways of eliminating or minimising the risk; and

(d) the availability and suitability of ways to eliminate or minimise the risk; and

(e) after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk."

The Acts do not prescribe specific measures that need to be taken but instead identify a duty to take whatever measures are available and practicable. Accordingly, over and above the adherence to any technical measures that may be identified in the CASRs relating to the operation of airport, aircraft and air traffic management facilities, it is necessary to demonstrate that there are no further practicable measures that may be taken to further reduce the risks and that any residual risks are maintained at acceptable levels. The objective of this document is to support the performance of that duty and to demonstrate that it has been properly discharged.

Further guidance is available to support the discharge of this rather broad duty and its associated objectives. For example, the NSW Department of Planning has a well-established integrated approach to land use planning and the assessment and control of potentially hazardous development (State of NSW 2011a). This approach has been designed to ensure that safety issues are thoroughly assessed during the planning and design phases of a facility and that controls are put in place to give assurance that it can be operated safely throughout its life. It is underpinned using systematic risk assessment methods (State of NSW 2011b) including quantitative assessment where appropriate and the evaluation of estimated risks against well-defined objective criteria (State of NSW 2011c).

In that context, risk, as distinct from the hazard that may give rise to a risk, is characterised in terms of 2 parameters as follows:

- the likelihood of occurrence of the hazard event
- the severity of its consequences, for example in terms of the scale of injuries or the numbers of individuals affected.

As described in the identified guidance documents (State of NSW 2011a, 2011b and 2011c) 2 distinct measures are available for characterising the risks estimated by quantitative risk assessment methods, as follows:

- individual risk: the annual probability of fatality for a hypothetical resident present at any given location relative to the source of a hazard
- societal risk: the annual probability of accidents causing any given number of fatalities in any area of development, taking account of the nature of the development, in particular the density of occupancy.

These risk metrics are routinely employed in the assessment of the risks associated with potentially hazardous facilities. The NSW Department of Planning guidance identifies quantitative criteria (State of NSW 2011b) to support the evaluation of the significance of estimated risks and their acceptability, in accordance with international best practice, for example as identified by the United Kingdom Health and Safety Executive (UK HSE 2001) and the Republic of Ireland Health and Safety Authority (ROI HSA 2010). Both metrics have been employed in this assessment, referring to the available risk criteria.

2.5 Aviation-specific safeguarding planning controls

International standards and associated guidance seek to ensure that airport and associated flight paths are appropriately safeguarded in respect of future development to ensure that safe and efficient aircraft operations can be effectively maintained. The DITRDCA has developed a comprehensive National Airports Safeguarding Framework (NASF) (DITRDCA 2022) to address these objectives across the Commonwealth of Australia.

A primary focus of the NASF is providing guidance to new development that might adversely affect the safety and efficiency of aircraft operations. This is achieved through the physical safeguarding of flight paths from intrusion by new obstacles (NASF F), the technical safeguarding of navigational aids and radar systems from interference (NASF G), control of development that may attract wildlife and associated hazards (NASF C), the control of potential distraction by lighting (NASF E) and the control of building and terrain induced wind shear (NASF B).

2.6 Airport public safety area policy

As explained earlier in Section 2.2, the international standards for airport design do not prescribe requirements for the control of new development near runways for the purposes of managing risks to the public from aircraft crashes; however, ICAO guidance advises that specific methodologies can be developed by contracting States for that purpose. Several countries have adopted Public Safety Zone (PSZ) policies for the control of new development near airports. The first PSZ policy was that adopted in the UK in 1957, following several accidents near runway ends, one of which caused the deaths of 2 people in their home. The UK policy was fundamentally revised in the late 1990s when a risk-based approach was adopted for defining the zone across which development was restricted, following a detailed technical review (Evans *at al.* 1997). A broadly similar risk-based approach has been adopted in the Republic of Ireland (ERM 2005). The crash of a Boeing B747 transport aircraft into an apartment block near Amsterdam Schiphol Airport in 1992 similarly led to the adoption of a risk-based policy in the Netherlands around this time, based on aircraft crash modelling referring to defined quantitative risk criteria (Piers 1998, Pikaar *at al.* 2000).

Subsequently, a risk-based approach has been adopted in Australia, under the NASF Guideline I on Public Safety Areas (PSAs) (DITRDCA 2018) which was agreed by the then Ministers at the Transport and Infrastructure Council in 2018. This recently introduced policy places development restrictions in areas where an individual is exposed to an estimated fatality risk of 1 in 100,000 per annum, a quantitative risk standard which defines the outer limit of a PSA. New residential development is generally discouraged within a PSA, but some low density uses may be allowed.

This use of this risk criterion is generally consistent with the practical interpretation of the principle under the *Work Health and Safety Act 2011* that risks should be eliminated "SFAIRP", as described earlier in Section 2.4 concerning general risk and related land use planning policy. The NASF Guideline I identifies an individual risk of 1 in 100,000 per annum as a relatively low level of risk compared with other risks of daily life more familiar to the community. In that context the guideline notes that the risk to an individual of being killed in a road accident in Australia is about 5 times that level.

However, it should be recognised that the PSZ and PSA approach to the control of new development in the vicinity of airports does not explicitly address the issues associated with a new runway development within an established built environment. These are 2 distinct development control issues, and the assessment of WSI requires consideration of the latter one relating to impacts on existing development. Nevertheless, PSZ and PSA policy and the associated risk criteria provided a useful reference point for the current assessment. As noted above, the basic safety requirement is to eliminate risks "SFAIRP", on a case-by-case basis, having regard to any additional potentially cost-effective measures that may be available.

Chapter 3 Methodology

This chapter provides an overview of the methodology for the hazard and risk assessment, including the approach to assessment, dependencies with other studies and any limitations and assumptions.

3.1 Impact assessment approach

3.1.1 Methodology outline

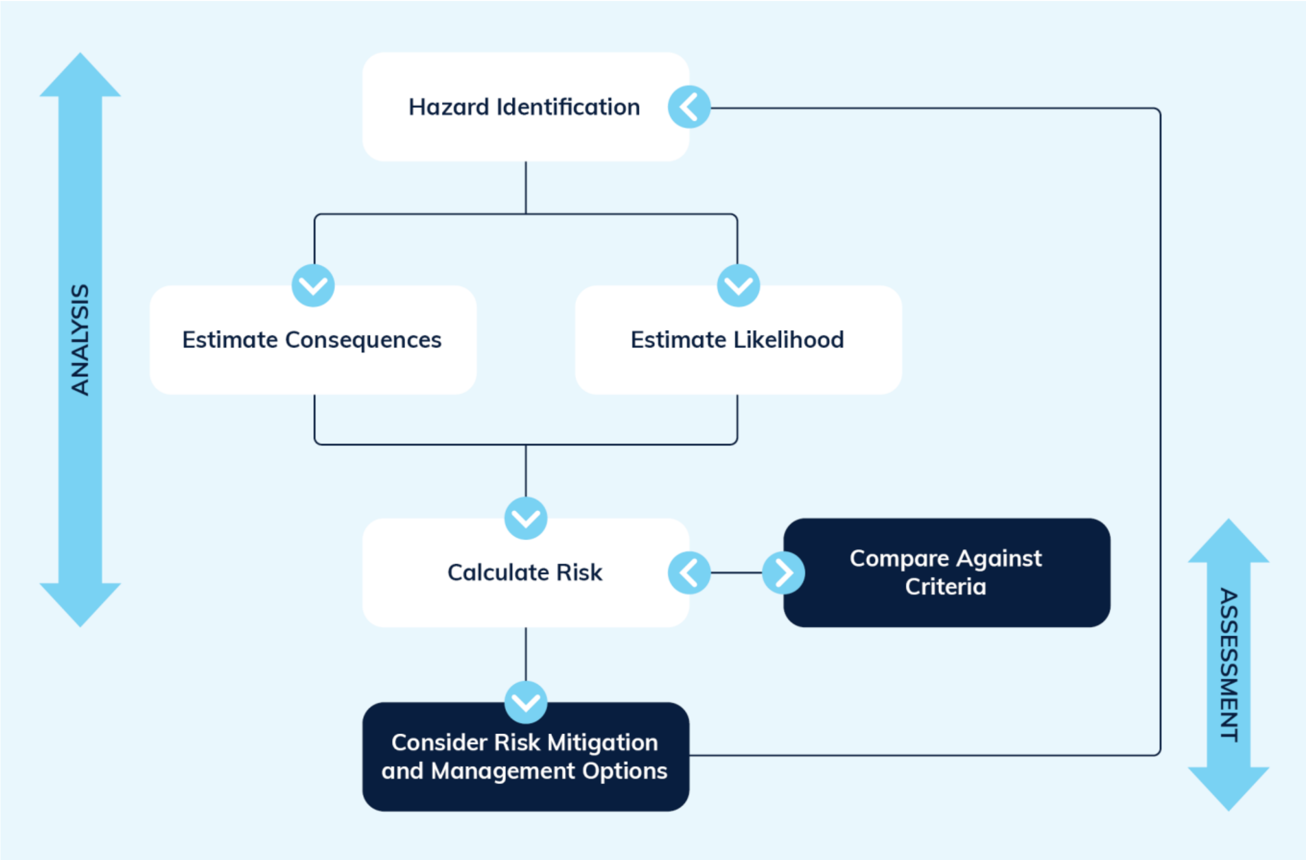
The generic process for hazard analysis that provides the basis for the approach adopted in this assessment is summarised in Figure 3.1. Whilst this schematic summary is derived from the available NSW hazardous industry land use planning guidance (State of NSW 2011c), equivalent processes are identified in aviation-specific risk assessment guidance (CASA 2014 ICAO 2018e). The key elements of the process are as follows:

- hazard identification
- risk characterization, including:
  - consequence assessment
  - likelihood assessment
- risk evaluation by reference to objective criteria
- identification of mitigation options.

Extensive hazard and risk identification exercises and assessments have been undertaken to support previous studies of WSI, namely those supporting the 2016 EIS (Commonwealth of Australia 2016, r2a Due Diligence Engineers 2016). These previous studies and related documentation have been reviewed to identify hazards of specific relevance to this Draft EIS, focusing on hazard scenarios during flight that may give rise to impacts outside the airport boundary. To ensure that all relevant off-site hazards have been identified and to characterize the relevant hazard scenarios in support of their assessment, reference has then been made to the Australian Transport Safety Bureau (ATSB) accident and incident database, and wider international operational experience.

Identified key risks relating to airspace operation summarised in Table 14.1 of the 2016 EIS (Commonwealth of Australia 2016) are as follows:

- bat and bird strike
- drone and model aircraft strike
- airspace obstruction
- mid-air collision with other aircraft
- military and emergency services operations
- high velocity air discharge
- adverse meteorology
- aircraft crashes into critical infrastructure
- falling aircraft
- terrorism incidents.



Source: Reproduced from State of Hazardous Industry Planning Advisory Paper No 3 Risk Assessment (NSW Department of Planning, 2011c)

Figure 3.1 Generic hazard analysis and risk assessment process

The list of identified hazards comprises several causal factors for potential hazards and specific incident scenarios (e.g., bat and bird strike and mid-air collision with other aircraft) and potential event consequences across the wider environment (e.g., aircraft crashes into critical infrastructure). The 2016 EIS hazard and risk review (r2a Due Diligence Engineers 2016) presents a more comprehensive list of potential threats, for example relating to aircraft operation such as inflight aircraft fire, fuel exhaustion, mechanical failure and pilot error.

In accordance with the EIS Guidelines (EPBC 2022/9143), the potential threats associated with fuel dumping are identified as requiring consideration. Finally, based on broader experience of potential off-site hazards and referring to previous EIS reports addressing hazards associated with runway development projects (AECOM 2020, Melbourne Airport 2022), wake vortex impacts on buildings and knock-on threats to people, and objects falling from aircraft were also identified as relevant hazards requiring consideration as part of this EIS.

Based on the above considerations, the following hazard and risk issues were identified for further and more detailed assessment in the context of this EIS:

- airspace conflicts between aircraft that might result in mid-air collisions and other potential threats to safe inter-operability associated with the introduction of additional flight operations into the existing Sydney Basin airspace, addressing interfaces with military and emergency services operations, current commercial and private civil aircraft operations and concerns relating to mid-air collision with other aircraft
- the general off-airport aircraft crash risks to people and critical infrastructure as may arise from the wide spectrum of causes evident from the recent historical accident record and reported in previous hazard identification studies
- aircraft fuel jettisoning
- objects falling from aircraft
- aircraft wake vortex strikes

- local meteorological hazards
- local bird and bat strike hazards.

In drawing up this focused list of hazards for inclusion in this Draft EIS, it has been assumed that the issues of airspace obstruction and high velocity gas discharge identified in the 2016 EIS will be adequately addressed by the current arrangements for safeguarding aircraft operations. Needless to say, it has been assumed that the airspace has been designed in the first instance to comply with established operational criteria under the relevant CASR and the NASF criteria to ensure a suitably obstacle free safe operating environment in accordance with international standards and that future safeguarding in accordance with NASF guidance will maintain that safe environment. It is further assumed that appropriate arrangements will apply in respect of drone and model aircraft operations to ensure these do not adversely impact on the safety of aircraft operations. Potential obstacle collision or other risks that might arise in non-standard operating environments were therefore not considered here. If any non-compliances were to be proposed, these would need to be justified on a case-by-case basis through appropriate safety assessments that are beyond the scope of this study. Terrorism incidents that may lead to off-site aircraft impacts are treated as part the generic off-airport aircraft crash risk model as one of many causal factors that may lead to aircraft impacts with the ground, but targeted attacks were not modelled.

These hazards are generic in nature and apply to all aircraft operations. There is a wealth of information provided by the wider historical accident record which can support the characterization of them. This approach was used extensively in this assessment. However, the risks associated with any hazard may vary with the specifics of the local operating environment. For example, risks associated with the generic hazard of a potential aircraft crash, into either urban areas in general or critical infrastructure, are estimated by using an empirical risk model informed by the review of relevant local, national and international operational experience, with regard to the locations of potential targets at risk along flight paths so as determine what specific harm can be expected on the ground if an accident were to occur. That more generic assessment can be supplemented where appropriate by location specific consideration of risk factors that may vary according to the local environment, such as wildlife and meteorological hazards. Overall, the primary means of characterising the relevant risks that was adopted here is by reference to historical accident and incident data derived from local, Australian and international aviation experience. These data provide a basis for the identification of potential hazards and for estimation of the residual risks, using empirical models that are informed by historical data that provide a basis for determining event frequencies and the associated severity of their consequences.

Finally, the significance of the estimated risks was evaluated against defined standards identified in national and international regulatory frameworks for aviation and for the management of risks more generally.

Further detail concerning the way that this general approach was applied to the consideration of the various relevant hazards is described below.

3.1.2 Airspace conflicts and system inter-operability

As explained in Section 2.2, safe and efficient airspace design is underpinned by well-defined technical standards that have been developed by the international aviation community over a considerable period of time. A well-defined safeguarding process is in place to ensure that safe and efficient operations can be maintained and will not be compromised by future developments, as set out in NASF guidance that addresses a comprehensive range of issues. The performance of these standards is demonstrated by the safety record of the industry over that time. The safety of the system is further supported by risk assessment and the ALARP principle. Specifically, air traffic service providers are subject to a regulatory requirement (ICAO 2018d, CASA 2020c) that *"any significant safety-related change to the ATS [Air Traffic Services] … shall only be effected after a safety risk assessment has demonstrated that an acceptable level of safety will be met and users have been consulted."*

This approach was followed during the design of the proposed WSI airspace and flight paths, and its interfaces with the existing airspace uses. The eventual outcome can be expected to be an overall airspace system that is safe by design within the various constraints inherent in it, minimising airspace conflicts and maximising system inter-operability. Details of the process by which the current design was established and supporting safety justifications are provided elsewhere. Such details are outside the scope of this technical paper, the purpose of which is to provide a concise but meaningful basis on which the validity of the choice of design concept can be evaluated. To that end, a summary of key safety-related aspects of the process to date, was provided, as set out in Chapter 6.

3.1.3 Aircraft crash risk assessment

The risks associated with civil aviation are well-established on the basis of considerable operational experience worldwide over a substantial period of time. Whilst crashes may be considered rare at any given airport and within any limited time period, reference to the wider international accident record over an extended time period provides an effective basis for characterising this risk. Site-specific risks to the public in the vicinity of airports can be estimated quantitatively by using an empirical modelling approach, based on historical accident data. That modelling approach was employed in this assessment, as described in Chapter 7. It characterises risk by reference to 3 key parameters as follows:

- the likelihood or probability (frequency per annum) of an aircraft crash occurring during landing or take-off operations, anywhere in the vicinity of an airport, having regard to the number of movements and the inherent reliability of different aircraft types, as determined from the available crash statistics
- the probability of impact at any specific location at or near an airport relative to each runway end and the flight paths beyond them, as described by the crash location distribution, determined by reference to crash locations in the historical accident data set
- the severity of the consequences of an impact on the ground, according to the size of the aircraft concerned and again determined by reference to the historical accident data set.

The model provides estimates for the first factor based on the crash rates derived for different aircraft types (e.g., civil passenger jet aircraft, civil passenger turbo-prop aircraft, business jet aircraft, jet and turbo-prop cargo aircraft) from the recent historical accident record. The model identifies different crash rates for take-off and landing operations. Based on the crash rates per movement for each aircraft type and the anticipated annual number of movements at WSI, the model provides an estimated annual crash rate for those operations.

The model provides estimates for the second factor by using generic crash location distribution functions that are determined for the observed historical distribution for civil aircraft accidents involving aircraft types that are generally representative of those operating at WSI.

The historical accident record demonstrates a relationship between the severity of crash consequences and the size of aircraft involved from which an empirical model relating the area affected to the take-off weight of the aircraft concerned has been derived to address the third factor. The crash consequences for the anticipated operations at WSI can therefore be expected to cover a range of severities. The empirical crash consequence model is used to estimate the severities of these accident consequences by reference to the aircraft types and the associated size characteristics of aircraft within the anticipated fleet mix.

The modelling approach employed in the current assessment is essentially that identified by the UK Department for Transport (Evans *et al.* 1997, Cowell *et al.* 2000) for the support of PSZ policy and adopted also in the ROI PSZ study (ERM 2005). Similar models based on empirical accident data have been developed by others (Piers 1998, Pikaar *at al.* 2000, GfL 2003). Whilst the precise details of these model may differ, they are based on broadly similar international data, and they provide essentially equivalent risk predictions within the limits of the uncertainty inherent in this sort of risk modelling. No equivalent model has been developed specifically for use in Australia and, given the time and effort that would be required to develop one, the adoption of the available UK Department for Transport (DfT) model represents a cost-effective practical solution in this instance. Whilst the general framework provided by the UK DfT model may be considered an adequate basis for risk modelling in the current context, it may nevertheless be appropriate to review and revise some of assumptions that underpin the model, for example the assumed crash rates for different aircraft types, taking account of recent operational experience in Australia. As such, reference was made to the ATSB accident and incident database and other relevant operational data to confirm the most appropriate assumptions to be employed. This data review process and the technical details of the refined model are described in Appendix A to this technical paper.

Overall, it is concluded based on this model review that, with limited modification, the UK DfT model represents a suitable approach for the current assessment. Key findings are as follows:

- aircraft crash rates: taking account of the more limited size of the dataset, the available Australian historical accident record is generally consistent with the crash statistics identified from the wider international experience and the crash rates developed to support the UK DfT model are therefore considered appropriate for use in the current assessment
- crash location distribution modelling: whilst some flaws are evident in this aspect of the UK DfT model, the primary concerns, relating to the treatment of overrun scenarios and the failure to address curved flight paths, can readily be addressed by minor modifications to the model
- crash consequence modelling: the UK DfT model is confirmed to provide estimates for the area impacted in the event of a ground collision dependent on aircraft mass that are consistent with the historical data by means of an empirical relationship that is supported by theoretical considerations. The model is considered appropriate for general application to the assessment of crash consequences following ground impacts in areas of typical urban development.

Whilst the predominant contribution to aircraft crash risk can generally be expected to be associated with landing and take-off operations, some risk may also arise from enroute operations along defined airways. Other empirical models (Byrne 1997) are available for the estimation of risks associated with these sorts of operations and reference has been made to them as appropriate.

In accordance with the risk model outline provided above, key inputs required to support the above modelling approach are therefore as follows:

- the geometrical characteristics of the runway layout, in particular the runway end locations that provide the reference points for the relevant landing and take-off operations, and the associated flight paths to and from the runway that define the areas over which aircraft fly
- the fleet mix of aircraft operating under the scenarios identified for assessment and the annual number of movements of each aircraft type which determine the scale of the risk.

To address this latter requirement, a series of operational scenarios have been identified for selected reference years and these are described in Appendix B of this Paper.

Aircraft routes are defined according to international standards for the design of instrument flight procedures that ensure the safe separation of aircraft in flight, having further regard to the objective of minimising noise impacts on neighbouring communities. The use of noise preferential routes that avoid flying over populated areas where practicable will assist in minimising the third party risk impacts.

The mode of operation of the runway is a further relevant consideration. Preferential use of one or other runway end, according to wind conditions, can further limit the impacts on sensitive receptors. The detailed operational specifications that have been developed to minimise noise impacts were employed as the basis for the third party risk assessments.

Two distinct measures are available for characterising the third party risks estimated by airport-related crash risk models, as follows:

- **individual risk:** the annual probability of fatality for a hypothetical resident present at any given location relative to the runway threshold and flight path to and from it
- **societal risk:** the annual probability of accidents causing any given number of fatalities in any area of development, taking account of the nature of the development, in particular the density of occupancy.

Both measures were employed in this assessment. They are routinely employed in the assessment of the risks associated with other potentially hazardous facilities, within Australia (Safe Work Australia 2012, State of NSW 2011b) and internationally (UK HSE 2001, ROI HSA 2012). The significance of the quantitative individual and societal risk estimates determined using the model was evaluated against defined quantitative criteria, based on established practice in Australia and internationally, as described below.

Individual risk is the measure employed for the definition of a PSA and PSZ. PSA and PSZ policy is a land-use planning tool for controlling new residential and other development in the vicinity of existing airport infrastructure. Certain land-uses are restricted in areas subject to a defined quantitative level of risk or more, on the basis that it is considered cost-beneficial to forego the development potential of the land, which involves a lost opportunity cost, in return for the benefit of reducing the risk of people on the ground being killed in areas along flight paths that are subject to elevated levels of risk. The individual risks are characterised in terms of a set of risk contours, representing the limit of the area subject to a defined level of risk. As noted earlier, the current assessment is concerned with a distinct land-use planning decision relating to the operation of a new runway development within an established built environment. Nevertheless, PSZ and PSA policy and the associated risk criteria provide a useful reference point for the current assessment to support the demonstration that the basic safety requirement to eliminate risks so far as is reasonably practicable has been met.

Risk contours for 3 different levels of risk are typically employed in the assessment of individual risk, as follows:

- a risk of 1 in 10,000 per annum, considered to be a relatively high risk and at the limit of what is an acceptable level of risk exposure for members of the public
- a risk of 1 in 100,000 per annum, considered to be a risk that is of potential concern but one that can nevertheless be considered acceptable in return for the economic benefits derived from the activity giving rise to the risk, provided that the risk is managed to be as low as reasonably practicable
- a risk of 1 in 1,000,000 per annum, considered to be a low risk that is a generally acceptable level of exposure for members of the public.

These identified risk levels provide a well-defined set of internationally recognised quantitative criteria for the evaluation of risk impact significance. In addition to the risk levels themselves, the relative numbers of people exposed to these risk levels provide a further criterion for evaluation of risk significance. In accordance with the approach that has been adopted in previous runway development studies (AECOM 2020, Melbourne Airport 2022) assessment criteria for individual risk significance that combine these 2 factors were identified, as summarised in Table 3.1, and were employed for the evaluation of the impacts of future flight operations into and out of WSI. They are based on professional judgement concerning the alignment of the established safety standards with the framework identified in Australia and elsewhere.

Table 3.1 Assessment criteria for individual risk significance

Significance of impact	Topic specific criteria
Negligible[1]	Individual fatality risk < 1 in 1,000,000 per annum across all areas of development and major transport links
Slight Effects	1 in 1,000,000 per annum < Individual fatality risk < 1 in 100,000 per annum Low numbers (up to a few tens) of people exposed
Moderate Effects[2]	1 in 1,000,000 per annum < Individual fatality risk < 1 in 100,000 per annum High numbers (hundreds to thousands) of people exposed Or 1 in 100,000 per annum < Individual fatality risk < 1 in 10,000 per annum Low numbers (up to a few tens) of people exposed
Significant Effects	1 in 100,000 per annum < Individual fatality risk < 1 in 10,000 per annum High numbers of people exposed
Very Significant Effects	Individual fatality risk > 1 in 10,000 per annum Low numbers (up to a few tens) of people exposed
Profound Effects	Individual fatality risk > 1 in 10,000 per annum High numbers (hundreds to thousands) of people exposed

1. The term “negligible” is typically employed in safety regulation for risk levels that are below regulatory concern and this category can be considered to equate essentially with the “not significant” impact significance category often employed in environmental assessment
2. There will be some overlap between scenarios meeting the criteria identified for “moderate effects”, according to the level of risk within the identified bands and the numbers of people exposed.

Whilst the identified individual risk criteria that underpin PSA policy in Australia can provide some insight into the extent to which people living and working in the vicinity of WSI are exposed to the risk of aircraft crash, the individual risk measure does not effectively characterise the true nature of the risk. For these purposes, the aircraft crash risk is better represented as a periodic event that may lead to multiple fatalities, where the number of fatalities will depend on the density of occupation of the crash site and size of the aircraft concerned. This sort of scenario can be characterised more effectively in terms of the "societal risk", typically characterised quantitatively in terms of the estimated frequency of accidents, *F(N)*, leading to a defined number of fatalities, *N*, or more. Societal risk estimates typically take account of the wide range of potential outcomes of an accident from the more common scenarios involving relatively few fatalities to less common ones involving larger numbers of fatalities. Usual practice is to present such societal risk estimates graphically in terms of an "FN curve" which summarises the full range of potential outcomes, by means of a plot on a logarithmic scale of the number of fatalities against the event frequencies for all foreseeable scenarios. The available criteria typically identify levels of societal risk defined in terms of the FN curve measure below which risks can generally be considered negligible, generally acceptable and not of any regulatory concern. Similarly, the criteria identify risks levels that may be considered of substantial regulatory concern and perhaps intolerable. The primary focus of safety regulation is on ensuring that risks between these 2 limits, identified in FN curve terms as the "ALARP" region, are appropriately managed so as to meet the ALARP requirement (UK HSE 1992).

Like the development of individual risk criteria set out earlier, the development of criteria for assessing the significance of societal risk generally draws on recent practical experience. Various societal risk criteria have been identified which are broadly similar to one another in most respects but differ in detail, for example in respect of the extent to which they reflect a greater aversion to events giving rise to higher numbers of fatalities. According to all the available criteria, a risk is considered increasingly significant at any given frequency with the increasing number fatalities that are associated with it. Similarly, a risk giving rise to any given number of fatalities is considered increasingly significant with the increasing frequency of the event. However, the increase in the level of concern about a risk with the increase in the number of fatalities is not consistent between the available criteria. Some criteria adopt no specific aversion to events giving rise to greater numbers of fatalities whilst others include an increasing aversion to multiple fatality events but to differing extents.

The UK quantitative criteria (UK HSE 1992) identify no aversion in that respect. Events leading to one fatality at a frequency of 1 in 10,000 years are identified as being at the upper limit of negligible risk, and the limit for ten fatality events is a ten times smaller rate of 1 in 100,000 years. Both events give rise to the same number of fatalities on average of 0.0001 per annum (the expectation value for the scenario) and are afforded equal significance. For each further factor of ten increase in the number of fatalities, a factor of ten decrease in the event frequency defines the upper limit of negligible risk. This criterion is represented by a straight line on the FN curve with a slope of -1. No additional importance is attached to events giving rise to higher numbers of fatalities. Nevertheless, UK guidance (UK HSE 1989) does raise the question as to whether some aversion might be factored into risk management decision making based on societal risk estimates.

On the other hand, Australian guidance (Safe Work Australia 2012) identifies societal risk criteria which include some aversion to events giving rise to higher numbers of fatalities. These criteria are part of what are identified as a set of 'interim' criteria that were set out in guidance prepared for the Government of Victoria (DNV Technica 1988). They are said to provide guidance but do not have legal status and would appear to reflect the practice employed by the technical consultants responsible for the guidance at that time. These criteria adopt the UK HSE reference point for negligible risk of one fatality at a frequency of 1 in 10,000 years but a one hundred times smaller frequency for events giving rise to ten fatalities, corresponding with a slope of -2 in the logarithmic FN curve format. This represents a substantial aversion to risks giving rise to higher number of fatalities: an average of 0.0001 fatalities per annum is considered negligible for single fatality events but not for less frequent events giving rise to higher numbers of fatalities. Risk criteria guidance identified by the State of NSW (2011b) differ again, adopting some aversion to events giving rise to higher numbers of fatalities but to a lesser extent than the Australian level guidance. They identify a factor of a thousand lower frequency for events giving rise to a hundred fatalities compared with a single fatality, corresponding with a slope of -1.5, and state that the criteria *"are indicative and provisional only and do not represent a firm requirement in NSW."* The 3 sets of criteria correspond with one another at some points across the range covered but diverge at others. The primary difference, evident in the figures in Section 7.2 and Appendix C which present the findings of the societal risk assessment of WSI operations, is the lower frequency at which higher fatality scenarios are considered acceptable. A slightly different approach to defining quantitative criteria for evaluating the significance of societal risks that includes an element of high fatality risk aversion is adopted (ROI HSW 2010) in the Republic of Ireland in the context of the regulation of major hazard facilities and land-use planning in their vicinity. These criteria are defined by reference to a “Scaled Risk Integral” (SRI) representing the sum over all scenarios of the accident frequency, *f(n)*, multiplied by the number of fatalities, *n*.

The risk integral is defined as:

$$SRI = \sum_{1}^{nmax} f(n).n^{a}$$

In this expression, *f(n)* is the frequency of events leading to *n* fatalities (in units of casualties per million years), and ‘*a*’ is a constant assigned a value of *a* = 1.4. The scale of the risk as measured by the risk integral can be judged against criteria of 2,000, identified as “broadly acceptable” in the wording of the guidance and 500,000, identified as “significant” in the wording of the guidance. The guidance states that the SRI is used “to provide a rapid initial assessment of the societal risk” and that “it must be emphasised that a full consideration of the FN curve is probably a more robust approach.” The more robust approach through consideration of the FN curve, based on estimates for the frequency, F, of events that cause N or more casualties, has been adopted in this assessment. The guidance further states that “there is ongoing debate as to whether scale aversion should be included at all in societal risk measures for land use planning, and so such risk integrals are only used as screening aids.”

Reference has been made to these different societal risk criteria in the evaluation of risk estimates associated with flight operations into and out of WSI, whilst recognising that there is uncertainty concerning the judgement of risk significance, in particular the extent to which an aversion to events giving rise to higher numbers of fatalities needs to be considered. High fatality risk aversion was considered carefully by the UK regulatory authorities (HSC 1991, Appendix 6) at the time the sorts of criteria identified in the Safe Work Australia and State of NSW guidance were being promoted by some risk practitioners. The UK view adopted at that time was that “differential risk aversion, if it is to be expressed, must be done explicitly, rather than buried within some mathematical analysis. It was further considered that, taking account of the cumulative nature of the FN curve representation (i.e., that the frequency F is the cumulative frequency of N or more fatalities), there is already an element of high fatality risk aversion inherent in an FN criterion with a slope of -1, as further elaborated by Vince (2011) whose analysis underlines the limitations of the more stringent criteria incorporating high fatality risk aversion. UK regulatory authorities considered the use of a slope of -2 “an extreme risk aversion”. Such criteria may be unachievable in practice, representing standards that cannot be met. On that basis, the preferred criteria identified here are those identified by the UK regulatory authorities, as discussed further in the context of the societal risk estimates presented in Section 7.2.

The expectation value, representing the average number of fatalities per annum associated with a hazardous event, represents an alternative societal risk measure which is neutral in terms of high fatality risk aversion: $\sum_{i=1}^{n_{max}} f_i\, n_i$, the sum over all foreseeable scenarios associated with a hazard giving rise to n_i fatalities with a frequency of f_i. Reference has also been made to this societal risk measure in the evaluation of the aircraft crash-related third-party risks associated with WSI operations.

The methodology outlined above was applied to operational scenarios characterising the anticipated level of aircraft activity at WSI in the 2 reference years, 2033 and 2055, representing relatively low levels of activity in the early years of operation and relatively high levels of activity as the single runway approaches capacity, respectively. Operational scenarios were characterised as follows:

- the average daily take-off and landing operations by aircraft type, providing the basis for the estimated annual operations
- a set of 51 arrival and departure flight paths employed for those operations
- a set of 7 scenarios representing different options for runway modes of operation (RMO) and use of the flight paths, according to the anticipated meteorological conditions determined by 10-years of historical data.

Following a review of the 7 operational scenarios, a single scenario was selected for assessment on the basis that it represented the most balanced case, representative on average of the whole set of options, and that it represented a worst-case in terms of the use of flight paths closer to areas of where development is predominantly located, to the north and east of the runway. Further detail concerning the operational specifications supporting the assessment is provided in Appendix B.

3.1.4 Assessment of other hazards

In accordance with the methodology outline described in Section 3.1.1, the risks associated with the other identified hazards were characterised by reference to operational experience, provided through the ATSB accident and incident data base and wider international experience. The international aviation authorities have established a sound framework for the reporting and investigation of accidents and lesser incidents that may be considered a potential threat to operational safety. A mandatory occurrence reporting system applies and, whilst this cannot necessarily be expected to capture all potentially relevant occurrences, this approach provides a comprehensive amount of information to support the characterisation of hazards. The findings of the application of this general approach to the assessment of the other relevant hazards is described in Chapter 8.

Within that framework, the ATSB undertakes systematic investigations of aviation accidents and incidents and publishes reports on those investigations. The available reports are provided through a searchable database describing events going back to the 1950s, covering over 7,000 events. The search criteria available include, amongst others, the following:

- incident locations and dates
- the type of operation, for example covering commercial air transport, charter, GA and other operations
- the injury level, from fatal to serious, minor and none
- the occurrence type, covering a wide range of accident and incident scenarios
- the occurrence category, including accident, serious incident and events with lesser consequences
- the aircraft type, including propulsion type and fixed and rotary wing categories.

A wider international dataset is available, for example through the US National Transportation Safety Board (NTSB), reference to which can assist in ensuring that reliable evidence for characterizing the risks associated with uncommon hazard scenarios is available. This dataset has been employed to characterize each of the identified hazards in terms of their frequency of occurrence and the range of severities of their consequences. The potential impacts were then assessed by reference to the environments along the flight paths that form the proposed airspace for WSI to provide a basis for evaluating the scale of the anticipated practical risks.

3.2 Dependencies and interactions with other technical papers

Two potential interactions with other study areas were identified, as follows:

- **aircraft noise:** flight path design has sought to minimise noise impacts on people, in part through avoiding overflight of areas that would give rise to the impacts on larger numbers of individuals. Some overlap is therefore expected between the 2 study areas in respect of optimising airspace design through selection of flight path locations
- **biodiversity:** wildlife strike risk management involves a balance between aeronautical safety and biodiversity objectives. On the one hand safety objectives are best served by eliminating those elements of the ecosystem whereas the biodiversity objectives will seek to preserve them.

Given the clear synergy between the noise and third party risk topics, little if any conflict between them is anticipated. In contrast, there is potential conflict between the biodiversity and third party risk topics, in principle at least. In practice, however, no real conflict is anticipated. A balance will need to be struck between biodiversity on the one hand, and aircraft and passenger safety, on the other. Wildlife management measures will be required to limit the potential for bird and bat strikes to maintain operational safety and efficiency, regardless of the implications of strikes for third party risks. The measures required as a minimum to achieve the required level of operational safety and efficiency can be expected to ensure that any contribution to third party risk from wildlife strike will be small. Not only will the occurrence of wildlife strike events be limited by those measures, the extent to which bird and bat strike can be expected to lead to significant off-site crash risks is inherently limited by several factors, for example:

- most incidents take place at relatively low altitude, mostly during take-off and landing operations and to a lesser extent shortly after take-off or during the final stages of descent and approach to landing. Given the runway's location in relation to areas of existing development, aircraft crashes that might arise due to bird and bat strikes can be expected to be very unlikely to lead to significant harm on the ground
- larger aircraft are generally quite resilient to bird and bat strike and can continue safe flight after single engine failure. Small aircraft that may be more susceptible to damage that may compromise safe flight would, given their small mass, be expected to lead to relatively limited damage on the ground in the event of an impact.

3.3 Limitations and assumptions

The assessment of the primary hazard of aircraft crash is based on an empirical model that was developed by reference to recent historical accident data which provides generic insight into the likelihood of aircraft crashes, the likely locations of events in relation to flight paths and the impact consequences on the ground. Future risks associated with operations at WSI were estimated using projected demand schedules provided by WSA, in terms of the numbers of aircraft movements following the available departure and approach paths and the aircraft types involved. There will inevitably be limitations to the reliability of any quantitative risk model based on this empirical approach, due to inherent modelling uncertainties and uncertainties in the forecasts for future operations. Careful consideration was given to the possible limitations of the third party risk modelling approach employed, as described in the review set out in Appendix A. It was concluded that this modelling approach is consistent with current best practice and provides a sound basis for assessing the implications for public safety of WSI's preliminary airspace design.

The assessment of other hazards is similarly based primarily on empirical evidence from operational experience and is subject to similar limitations and assumptions.

Chapter 4 Existing conditions

This chapter describes the existing conditions and features of the study area to provide a baseline against which the project's impacts can be assessed. This includes information on the study area, covering the more immediate vicinity of WSI and the wider Sydney Basin airspace, the nature of potential sensitive receptors in the study area and baseline hazards and risks.

4.1 Study area

The primary study area is defined by the more immediate vicinity of WSI For example in the case of the third party risk assessment centred on the single runway (05/23) and covering 40 km laterally and 45 km longitudinally, where any additional risks can be expected to be more concentrated. Some further consideration has been given to the Sydney Basin area airspace which sets the baseline for existing risks associated with the existing aviation infrastructure.

The Sydney Basin airspace is likely the most complex and busiest airspace in Australia. It supports Australia's busiest international airport — Sydney (Kingsford Smith) Airport, and several satellite airports and aerodromes. Within the Sydney Basin airspace, and in addition to high numbers of airline operations, there are numerous flights by private operators, flying training activities, aeromedical and military operations and a range of other general and sports aviation activity. According to Airservices Australia reporting for movements at Australian airports, in calendar year 2019, more than 700,000 aircraft movements were recorded at Sydney (Kingsford Smith) Airport, Bankstown and Camden Airports in the Sydney Basin airspace.

Air traffic at WSI will be managed by Airservices Australia. As the national ANSP, Airservices Australia ensures that aircraft are separated (for safety) throughout their flight, and sequenced (for efficiency) during arrival to, and departure from an airport.

The proximity of WSI to Bankstown and Camden Airports, Sydney (Kingsford Smith) Airport and RAAF Base Richmond creates the potential for conflictions between aircraft wishing to access the same piece of airspace for their operation.

Most of the land within and immediately surrounding the Airport Site comprises low density rural residential and agricultural land uses with a few residential areas adjacent to The Northern Road and Park Road intersection and further south of The Northern Road. Surrounding rural residential tenancies range from approximately one to 40 ha in area. Agricultural land uses include cattle grazing and horticulture.

The villages of Luddenham and Wallacia are located immediately west of the Airport Site, generally straddling The Northern Road between Park Road and Adams Road, and Mulgoa Road, north and south of the intersection of Park and Silverdale Roads. As of 2021, the estimated resident populations living in Luddenham and Wallacia was around 2,000 (Australian Bureau of Statistics (ABS) 2021). Luddenham village comprises neighbourhood retail shops and low-density residential housing with average lot sizes of around 500 square metres (m^2).

South-west of WSI in the locality of Greendale, land use is predominantly large lot rural-residential. The villages of Silverdale and Warragamba support an estimated resident population of around 5,000 people in some 2,000 dwellings (ABS 2021).

Around 5 km north of WSI is the Twin Creeks Golf and Country Club, a 340 ha estate comprising an 18-hole golf course, function centre, restaurant and more than 200 residential dwellings. The DEOH is located approximately 9 km north of the Airport Site and is used for storage, distribution and Defence explosive ordnance training.

To the north-east and east of WSI are the localities of Badgerys Creek, Kemps Creek and Mount Vernon. These localities support an estimated resident population of around 1,800 living in rural residential dwellings with average lot sizes of 10 ha (ABS 2021). The Badgerys Creek riparian corridor defines the eastern boundary of the WSI site. The land to the east of Badgerys Creek is largely used for agriculture. Also located to the east of WSI are the recreational areas of Kemps Creek Nature Reserve and the Western Sydney Parklands.

The gently undulating hills and expansive valleys of the Cumberland Plain extend westwards incised by an extensive network of tributaries draining to the main channel of the Nepean-Hawkesbury River before intersecting the foothills of the Greater Blue Mountains Area (GBMA) World Heritage property. The GBMA is an amalgam of plateau escarpments, eucalypt forests, mountain peaks and valleys rich in biodiversity, Aboriginal values and other historic places that rises to 3,901 ft (1,187 metres (m)) at its highest point to the northeast of Lithgow. Lake Burragorang, a man-made reservoir, and part of the major water catchment area for Sydney is also located to the south-west of WSI.

Beyond the immediate Local Government Areas (LGAs), the Blue Mountains LGA lies to the west; Wollondilly, Camden and Campbelltown LGAs lie generally to the south; and Bankstown and Fairfield LGAs lie generally to the east; and the Blacktown LGA lies to the north of the Airport Site. Together these LGAs and the City of Parramatta, Cumberland Council, Hawkesbury City and the Hills Shire make up the Western Sydney LGA, which encompasses a land area of nearly 9,000 km^2. According to the ABS, in 2021 the estimated resident population of the Western Sydney LGA was 2.6 million people occupying more than 870,000 dwellings. Generally to the east, the Liverpool and Penrith LGAs cover a total land area of 710 km^2 and in 2021, the estimated resident population was reported to be around 450,000 (ABS 2021) equating to a population density of around 6.5 persons per km^2.

The network of roads currently serving WSI are:

- Elizabeth Drive – a classified road which forms the northern border of the Airport Site
- The Northern Road – a classified road bounds the western part of the airport site on a north-west to south-east alignment
- Badgerys Creek Road – a local road which intersects the eastern part of the airport site on a north to south alignment, connecting Elizabeth Drive to The Northern Road.

Additional road infrastructure under construction to integrate WSI to the arterial network includes the new M12 Motorway and associated connections.

4.2 Sensitive receptors

In respect of aircraft crash hazards, the primary sensitive receptors for consideration fall within the following categories:

- areas of development along flight paths where people live, work or otherwise congregate that may be impacted by aircraft crash
- critical built infrastructure such as transport links
- major hazard industrial facilities, for example chemical processing and storage facilities and nuclear facilities at which an aircraft crash may lead to serious knock-on consequences
- water supplies that may be contaminated, either by a crash or by fuel dumping in an emergency
- any other facilities or environmental assets of notable value that may be harmed by the identified hazard scenarios.

In practice, risks are more specifically located in areas along flight paths close to each runway end, as shown by the individual risk contour assessment presented in Section 7.1. These individual risk contours provide a basis for focusing on sensitive receptors that are considered to be subject to elevated risk levels, as discussed further in Chapter 7. Outside those areas, the risks associated with aircraft crash at any particular location can generally be considered negligible.

4.3 Baseline hazards and risks

The list of hazards identified earlier in Chapter 3 apply to existing operations. The baseline risks associated with them have not been assessed in any detail. Broadly speaking, these risks can be expected to scale with the volume of activity and to be more particularly focused on areas in the immediate vicinity of the existing airport infrastructure and associated flight paths. In general, the findings of the detailed assessment of the risk impacts associated with WSI operations read across to the existing risks associated with current operations. Operational experience indicates that these risks can be considered to be acceptable and to meet the ALARP requirement.

Chapter 5 Facilitated changes

Several airspace changes will be required prior to the opening of WSI in 2026, including changes to vertical and lateral flight path profiles of aircraft arriving and departing from Sydney (Kingsford Smith) Airport and Bankstown Airport to maintain Minimum Safe Altitude (MSA) separation. The facilitated changes are not the primary subject of the approval currently under consideration, but the Draft EIS is required to assess the significance of any potential impact on the environment and communities associated with these changes. They broadly include:

- changes to Sydney (Kingsford Smith) Airport STARs
- changes to Sydney (Kingsford Smith) Airport SIDs and the introduction of Bankstown SIDs and STARs
- changes to RAAF Base Richmond SIDs, STARs, and Prohibited Restricted Danger (PRD) Areas
- VFR changes (VFR flights moved out of the way so the airspace is clear in anticipation of WSI flights).

The key points to made concerning the safety impacts associated with these preceding airspace changes are as follows:

- it can be expected that the preceding changes will lead to no significant impacts on the safety and operability of the wider Sydney Basin airspace system
- it can be further expected that there will be no significant changes in the third-party risks to members of the public associated with operations at other Sydney Basin airports arising from the preceding changes.

With regard to the first point, it has already been noted in Section 2.2 that air traffic service providers are subject to a regulatory requirement (ICAO 2018d, CASA 2020c) that *"any significant safety-related change to the ATS [Air Traffic Services] … shall only be effected after a safety risk assessment has demonstrated that an acceptable level of safety will be met and users have been consulted."* The way this requirement is being met for the proposed airspace changes are set out in more detail in Chapter 6. The preceding changes are part of the same design process, and the same conclusions apply to them as set out more generally for the overall airspace design. These changes can be expected to meet the key goals of operational safety risks being ALARP and achieving an acceptable level of safety. Reference should be made to Chapter 6 for a fuller account of the basis on which that conclusion can reliably be made.

With regard to the second point, it is recognised that there will be an element of third-party risk associated with operations at other airports in the Sydney Basin, irrespective of the development of WSI. In accordance with the general predictions of the modelling approach adopted for estimating the third-party risks associated with WSI operations, those risks can be expected to be more concentrated closer to the end of each runway and along flight paths used more predominantly in the earlier stages of take-off and latter stages of approach and landing, irrespective of the SIDs and STARs in use elsewhere in the system. Such risks can be expected not to be influenced specifically by the details of the SIDs and STARs employed but to be determined primarily by the characteristics of technical faults or other off-normal occurrences with the potential to lead to ground collisions. Whilst there is the possibility that the re-design of SIDs and STARs might lead to some redistribution of the areas subject to risks, those changes can be expected not to lead to a significant change in risk levels overall.

Chapter 6 Airspace conflicts and system operability

6.1 Outline

The design of the required airspace changes to accommodate WSI in a manner that minimises airspace conflicts and avoids mid-air collisions or other threats to operational safety is a complex and ongoing process. The details relating to safety aspects of the process by which the current preliminary design was established are recorded elsewhere (Airservices Australia 2021a; Airservices Australia 2021b). Such details are outside the scope of this technical paper, the purpose of which is to provide a concise but meaningful basis on which the validity of the choice of design concept to support that objective can be evaluated at a time when some of the finer details of the required airspace design have still to be developed. A summary is provided here of key safety-related aspects of the process to date, covering the following:

- the general safety regulatory and management framework underpinning the delivery of safe air traffic services in Australia
- defined safety objectives for the airspace design development and the criteria applied to assist in meeting them
- the high-level airspace concept design process by which potential options for the design were identified and evaluated and the preferred concept was selected
- the development of the preliminary airspace and flight path design that has sufficient accuracy and definition to support the environmental assessment.

6.2 Air traffic control safety regulatory and management framework

The airspace design change is being delivered by Airservices Australia. Airservices Australia is Australia's air navigation service provider and is a government-owned organisation. Under the *Air Services Act 1995* (Cth), Airservices Australia is required to provide:

- safe, secure, efficient, and environmentally responsible air navigation.
- aeronautical information, aviation communications and radio navigation aids.
- aviation rescue firefighting services to the aviation industry.

Section 9 of the Act defines the way Airservices Australia must perform its functions as follows:

(1) In exercising its powers and performing its functions, Airservices Australia must regard the safety of air navigation as the most important consideration.

(2) Subject to subsection (1), Airservices must exercise its powers and perform its functions in a manner that ensures that, as far as is practicable, the environment is protected from:

  (a) the effects of the operation and use of aircraft; and

  (b) the effects associated with the operation and use of aircraft.

(3) [Airservices] must perform its functions in a manner that is consistent with Australia's obligations under:

  (a) the Chicago Convention; and

  (b) any other agreement between Australia and any other country or countries relating to the safety of air navigation.

As set out earlier in Section 2.2, in performing its duties under the regulatory oversight of CASA, Airservices Australia is subject to the requirement that *“any significant safety-related change to the ATS [Air Traffic Services] … shall only be effected after a safety risk assessment has demonstrated that an acceptable level of safety will be met and users have been consulted.”* As required by regulation, Airservices operates a safety management system, as summarised in the organisation’s Safety Management System (SMS) framework (Airservices Australia 2019) which reiterates the requirement that Airservices Australia *must regard the safety of air navigation as the most important consideration* and identifies a set of supporting objectives.

The above air traffic control safety regulatory and management framework establishes the basis on which Airservices Australia provides services meeting the required safety standards.

6.3 Airspace safety plan objectives and supporting criteria

To support the delivery of the Airspace Change Proposal (ACP) in accordance with the principles identified above, the Western Sydney Airport Airspace Safety Plan (Airservices Australia 2021a) identifies 2 key safety goals and associated sub-goals, as follows:

- Goal 1: Operational safety risks are ALARP
  - Sub-Goal 1.1: All operational safety risks have been identified and assessed
  - Sub-Goal 1.2: All operational safety risks have been managed through the identification of all reasonable controls and are ALARP.
- Goal 2: The introduction of air traffic services at WSI is acceptably safe
  - Sub-Goal 2.1: The airspace design is acceptably safe
  - Sub-Goal 2.2: ATS and supporting systems designs are acceptably safe
  - Sub-Goal 2.3: Design of procedures meets requirements
  - Sub-Goal 2.4: Implementation is acceptably safe.

In relation to sub-goal 1.2, further clarification is provided, stating that safety risk controls and requirements will be identified to eliminate residual risk where possible and that remaining residual risk will be reduced to ALARP.

These 2 goals are fundamental to the objectives-based approach to safety management outlined earlier in Section 2.4. All practicable measures must be taken to reduce risks, in accordance with goal 1, and any residual risk must be sufficiently low for the level of safety achieved to be considered acceptable, in accordance with goal 2. Reference to established safety performance provides a basis for determining what constitutes an acceptable level of risk, with the further general requirement to seek future improvement.

Meeting those goals has been supported using concept options development safety criteria. The preliminary airspace design concept was developed through the consideration of multiple options that were assessed by performance evaluations against a series of criteria which included safety criteria. The key safety criteria that were identified addressed the following:

a. Systemic separation of aircraft through the physical layout of the system: the preferred design options are those that minimise the number of conflict pairs of tracks that do not provide systemic separation.

b. Air traffic controller workload minimisation: the preferred design options are those that minimise air traffic controller workload since the level of safety is a direct function of air traffic controller workload where higher workload levels required to operate a system provide reduced levels of safety, compared with lower workload requirements.

These 2 criteria provide the basis for selection of the concept option that inherently has the best safety performance. They underpin the process of delivering a system that is safer by design and as safe as reasonably practicable within the constraints of the environment within which it sits.

6.4 Options identification and evaluation and selection

The preliminary airspace design for WSI seeks to integrate with existing airspace arrangements in the Sydney Basin and that:

- has safety as its most important consideration
- is efficient by design
- provides the capacity to meet demand
- takes account of noise and other environment considerations.

The design process began through consultation with key Sydney Basin airspace users in 2018 to develop a specification for the functional requirements of the system and key performance areas (KPAs) in Safety, Capacity, Efficiency, and Environment to be used to determine the capability of concept design option to deliver optimal solutions. Independently, the DITRDCA and Airservices Australia developed several concept options based upon those Input assumptions. Concept option candidates were then subjected to screening and evaluation and were evaluated for expected safety outcomes, based on their performance against the functional requirements and safety criteria.

This process was supported by fast-time simulation of airspace concept designs for single runway operations to determine, at a high-level, the best overall method of processing aircraft into and out of WSI on a “typical day of operation” at traffic levels appropriate to the ultimate single runway capacity. These simulations provided a basis for evaluating options against the safety criteria identified in Section 6.3. For example, conflicts/interactions were employed as a proxy for workload where a conflict/interaction represents a reported position of 2 aircraft within 1,000 feet (ft) and/or 3 nautical miles (nm) or around 5–6 km. The goal was to identify elements of the design that would necessitate high levels of interaction and therefore workload from the controller and to appraise each design in the lead up to the selection of a preferred design. Through further supporting desktop and workshop reviews, a preferred concept option shortlist was developed.

At this stage an independent document review was undertaken by NATS, the UK ANSP and equivalent of Airservices Australia.

The scope of the document review was to undertake a high-level analysis of the information provided and to determine if there were any ‘Red Flags’ (serious omissions, errors, or flawed methodology) or ‘Amber Flags’ (areas of possible concern, incomplete or not fully documented methodology, or omissions which would ordinarily be expected to be included) and to provide additional comments, recommendations, and expert opinion of a wider nature in relation to the planned new airport and airspace planning from an air traffic management perspective. The outcome of the review was that no “Red Flags” were identified in the field of safety. Comments and recommendations to enhance the process were provided by NATS and were accommodated where relevant into the safety processes for the Preliminary Design and EA Phase.

After some further concept refinement, validation and evaluation and high-level consultation with a small group of stakeholders, the preferred high level concept design option was approved.

6.5 Preliminary design development

Following the approval of the preferred high level concept design option a preliminary airspace design was developed that has sufficient accuracy and definition to support an environmental assessment. More specific detail was added to the initial concept using a design-validate-review methodology through which the design evolved iteratively as a series of preliminary design versions. These more detailed design specifications are amenable to real time simulation which has been employed to evaluate performance by recording key indicative operational parameters and by feedback from participants. The design process was supported by adoption of established safety assessment and management methods, as summarised in Section 3.1.1, for example, hazard identification and analysis workshops. Given its potential importance, specific consideration was given to human factors to highlight key human factors impacts at the beginning of the design process and identify key actions. This supports the early identification of potential impacts and ensures Airservices Australia implements intuitive and error tolerant systems that adhere to ”Safety by Design” principles.

This phase of the design development was further supported by a collision and conflict risk model that estimates the probability of aircraft on 2 procedures being either in conflict or at a risk of collision. The underlying collision risk for preliminary airspace and flight path design must be below the Target Level of Safety (TLS), which is set at 5×10^{-9} per movement for each procedure pair with 20 aircraft per hour assumed on each respective procedure. This TLS is in line with international levels of 5×10^{-9} fatal accidents per flight hour for each of the lateral, longitudinal and vertical dimensions, and between 0.5×10^{-9} to 10×10^{-9} fatal accidents per movement for aircraft approaches. This TLS is conservative since few procedure pairs will simultaneously have this level of traffic. Whilst the available conflict risk assessment report indicates areas for further investigation, there are no major areas of concern regarding collision risks associated with the preliminary airspace design.

6.6 Conclusions

The overall conclusions to be reached from the preceding review of relevant safety aspects of the design process are that the proposed airspace can be expected to be safer by design and to meet the key goals of being ALARP and achieving an acceptable level of safety, due to the following key features:

- the airspace design has been delivered within a safety regulatory and management framework in which the safety of air navigation is regarded as the most important consideration and where management systems are in place to ensure that such a commitment is met
- the airspace design is underpinned by defined goals established at the outset that all risks will be managed to be ALARP and that any residual risk will be acceptable
- the airspace design is further underpinned to 2 design principles supporting inherent safety: systemic separation of aircraft and air traffic controller workload minimisation
- the identification and evaluation options for airspace design and the selection of the preferred concept option has followed a rigorous process which can be expected to deliver an optimum solution within the inherent constraints of the existing operational requirements that is safer by design
- the subsequent development of the preliminary airspace design from the selected concept option follows established industry practice and has delivered a more detailed operational specification that can be expected to deliver an eventual outcome meeting the identified objectives, minimising airspace conflicts and maximising system operability.

Chapter 7 Third party risk impact assessment, including development scenarios (quantitative)

7.1 Individual risk

In accordance with the modelling approach summarised earlier in Section 3.1.3 and described in further detail in Appendices A and B, crash risk to an individual is dependent upon 2 key parameters, the crash rate and the area destroyed in the event of a ground impact. To determine the risk contours, the annual average crash rate and average area destroyed was determined for the relevant arrival and departure routes, taking account of the fleet mix and movement numbers for each individual route. In all cases, the movement-weighted average was employed: i.e., the contribution to the average from each aircraft type was weighted in proportion to the fraction of aircraft of that type within the fleet mix. The average values for operations across all routes are summarised in Table 7.1.

Table 7.1 Summary of individual risk contour modelling parameters

Scenario	Annual movements	Crash rate per million movements	Crash rate per annum	Destroyed area (hectares)
2033 – No runway preference	81,190	0.0986	0.00801	0.494
2055 – No runway preference	227,499	0.0889	0.02022	0.629

The individual risk at any point was then determined by reference to the crash location element of the UK DfT model, integrating over the destroyed area and determining the contributions from each relevant take-off and landing operation at each runway in accordance with the route specific fleet mix data provided. The individual risks for 2033 and 2055 at the north-east and south-west ends of the runway, as characterised in terms of risk contour plots, are shown in Figures 7.1 and 7.2. The dark blue, mid blue and light blue lines in these figures delineate the annual 1 in 10,000 (10^{-4}), 1 in 100,000 (10^{-5}) and 1 in 1,000,000 (10^{-6}) risk contours, respectively.

The geographic extent of the contours have been characterised in terms of their area coverage and lengths, including the distances they extend beyond the boundary of the airport and the associated area outside the boundary[1]. These area and length characteristics of the contours are summarised in Table 7.2 and Table 7.3 for the 2033 and 2055 reference years, respectively. In both reference years, the 1 in 10,000 per annum upper risk contours for both ends of the runway are contained entirely within the airport boundary[2]. For 2033, the 1 in 100,000 per annum contour at the south-west runway end is also contained within the Airport Site boundary. Whilst the majority of the 1 in 100,000 per annum contour at the north-east runway end in 2033 is also contained within the Airport Site boundary, 1.64 hectares (around 20 per cent of its area), is located outside the airport, beyond Elizabeth Drive. A substantial part of the area covered by the 1 in 100,000 per annum risk contours at both runway ends is located inside the Airport Site boundary in 2055 but 23.06 ha, (around 37%), are estimated to be located outside the Airport Site boundary. The 1 in 1,000,000 per annum contours for the 2033 and 2055 reference years extend well beyond the Airport Site boundary at both runway ends.

The 1 in 100,000 contours can be seen to be very much runway-aligned for both cases, reflecting the concentration of flight paths along the runway extended centreline out to the distances to which these contours extend. The 1 in 1,000,000 per annum contours are similarly runway-aligned but the influence of turns associated with some of the departure flight paths on these contours is evident to some extent, in particular at the north-east runway end in 2055 where the concentration of risks along specific flight paths involving turns to the north are evident.

1 The airport boundary has been estimated from Figure 4 (Indicative Airport layout (Long Term)) of the WSI Airport Plan 2020

2 In practice, the 1 in 10,000 per annum risk contour may be slightly greater than the identified estimates in the tables if the contribution from overruns were to be considered but will nevertheless be expected to be contained within the airport boundary.

Figure 7.1

Risk contours - 2033

Legend

WSI Runway

Western Sydney International (Nancy-Bird Walton) Airport land boundary

Risk contours

10,000 per annum

100,000 per annum

1,000,000 per annum

0 1 2 km

Coordinate system: GDA 1994 NSW Lambert

Scale ratio correct when printed at A4

1:100,000

Date: 10/05/2023

Data sources: - DITRDC, DCS, Nearmap, Geoscience Australia
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

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Figure 7.2

Risk contours – 2055

Legend

- WSI Runway
- Western Sydney International (Nancy-Bird Walton) Airport land boundary
- Aboriginal Gazetted Places

Risk contours

- 10,000 per annum
- 100,000 per annum
- 1,000,000 per annum

Coordinate system: GDA 1994 NSW Lambert

Scale ratio correct when printed at A4

1:100,000 Date: 10/05/2023

Data sources: - DITRDC, DCS, Nearmap, Geoscience Australia
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Table 7.2 2033 individual risk contour characteristics

Contour characteristic	Runway end	
	South-west	North-east
1 in 10,000 per annum individual risk contour		
Distance from runway end	61	67
Distance outside airside limit	–	–
Total area (hectares)	0.39	0.43
Area outside airside limit (hectares)	–	–
1 in 100,000 per annum individual risk contour, excluding 1 in 10,000 contour		
Distance from runway end	975	1,042
Distance outside airside limit	–	302
Total area (hectares)	7.39	8.05
Area outside airside limit (hectares)	–	1.64
1 in 1,000,000 per annum individual risk contour, excluding 1 in 100,000 contour		
Distance from runway end	5,910	5,722
Distance outside airside limit	4,030	4,982
Total area (hectares)	100.9	106.5
Area outside airside limit (hectares)	37.86	75.90

Table 7.3 2055 individual risk contour characteristics

Contour characteristic	Runway end	
	South-west	North-east
1 in 10,000 per annum individual risk contour		
Distance from runway end	278	296
Distance outside airside limit	–	–
Total area (hectares)	2.03	2.17
Area outside airside limit (hectares)	–	–
1 in 100,000 per annum individual risk contour, excluding 1 in 10,000 contour		
Distance from runway end	2,688	2,750
Distance outside airside limit	808	2,010
Total area (hectares)	31.01	32.03
Area outside airside limit (hectares)	5.22	17.84

Contour characteristic	Runway end	
	South-west	North-east
1 in 1,000,000 per annum individual risk contour, excluding 1 in 100,000 contour		
Distance from runway end	10,538	10,823
Distance outside airside limit	8,658	10,083
Total area (hectares)	355.2	356.4
Area outside airside limit (hectares)	199.4	299.2

The extent to which the operations giving rise to these risk contours will represent a real threat to people and other facilities on the ground will be dependent on the extent to which developments are located within them. A limited number of people associated with a limited number of occupied dwellings are found to be located within the contours, as summarised in Table 7.4. For 2033, there are no dwellings located within the 1 in 100,000 per annum risk contour and 6 dwellings housing 22 people outside that contour but within the 1 in 1,000,000 per annum risk contour. Referring to the assessment criteria for individual risk significance set out in Table 3.1 in Section 3.1.3, the risks for the 2033 reference year are classified as “slight effects”, corresponding with low numbers (up to a few tens) of people exposed to an individual fatality risk between 1 in 1,000,000 per annum and 1 in 100,000 per annum. For 2055, a small number of people (5) are estimated to be exposed to risks above 1 in 100,000 per annum and 108 people are estimated to be exposed to an individual fatality risk between 1 in 1,000,000 per annum and 1 in 100,000 per annum. These quantitative risk estimates for the 2055 reference year are towards the lower end of the “moderate effects” risk significance classification, corresponding with the low numbers (up to a few tens) of people exposed to an individual fatality risk above 1 in 100,000 per annum or high numbers (hundreds to thousands) exposed to an individual fatality risk between 1 in 1,000,000 per annum and 1 in 100,000 per annum. Except for 2 dwellings in the 2055 reference year, the risk impacts are consistent with the PSA criterion of an individual fatality risk of 1 in 100,000 per annum.

Table 7.4 Summary of exposed individual and dwellings

Scenario	Dwellings	Persons
2033 – No runway preference 10^{-5} per annum	0	0
2033 – No runway preference 10^{-6} per annum	6	22
2055 – No runway preference 1 10^{-5} per annum	2	5
2055 – No runway preference 10^{-6} per annum	30	108

7.2 Societal risk

The societal risk impacts have been determined by consideration of the full range of accident scenarios involving aircraft of different sizes from the fleet mix anticipated in 2033 and 2055 and impacts in different locations with different densities of occupation. This approach provides for the determination of the probability of accidents giving rise to a defined number of fatalities from one up to the maximum number estimated for a crash of the largest aircraft type into an area with the highest density of occupation.

In accordance with the crash risk outline presented in Section 3.1.3, accidents occur predominantly during take-off and landing and accident sites are concentrated along flight paths closer to runway ends. The likelihood of a crash at any given location in the vicinity of an airport can be estimated by the use of the airport-related crash risk model, as described in further detail in Appendix A, that was applied to the estimation of individual risks set out in the previous section. The airport-related model is applicable out to around 20 to 30 km or so from the runway and this model was used to determine the societal risks across that area. This area accounts for the majority of airport-related crash locations and also encompasses the primary areas of development where crash risks are identified as a potential concern. It can therefore be expected to account for a significant proportion of the total societal risk associated with WSI operations.

Outside that area, the network of airways providing access to and from WSI involves flight predominantly over sparsely populated areas. Given the low crash rates per unit area in these locations and their low population densities, their contribution to the total societal risk can be expected to be small. However, there are several airways that involve flight over more densely populated areas of the Sydney Basin, including those supporting arrivals from the north and departures to and arrivals from the east. Taking account of the flight distances over more densely populated areas associated with the use of these routes, the possibility that these operations might also make a significant contribution to the total societal risk requires consideration. These risks have therefore been assessed using the available airways risk model which provides an estimate for the crash rate per annum along a given route based on the estimated historical crash rate per flight km and the number of flight km per annum along the route.

The number of fatalities in the event of a crash is estimated on the basis of the density of occupancy that has been characterised by reference to the available census data. This approach considers residential areas only and assumes that all individuals are permanently resident at those locations. In practice, individuals will leave these residential areas for periods of time and so the risk associated with crashes into them will be over-stated. On the other hand, there will be additional crash scenarios involving impacts into workplace and other sites that are not explicitly covered by this approach. These 2 factors can be expected to balance one another to some extent such that the overall estimate of residential impacts will provide a reasonable representation of the true situation. This simplified approach is therefore considered adequate for the current purposes and is preferred due to the ready availability of residential data to support it.

Further details of the approach employed for the estimation of societal risk are provided in Appendix C.

The findings of the societal risk assessment are summarised in terms of the "FN curve" in Figure 7.3 and are further described in terms of summary characteristics shown in Table 7.5. The assessment indicates that crashes involving one or more fatalities will be around 1 in 4,245 year and 1 in 1,416 year events in 2033 and 2055, respectively. The average number of fatalities estimated for the full range of scenarios involving crashes of different sized aircraft into the range of population densities encountered along flight paths is around 9.6 and 10.7 for 2033 and 2055, respectively. The potential for incidents giving rise to a hundred or more third party fatalities on the ground is identified where larger aircraft crash in more densely populated areas but such events are predicted to be very uncommon, with estimated rates of 1 in 7.3 million years and 1 in 1.3 million years for 2033 and 2055 movement levels, respectively. Such risks can be seen to be very small when viewed in the context of the number of fatalities anticipated among those on board an aircraft during a crash and the very considerably greater likelihoods involved.

Table 7.5 Summary of societal risk assessment estimates for 2033 and 2055

Risk measure	2033	2055
Crashes involving 1 or more fatalities per annum	2.36×10^{-4}	7.06×10^{-4}
Crashes involving fatalities (return period in years)	1 in 4,245	1 in 1,416
Average number of fatalities per crash	9.6	10.7
Expectation value (fatalities per annum)	2.27×10^{-3}	7.55×10^{-3}
Expectation value (return period in years)	1 in 441	1 in 132
Scaled risk integral value	6,770	24,244

When assessed against the preferred significance criteria, the societal risks described by the FN curves in Figure 7.3 for both 2033 and 2055 are seen to be within the middle to lower risk part of the ALARP region. These risks can therefore be considered acceptable, provided that no further practicable means for mitigating these residual risks is available. Given the inherent risks of crashes, further mitigation might only be provided by flight path relocation away from populated areas to reduce the likelihood of third-party fatalities on the ground in the event of a crash. It may readily be concluded that risks associated with take-off and landing in the more immediate vicinity of WSI may be regarded as meeting the ALARP requirement. The location chosen for the runway means that overflight of developed areas during take-off and landing is relatively limited, in particular to the south-west of the runway. Overflight of developed areas to the north-east of the runway is substantially avoided, for example by turns shortly after departure. Within the constraints associated with the requirements for runway alignment on approach and more generally with routing to and from WSI airspace, overflight of developed areas during take-off and landing can therefore be considered to be effectively minimised by flight path design, as far as is practicable. Expectation values, representing the number of fatalities on average in a year to be expected from the range of identified crash scenarios in terms of the number of fatalities (n) and event frequencies (F), are also shown in Table 7.5. This measure provides a relatively simple means of combining the 2 elements of societal risk into one number for comparison with other risks. The fatality rates of 1 in 441 years and 1 in 132 years estimated for 2033 and 2055, respecitively, can be seen to represent relatively low risks but the expectation value is not employed formally as a basis for defining any risk acceptability criteria.

The review of airways employed for access to and from WSI take-off and final approach paths supporting the societal risk assessment that is presented in Appendix C has demonstrated the limited extent of overflight of populated areas. Five of these routes have been identified to involve flight over more populated areas whilst, outside the limits of the airport-related crash risk model, the remainder involve flight over generally quite sparsely populated areas. If some relocation of these 5 routes were possible, some reduction in the third-party risk might be provided. In practice, the contribution made to the total risk from operations along these flight paths is small compared with the total risk and the scope for risk reduction is therefore limited. Given the limited risk reduction that might be available, this option could be considered beneficial only if it did not compromise operational safety and efficiency more generally.

As shown in Figure 7.3, the total societal risks for 2055 slightly exceed the risk limits identified under the high fatality risk aversion criteria that have been identified (State of NSW 2011b, Safe Work Australia 2012) in previous Australian guidance. On the other hand, application of the scaled risk integral identified in guidance from the Republic of Ireland to account of high fatality risk aversion indicates a relatively moderate societal risk. The value of 24,244 determined for 2055 compares with a reference value for “broadly acceptable” or “negligible” risk of 2,000 and a reference value for “significant” risk of 500,000. That finding is generally consistent with the conclusions to be drawn from the application of UK criteria: the estimated risks are in the ALARP region, above the lower limit where risks can be considered entirely negligible but below the upper limit for which risks might be considered unacceptable.

Consideration of this individual case, having regard to likely number of third-party fatalities in comparison with scale of potential onboard fatalities, further supports this conclusion. The average number of third-party fatalities, estimated at around 10, is very substantially below the number of fatalities that would be expected onboard the typical passenger aircraft and does not represent a particularly high number that would merit the application of a significant high fatality risk aversion factor. In addition, for higher numbers of third-party fatalities, of the order of 100 or more, the risk is below the limit identified in the high fatality risk aversion criteria that have been identified in previous Australian guidance. These observations underline the impracticability of those criteria, the limitations of which have already been identified in Section 3.1.3. Third-party risks at least at this level if not somewhat higher would be expected at other airport facilities serving comparable numbers of movements.

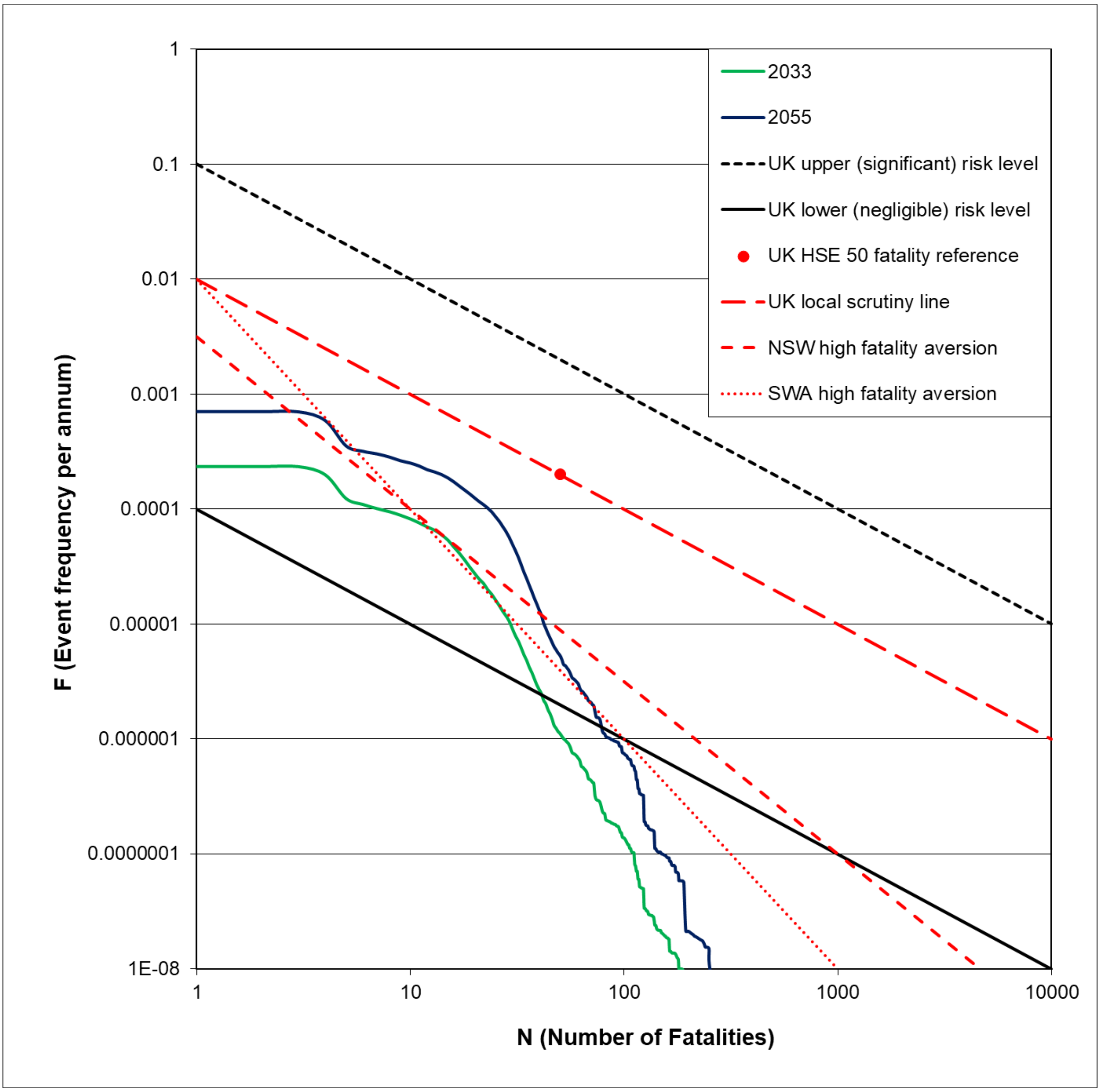

Figure 7.3 Societal risk FN curves for 2033 and 2055

7.3 Risks to critical infrastructure

7.3.1 Assessment approach outline

In accordance with the outline presented in Section 4.1, it is appropriate to consider risks to specific elements of critical infrastructure in addition to the wider fatality risks to people live in the vicinity of WSI. A list of specific infrastructure targets has been identified for assessment, as follows:

- transport links in the more immediate vicinity of flight paths, including Elizabeth Drive, the A9, M7, M4 and Nepean River Bridge crossing
- DEOH which serves as a munitions store
- major hospitals
- reservoir facilities, both from the perspective of structural integrity and contamination risk to water supplies in the event of a crash or by fuel dumping in an emergency
- fire initiation risk, in particular in relation to the GBMA.

As demonstrated by the assessment of individual risk set out above in Section 7.1, the areas in the vicinity of WSI subject to relatively high risk are located along flight paths towards each runway end. The individual risk contours provide a guide to the areas in the vicinity of the runway and flight paths at WSI that are subject to more elevated levels of risk and those areas where risks at any individual site can normally be considered to be negligible and acceptable. No infrastructure that might be considered particularly sensitive or critical is located within the area of elevated risk delineated by the 1 in 1,000,000 per annum individual risk contour for the 2055 case. The above list of infrastructure receptors has been drawn up in accordance with those observations, on that basis this limited selection will adequately serve to demonstrate the levels of risk to which specific facilities more generally can be expected to be exposed from aircraft crash which vary according to the proximity of sites to flight paths and the overall scale of the facilities and associated target area.

Impact event frequencies have mostly been estimated using the airport-related crash risk model, supported by use of the airways model for a limited number of assessments of sites further from the runway, in accordance with the general modelling approach employed to assess third party fatality risks.

7.3.2 Transport link impact risks

Existing road links cross the runway extended centreline immediately to the east and to the west of the runway, in areas where the flight paths are concentrated along the runway extended centreline. Elizabeth Drive passes through the area covered by the 1 in 100,000 per annum contour for the 2055 reference year at the north-east runway end and the A9 passes through the area covered by the 1 in 100,000 per annum contour for the 2055 reference year at the south-west runway end. Given that no individual will be expected to spend a significant amount of time within this area of elevated risk but will pass through transiently, it can be expected that no individuals will be subject to an individual risk above the identified negligible level of 1 in 1,000,000 per annum. It is nevertheless recognised in NASF Guideline I that many people may be using a transport link at any given time. The guidance there indicates that transport links within a PSA should be assessed in terms of the density of people using them that might be exposed to the risk. Similar provisions are identified under UK PSZ policy where experience of the assessment of individual schemes indicates that transport links that pass-through areas subject to these sorts of levels of risk can generally be considered to be acceptable. The risks associated with these roads have therefore been quantified, using the modelling approach employed earlier to estimate individual and societal risk, as described in the previous sections of this report.

The risks of impact with the A9 are estimated to be 5.36×10^{-5} per annum (1 in 18,641 years) and 1.54×10^{-4} per annum (1 in 6,495 years) for 2033 and 2055, respectively. The risks of impact with Elizabeth Drive are estimated to be 4.28×10^{-5} per annum (1 in 23,367 years) and 1.23×10^{-4} per annum (1 in 8,137 years) for 2033 and 2055, respectively. These risks were estimated by reference to the crash risks that are predicted by the model across the carriageways out to distances of several kilometres either side of the runway extended centreline. These risk estimates demonstrate that the risks are very much concentrated closer to the runway extended centreline. The total risk estimated for the identified routes depends on the length assessed. For the purposes of evaluating the significance of the identified potential impacts, it may be more useful to consider the impact risks per unit length per annum for comparison with some reference provided by wider statistics for road disruption. For 2055, the maximum risk per unit length of carriageway determined for Elizabeth Drive along the runway extended centreline at a distance of 780 m from the runway end is 4.2×10^{-4} impacts per km per annum whilst the risk at around 2.5 km to the side of the extended centreline is a thousand times smaller. For the A9, at a distance of 1.3 km from the runway end, the comparable risk is 2.5×10^{-4} impacts per km per annum, again reducing by a factor of 1,000 at a distance of around 2.5 km to the side of the extended centreline.

By way of comparison, a further assessment has been made of the risks of impact with the M7 which is located further from the runway end and outside the limit of the 1 in a million per annum risk contour but nevertheless crosses the line of the arrival routes to Runway 23 and may therefore be subject to an elevated risk of impact. The risks of impact with the M7 are estimated to be 3.37×10^{-6} per annum (1 in 296,742 years) and 9.14×10^{-6} per annum (1 in 109,396 years) for 2033 and 2055, respectively. These risks are approximately a factor of 15 times lower than those associated with the A9 and Elizabeth Drive. Given its broadly similar proximity to flight paths, the risk impacts for the M4 can be expected to be at a comparable level. Other transport links are located further from flight paths than the 3 routes that have been quantitatively assessed and can therefore be expected to be at lower risks of impact.

The potential impact consequences will include fatalities to road users and infrastructure damage. The area affected in the event of an aircraft crash is estimated to be of the order of 0.5 to 0.6 ha for 2033 and 2055 fleet mixes, respectively, equivalent to a circle of 40 m radius. On that basis, the number of fatalities for typical densities of use of road links can be expected to be of the order of tens or fewer, assuming that that several vehicles each with several occupants are impacted. This value is generally consistent with the average number of fatalities identified for impacts in residential areas in the societal risk assessment presented in the previous section. Given the identified event frequencies, the overall risks associated with these scenarios would not be judged to be particularly significant when assessed against the available societal risk criteria. The identified risks for these transport link impact scenarios that have been assessed do not represent additional risks that need to be included explicitly in the societal risk assessment. As has already been discussed in the previous section, the societal risk assessment uses an assumption of permanent occupation of dwellings and will therefore overstate those risks due to the failure to take account of the times when individuals are away from home, for example using the transport network. The societal risks associated with use of the transport network by the local population is therefore inherently covered by the simplified approach to the treatment of occupancy that has been adopted in the societal risk assessment.

For impacts with standard carriageways, the associated disruption can be expected to be limited with repairs readily made over a relatively short period of time during which alternative routes available from the wider network provide mitigation prior to clean up operations being completed. Longer term disruption might arise from impacts at interchanges that lead to damage to bridge structures. However, closer inspection shows that there is limited scope for such events, given the proximity of interchanges to flight paths. The M4/M7 interchange is identified as the major interchange at most potential risk due to its proximity to Runway 23 arrival routes. However, it is located around 1.5 km from these routes where the impact risk is not particularly concentrated. Taking account of the area of the target presented by the interchange of around 35 ha and the unit area impact probability, an impact anywhere across it is estimated to be a 1 in 1,000,000 year event.

For smaller elements of infrastructure further from flight paths, the impact risks will be lower. By way of example, the risk of impact with the Nepean River Bridge crossing has been estimated as 5×10^{-9} per annum, equivalent to a 1 in 200 million year event. Whilst the consequence may be more severe in the event of elements of the transport infrastructure such as the Nepean River Bridge crossing, the likelihood of such events will be low and hence the risks may be regarded as low overall.

7.3.3 Defence Establishment Orchard Hills

The DEOH is a large military site of around 1,740 ha, located to the north of the east end of the WSI runway. It is some distance from Runway 23 approach flight paths but some Runway 05 departure routes pass close by the DEOH. It serves for training and as a munitions store. Given its munitions storage function, some specific consideration of the risk of aircraft impact and potential associated knock-on impacts is appropriate.

Application of the airport-related crash risk model using the fleet mix assumptions that support the third-party risk assessment indicates crash risks across the DEOH of around 10^{-5} per annum (1 in 100,000 years) and 2.3×10^{-5} per annum (1 in 43,000 years) for 2033 and 2055, respectively. Much of the site is open space and the risk of impact with site infrastructure will be lower than these estimates. The munitions storage area covers an estimated 90 ha to the north-east of the site. On that basis, taking further account of the crash impact area and the spacing of munitions storage facilities, the risks of an impact with a munitions storage building are estimated to be 5×10^{-7} per annum (1 in 2 million years) and 1.2×10^{-6} per annum (1 in 835,000 years) for 2033 and 2055, respectively.

The spacing of the storage buildings is similar to the typical area affected by a crash, as determined by the empirical consequence model. Accordingly, crashes can be expected normally to affect a single building only or 2 buildings in the case of impacts of larger aircraft. It is understood that the protocols for munitions storage at the site will limit the knock-on impacts to other storage buildings in the event of an explosion at one building. Accordingly, the consequences of an impact are expected to be those resulting directly from an impact only.

7.3.4 Major hospitals

Three major hospitals have been identified in the general vicinity of WSI: Penrith Hospital, Liverpool Hospital and Westmead Hospital. They represent relatively large potential exposed areas for an aircraft crash, of between around 15 to 25 ha, compared with the estimated crash impact areas of 0.5 to 0.6 ha. A crash can therefore be expected to affect a small proportion only of these sites, estimated to be around 2 per cent to 4 per cent. The highest overall site crash risk probabilities are estimated for Penrith Hospital which is closer to higher levels of flight activity than the other 2 hospitals. Crash risks at Penrith Hospital of 5.4×10^{-8} per annum (1 in 19 million years) and 1.44×10^{-7} per annum (1 in 7 million years) have been estimated for 2033 and 2055, respectively, using the airport-related crash risk model. Flight activity near Liverpool and Westmead Hospitals is much lower and lower crash risks have been estimated for these sites using the airways-related crash risk model.

Given the densities of occupation of these sites, high levels of fatalities may potentially arise in the event of an aircraft impact. However, the scale of the fatalities is unlikely to exceed the upper levels that have been estimated according to the societal risk assessment described in the previous section. Overall, taking further account of the low event frequencies, the risk associated with these scenarios can be considered to be low and acceptable when assessed against the available societal risk criteria.

7.3.5 Warragamba Dam and Prospect Reservoir

A limited number of Runway 23 departures pass close to the Warragamba Dam barrage whilst the Prospect Reservoir lies relatively close to but not directly beneath the Runway 23 approach path.

The probability of an impact directly on the barrage of the Warragamba Dam is estimated using the airport-related crash risk model to be 2.5×10^{-8} per annum (1 in 40 million years) and 7.5×10^{-8} per annum (1 in 13 million years) for 2033 and 2055, respectively. The extent to which the identified impact scenarios covered by these frequency estimates would have the potential to cause significant structural damage has not been considered in any detail. Some impact scenarios, for example those involving smaller aircraft and crashes towards the ends of the barrage length that has been assessed, including the auxiliary spillway, may have a limited structural impact. Nevertheless, the possibility of substantial structural damage for a proportion of the foreseeable scenarios should be assumed for the purposes of this assessment, unless other more detailed structural assessment indicates otherwise. Overall, structural collapse of the barrage with a frequency somewhat less than 1 in 13 million years is therefore indicated.

A substantially larger area of water of Lake Burragorang will be exposed to a crash risk and the likelihood of events giving rise to potential contamination will be greater than the above impact risk estimates. Risks of crashes into the lake will be dominated by those associated with Runway 23 departures which cross the water within the area over which the airport-related risk model is applicable and Runway 05 arrivals which are predominantly cross the water when runway-aligned beyond that limit and have been assessed using the airways model. For those operations, the frequency of impacts in the lake are estimated to be 4.1×10^{-6} per annum (one in 240,000 years) and 1.2×10^{-5} per annum (one in 87,000 years) for 2033 and 2055, respectively.

Whilst contamination of the water is a possibility in the event of a crash, it can be expected that significant adverse impacts will not necessarily occur in all instances. The Lake Burragorang capacity is 3 million tonnes and limited fuel spillages may have limited impacts on water quality, given the dilution involved. Water treatment systems may have the capacity to mitigate the likely impacts on drinking water supplies but this possibility has not been considered in any further detail here.

The barrage impact risks for the Prospect Reservoir are estimated to be 4.7×10^{-8} per annum (1 in 21 million years) and 1.4×10^{-7} per annum (1 in 7 million years) for 2033 and 2055, respectively. The risks of impacts in the water with the potential to cause contamination are estimated to be 3.0×10^{-6} per annum (1 in 330,000 years) and 8.3×10^{-6} per annum (1 in 120,000 years) for 2033 and 2055, respectively. These event frequencies are similar to those estimated for the Warragamba Dam and Lake Burragorang.

7.3.6 Blue Mountains and other fire initiation risks

Given the fuel load on aircraft, particularly during and shortly after take-off, fuel fires are a potential concern in the event of a crash. Commonly encountered fire impacts following impacts are taken into account in the consequence model used for the assessment of fatality risks set out in Sections 7.1 and 7.2. The potential for wider knock-on bushfires in the event of a post-impact fire also merits attention. Jet aviation fuel is of relatively low volatility and requires a fairly powerful ignition source for fire initiation which may be present in some impacts. Previous analysis (Byrne 1997) of historical incidents has indicated around 50 per cent of crashes involve post-impact fire.

As set out in Table 7.1, the estimated crash rate during take-off and landing for 2055 operations is estimated to be around 1 in 50 years and the corresponding post-impact fire rate is therefore estimated to be around 1 in 100 years. This rate applies in the more immediate vicinity of the runway and covers the majority of the crash events. An additional but relatively small risk applies along airways, beyond the immediate runway and has been estimated using the available airways model, as described in Appendix C. Given its importance, particular importance, specific attention has been given to the crash risk in the GBMA.

Operation of flight paths over the GBMA is found to present a low risk of introducing fire through aircraft accidents. This is based on an estimate for the crash rate from aircraft during flight over the GBMA ranging between approximately 1 in 1,700 to 1 in 2,400 years in 2055, as set out in Section C3, Appendix C, and a post-impact fire initiate rate of around half that value: 1 in 3,400 to 1 in 4,800 years in 2055. The range in the crash rate risk reflects the likely distribution of traffic movements using the flight paths over the GBMA. This estimate covers all events throughout the year, including events outside the season of primary bushfire risk. Compared with the current fire initiation rates from other causes, this risk can be seen to be very small.

Chapter 8 Assessment of other risks

8.1 Fuel dumping

8.1.1 Historical incident review

The ATSB National Aviation Occurrence Database provides access to accounts of accidents and incidents that have been reported to the ATSB since 1 July 2003. The database is searchable by type of occurrence and includes a "Consequential event – fuel dump/burn off" category. Using that search category, a total of 145 such events involving air transport movements in Australian airspace have been identified in the database. Only one of those events occurred before 2010 and it appears that systematic reporting and recording of these sorts of events did not begin until 2010.

For the most part, the occurrences were evidently relatively minor incidents, and the database provides quite limited information about them, including date, location, aircraft type and a short incident summary. The available summaries specifically identify whether fuel burn off or dumping occurred in 78 per cent of cases. For the remainder, reference to the aircraft type provides a basis for determining whether fuel burn off or dumping occurred. Overall, fuel dumping is understood to have occurred in 43 per cent of the occurrences. The summaries also provide a basis for determining the phase of flight in which the requirement for aircraft weight reduction by fuel burning or dumping arose.
Most occurrences (77 per cent) were associated with problems that occurred shortly after take-off or during the climb. One occurrence was associated with landing and the remaining occurrences were enroute incidents.

Fuel dumping in accordance with appropriate procedures (specifically, the Manual of Air Traffic Services (MATS) Section 4.2.11 – Fuel Dumping) can generally be expected to ensure that there are no impacts at ground level. Fuel jettisoned at a sufficient altitude will volatise as it falls and is completely dispersed as vapour before any liquid reaches ground level to avoid any ground contamination.

The entries in the ATSB National Aviation Occurrence Database do not provide any detail concerning the nature of the identified fuel dumping events. Given the broader safety implications, the ATSB conducted detailed safety occurrence investigations of 6 incidents in which fuel dumping was reported that provide further information on the fuel dumping procedures involved. Brief summaries of relevant aspects of these incidents are summarised in Table 8.1. It is evident from these reports that fuel dumping occurred at altitudes of 7,000 ft or more on all 6 occasions. On 4 occasions, the reports explicitly identify that the fuel dumping took place over the sea or identify a specific location that is over the sea, in one case after a deliberate diversion from the original flight path. On the remaining 2 occasions, it appears from the departure and intended destinations and wider circumstances of the incidents that the fuel dumping took place over the sea.

An ATSB safety investigation report describes a further relevant incident that occurred on 21 November 2013 in which a problem encountered on take-off led to a decision to return to the departure airport. On this occasion, the problem was encountered when the aircraft was climbing through an altitude of 1,360 ft and a return to Brisbane Airport was initiated with the aircraft at a height of 2,000 ft. Fuel was not jettisoned, and an overweight landing was executed.

The report on this incident is focused on the technical issues that caused the problems concerned and does not mention the circumstances under which the crew elected to undertake the overweight landing. However, it is evident that the crew had encountered an air data system failure with the apparent capacity to seriously threaten the safety of the aircraft. Under those circumstances, it appears that the crew felt that an immediate return to the departure airport was the preferred option. Given the altitude at which the decision was made, fuel dumping in accordance with appropriate procedures, i.e., at sufficient altitude to avoid ground level impacts, was not an option and the crew elected to perform an overweight landing. The report records that the actual landing weight was 199.7 tonnes while the maximum landing weight was 182 tonnes and that, after an overweight landing, depending on the vertical speed and acceleration at touchdown, an aircraft inspection may be required. Performing an overweight landing therefore has operational and cost implications since it may lead to an aircraft being taken out of service, but the flight crew can exercise their discretion according to the circumstances which they evidently did in this instance. Since fuel dumping at the altitude that the aircraft had reached was not appropriate and further climb to execute fuel dumping at altitude was not considered to be a safe option, an overweight landing was the preferred option, despite its operational and cost implications.

Table 8.1 Selected aircraft fuel jettisoning incidents in Australia since 2009

Date	Incident summary
20 March 2009	An Airbus A340-541 sustained a tail strike and overran the end of the runway on departure from Melbourne Airport, Victoria. The flight crew climbed the aircraft to 7,000 ft and circled over Port Phillip Bay, Victoria, while jettisoning fuel to reduce the aircraft's weight. The flight crew then returned the aircraft to Melbourne Airport for an uneventful landing on Runway 34.
7 May 2010	A Boeing B747 suffered a tail strike on take-off from Sydney (Kingsford Smith) Airport that went unnoticed by the crew. The crew was advised by the Sydney Terminal Control Unit of the strike and having reached an altitude of 8,000 ft, completed the appropriate incident checklist. After dumping fuel to bring the aircraft to below its maximum landing weight, the aircraft was landed at Sydney (Kingsford Smith) Airport. The ATSB report does not identify the location at which the fuel dumping took place, but it appears that the aircraft will have been over the sea when reaching 8,000 ft, given that San Francisco was the intended destination.
15 November 2010	A Boeing B747 departed Sydney (Kingsford Smith) Airport on a scheduled passenger service to Buenos Aires, Argentina. While on climb, the flight crew noticed a strong electrical smell in the cockpit, followed by smoke emanating from the flight instrument system control panel. The flight crew elected to return to Sydney (Kingsford Smith) Airport, a fuel dump was commenced and a descent to 10,000 ft initiated. The ATSB report provides no indication of where the fuel dumping took place, other than before descent to 10,000 ft, but it appears likely that the aircraft will have been over the sea after the aircraft had reached that altitude, given that Buenos Aires was the intended destination.
11 November 2012	An Airbus A380 aircraft, departed Sydney (Kingsford Smith) Airport for Dubai International Airport. While climbing through an altitude of approximately 9,000 ft, the crew reported hearing a loud bang, accompanied by an engine No. 3 exhaust gas temperature over-limit warning. Shortly thereafter, the engine went through an uncommanded shut down. The crew jettisoned excess fuel and returned the aircraft to Sydney (Kingsford Smith) Airport for a safe landing and disembarkation of the passengers and crew. The aircraft had originally been travelling north-west when engine failure occurred, but the ATSB report shows that an easterly flight path to the sea was then taken where it is understood the fuel was dumped at an altitude of around 9,000 ft or more.
21 November 2013	An Airbus A330, encountered control problems on take-off from Brisbane Airport, associated with an airspeed indication failure, while climbing through a pressure altitude of 1,360 ft. A return to Brisbane Airport was initiated with the aircraft at a height of 2,000 ft. Fuel was not jettisoned and an overweight landing was executed.
21 December 2015	A Boeing B787 enroute from Melbourne Airport to Singapore Changi Airport at 40,000 ft and about 250 nm (463 km) north of Darwin, encountered erratic airspeed indications which necessitated a precautionary diversion to Darwin. Fuel was jettisoned ahead of the landing, evidently at a significant altitude and over the sea.
17 April 2016	A Boeing B787-9 suffered an electrical fault on catering equipment shortly after take-off from Sydney (Kingsford Smith) Airport which was isolated by cabin crew. A precautionary decision to return to Sydney (Kingsford Smith) Airport was made and, about 59 nm (110 km) east of Port Macquarie, NSW, the crew commenced a return to Sydney (Kingsford Smith) Airport. As the aircraft was more than its allowed landing weight, fuel was dumped during the descent. The point at which the decision to return to Sydney (Kingsford Smith) Airport was made, the aircraft was around 16 nm (30 km) to the north of its departure point and, whilst the ATSB report does not identify the aircraft height at that time, it is evident that it will have been at several thousand feet, as well as over the sea.

The general conclusions to be drawn from the review of incidents identified in the ATSB National Aviation Occurrence Database is that fuel dumping can be carried out safely and without any impacts at ground level where appropriate procedures are followed. Review of the wider international data set supports that general conclusion.

However, one incident in which fuel dumping caused contamination at ground level has been identified. This incident can be regarded as an exception since the available information describing it indicates that the crew did not follow appropriate procedures. Delta Air Lines Flight 89 was a scheduled flight from Los Angeles to Shanghai. On January 14, 2020, the Boeing B777-200ER conducting the flight had engine problems shortly after take-off. While returning to the origin airport for an emergency landing, it dumped fuel over populated areas adjacent to the city of Los Angeles. No official US FAA report on the incident has been published but information is available from press and other unofficial sources. These sources state that the aircraft had suffered a compressor stall affecting one engine but could be safely flown on the remaining engine. The incident occurred over the Pacific Ocean during the climb. It is reported (https://en.wikipedia.org/wiki/Delta_Air_Lines_Flight_89) that air traffic control asked Flight 89's pilots if they wanted to remain over the ocean to dump fuel, but the pilots declined, saying "we've got it under control... we're not critical." Controllers again asked, "OK, so you don't need to hold or dump fuel or anything like that?", to which the pilots responded, "Negative." While over land and approaching for an emergency landing, the aircraft subsequently dumped fuel over a 5 nm (9 km) portion of Los Angeles. It is therefore evident from the available narrative that the incident could have been managed effectively by fuel dumping at an appropriate altitude over the sea. In the absence of an FAA report which appears to have been delayed due to on-going legal proceedings, no further insight into why normal procedures were not followed. This incident can therefore be regarded as an anomalous event that is not representative of future WSI operations.

8.1.2 Quantitative risk assessment

From the perspective of potential risks to land in the general vicinity of WSI, fuel dumping events associated with failures during take-off and climb will be of primary relevance. The available statistics from 2010 onwards indicate 144 occurrences of which 43 per cent involved fuel dumping and 77 per cent of which occurred on take-off, representing a total of 48 fuel dumping incidents following take-off. Referring to the operational statistics presented in Table A.3 and Table A.4 (refer to Appendix A), a total of 9,281,707 commercial air transport take-off operations are estimated to have taken place over the period 2010 to 2020 from which an incident rate of 5.17×10^{-6} per take-off movement is estimated. For a movement rate of 226,000 per annum, as single runway operations at WSI approach capacity, that rate translates to slightly less than one fuel dump event per annum.

As shown by the review described in the previous section, these incidents can be expected not to give risk to any impacts at ground level. No such occurrences are identified to have occurred in the history of commercial jet aviation in Australia. On that basis and following the approach using Poisson statistics applied to the estimation of jet aircraft crash rates, as set out in Appendix A, the likelihood of a fuel dumping event giving rise to ground level impacts can be expected to be less than the likelihood of an aircraft crash during take-off or landing at WSI.

In terms of the potential risks to sensitive components of the environment such as water supplies, rational analysis based on the available statistical data indicates that fuel dumping represents less of a threat than a direct aircraft crash impact. A fuel dumping incident giving rise to impacts at ground level anywhere in the vicinity of WSI is estimated to be extremely remote. Events with tangible impacts on potentially sensitive receptors will be less likely and therefore be exceedingly remote.

8.1.3 Conclusions

Reference to the available incident data shows that fuel dumping is a relatively uncommon non-standard operational requirement that will have no impacts at ground level if carried out in accordance with appropriate procedures. It may therefore be concluded that there will be no significant adverse impact associated with fuel dumping associated with WSI operations. Whilst it cannot necessarily be guaranteed that such impacts could never occur, the historical record indicates that they will be very remote events.

8.2 Objects falling from aircraft

A total of 189 occurrences of objects falling from aircraft involving commercial air transport movements between 2003 and 2022 have been identified from a search of the ATSB National Aviation Occurrence Database. Across all phases of flight, 115 occurrences out of that total were identified as being associated with commercial air transport movements of fixed-wing turbo-fan and turbo-prop aircraft which may be considered representative of future operations at WSI. Approximately 50 per cent of these occurrences took place in the general vicinity of airports during take-off, initial climb, approach and landing. Referring to the number of flights over that period of time, it is estimated that these sorts of incidents occur during those phases of flight in around 1 in 300,000 flights (1 in 600,000 take-off and landing movements). On that basis, it is estimated that such incidents would be one in 3-year events for the level of activity forecast in the 2055 reference year.

Two of the identified occurrences affecting fixed wing commercial air transport movements are identified as serious incidents and the remainder are identified as incidents. No injuries are reported to have occurred in any of these occurrences and those classified as serious incidents were evidently given that classification due to the potential threat to aircraft safety associated with the loss of the falling object rather than any identified threat to third parties.

Further insight into the potential threat to third parties from objects falling from aircraft can be gained from review of the objects concerned in the identified occurrences. A wide variety of objects are involved in these occurrences, including maintenance inspection panels as a relatively common item, baggage from aircraft holds following cargo door failure events and various smaller items such as windscreen wipers and VHF antennas. Whilst these can all be seen to be relatively small items, some of them at the upper end of the range of sizes might be expected to lead to potentially significant injury in the event of a direct impact with an individual on the ground. Given the possible severity of such incidents, some further consideration of this scenario is appropriate.

It Is evident from qualitative considerations based on object size that the consequences of an impact associated with a falling object will be substantially smaller than those associated with an aircraft impact. However, risk is characterised in terms of incident frequency as well as consequence and the frequency of incidents involving objects falling from aircraft is greater than that for aircraft crash events. Nevertheless, the risks associated with objects falling from aircraft can be shown to be small compared with the risks associated with aircraft crash when both elements are considered together.

As set out in Table 7.1 in Section 7.1, the impact area associated with the average aircraft impact in the event of a crash is estimated to be 0.629 ha: over 6,000 m^2. The area affected by the largest of the items identified in occurrences involving objects falling from aircraft will be very considerably smaller. Not only are the items themselves much smaller, the velocities with which they will impact the ground will also be much smaller. The velocity of small items that fall from aircraft will be significantly limited by friction. Any forward velocity at aircraft speed at the point of detachment of the object will reduce and the object will tend towards a downwards terminal velocity, determined by its weight and surface area that determines the decelerating friction forces acting upon it. On that basis, the impact area associated with the largest of the objects identified as falling from aircraft will not be greater than around 1 m^2, over 6,000 times smaller than the average aircraft impact area in 2055, and the scale of the associated consequence of a physical impact can be expected to reflect that.

Compared with the one in 3-year rate of an object falling from aircraft, the aircraft crash rate estimated in the 2055 reference year is around one in 50 years, a factor of around 17 differences between the 2 rates. Quantifying risk as the combination of frequency and consequence, it is readily confirmed that the risk associated with objects falling from aircraft is very small compared with the risk associated with aircraft crash. Taking together the factor of 6,000 or more in the scale of the consequence and that factor of 17 difference in the incident rates, the risk associated with objects falling from aircraft is estimated to be more than 300 times smaller than the risk associated with aircraft crash. Given that the risk associated with aircraft crash was shown to be small and acceptable when judged against identified risk criteria, it is evident that the risk associated with objects falling from aircraft is very small and can similarly be considered acceptable in return for the benefits associated with air transport.

The above general conclusions are supported by reference to wider international incident data. In addition to the various items identified from the ATSB occurrence database, there are reports of metal debris falling to ground following aircraft engine failure events. There are also multiple reports of ice derived from aircraft falling to ground, the primary cause of which is reported to involve frozen condensation slipping off the aircraft wings as they reach warmer air on their approach to land. There are some reports of property damage associated with these incidents and one report of minor injury associated with falling ice that hit someone on the ground. The overall conclusion to be drawn from these observations is that the risks associated with objects falling from aircraft is negligible and can therefore be considered to be acceptable.

8.3 Wake vortex damage impacts

8.3.1 Background

In generating the lift forces necessary to allow an aircraft to fly, its wings generate movements in the volume of air through which the aircraft passes. The most significant of these are spiralling movements of air flowing from each wingtip leading to a pair of wake vortices that trail behind the aircraft and tend to descend as they rotate. Vortices are an unavoidable consequence of aerodynamic lift and are generated by all aircraft in all phases of flight. In most instances, the vortices dissipate into the general air turbulence without causing any physical impacts. However, during landing operations when aircraft are relatively close to the ground, shortly before touchdown, vortices sometimes reach the ground when they have sufficient power to cause building damage.

The vortices left behind following passage of an aircraft initially descend at several hundred feet per minute. If generated at altitude, the vortices from a large aircraft will dissipate and stop descending after falling about 500 ft to 900 ft. At relatively low altitude, the vortices fall initially to about 100 ft to 200 ft above the ground, where they stop descending and separate laterally due to ground effects. In still wind conditions, vortices will descend directly beneath the path of the generating aircraft, but they will move laterally from the flight path in cross wind conditions. Further general background into the behaviour of vortices is provided elsewhere (Halcrow, 2010).

Whether a vortex persists for sufficient time and with sufficient energy to cause damage at or near ground level depends on its energy at generation, the height at which it originated and weather conditions. A ground level vortex strike is more likely to occur and be damaging when conditions are still, and the aircraft is low. The initial strength of the vortex is proportional to the aircraft's weight but reduces with aircraft speed and wingspan. The strongest vortices are therefore generated by heavy aircraft flying at low speed, during approach.

Vortex damage incidents typically involve the disturbance of tiles or slates on the roofs of traditionally constructed houses. The pressures generated by aircraft trailing wake vortices can exceed the normal design load for roofs. Damage is generally confined to small-format roofing elements, such as tiles and slates. Tiled roofs in the UK are susceptible because the tiles are mostly laid down without being nailed firmly to the wooden battens that they hang from. The tiles are held in place largely by gravity and a vortex can lift them up and dislodge them. The mitigation that is typically provided at large airports, like Heathrow where wake vortex strikes are an issue, is to fix the tiles firmly with nails in areas close to landing flight paths that are susceptible to damage. Wider structural damage to buildings is not a normal feature of wake vortex impacts.

In summary, vortex damage to buildings occurs across a limited area along approach flight paths relatively close to runway ends. The likelihood of vortex damage being encountered in any location at any given airport is dependent upon several different factors, as follows:

- the size of the aircraft operating at the airport
- the vertical margin between the approach path and buildings along it
- the lateral margin between the approach path and buildings along it
- weather conditions at the time of the operation
- the nature of the building construction and its inherent susceptibility to damage when exposed to a wake vortex that reaches it.

Overall, vortex damage is more frequently encountered at busier airports serving larger wide-body jets (WBJ) where housing is located close to the flight paths and runway ends. Given the nature of operations and proximity of flight paths to housing, incidents at London Heathrow Airport (Heathrow Airport) have been a primary focus of attention. The reported characteristics of incidents at Heathrow Airport, in particular locations where damage occurred, provide a useful reference point for evaluating to potential for wake vortex damage associated with operations at WSI. It is reported that a Heathrow Airport study found that 80 per cent of damage cases occurred within 2.1 km of the runway end. Other evidence indicates many of the 1,990 strikes around Heathrow Airport occurred within 4 km and within a funnel of around 14 degrees either side of the extended centreline from the runway threshold. Damage may more occasionally arise from vortices associated with smaller narrow-body jet (NBJ) aircraft (Halcrow, 2010) but such incidents can be expected to be located much closer the runway ends and approach paths than the limits identified above for WBJ operations at Heathrow Airport.

There appears to be no evidence for direct adverse impacts of wake vortices on people. The possibility of harm from dislodged tiles is acknowledged. However, unlike structural damage caused by strong winds, vortex damage is generally quite localised. For example, dislodged tiles are often lifted and dropped back onto the roof top and therefore do not give rise to a particularly high risk of knock-on adverse public safety impacts.

Formally, liability for damage or injury caused by the operation of an aircraft normally lies with the aircraft owner. However, it is usually quite difficult or even impossible for a property owner to identify the aircraft which generated a damaging vortex. Consequently, most UK airports where incidents are common have taken responsibility and implemented voluntary schemes to repair damage at no cost to the owner. In most cases this includes reinforcement of the roofs considered to be at greater risk due to their location to mitigate the risk of future damage, as well as providing for repair of other roofs that have not been specifically strengthened. In Australia, provision is made for applications to be made to Airservices Australia for compensation for wake vortices damage caused by Commonwealth jurisdiction aircraft under the *Air Services Regulations 1995* (Cth).

As noted earlier, vortex damage is generally limited to roof tiles and susceptibility of buildings to vortices may be dependent upon local construction practices which may limit the extent to which vortices represent a real threat internationally. However, impacts are evident elsewhere in Europe from reports of damage to roofs in Florsheim, Germany associated with operations at Frankfurt Airport and in Belgium associated with operations at Brussels Zaventem Airport were identified as part of this assessment. Further evidence of concern in Germany is evident from research into vortex damage to house roofs being undertaken at the Institute of Aerospace Systems at Aachen University. Press reports of damage to tiled roofs on buildings near Sydney (Kingsford Smith) Airport have also been identified and the arrangements for compensation under the *Air Services Regulations 1995* (Cth) provide clear evidence that wake vortex damage is a real issue in Australia.

8.3.2 Assessment of likely WSI wake vortex impacts

A review of the forecast fleet mixes indicates that around 20 to 30 per cent of operations are expected to involve WBJs. On that basis, the potential for wake vortex impacts across a zone like the one at Heathrow Airport is identified. A review of vortex strike records for Heathrow Airport indicates an annual average of approximately 102 verified strikes for the period between 2006 and 2010. Annual movements during that period were around 470,000. Given the prevailing westerly wind conditions, most approach operations at Heathrow Airport, typically 75–80 per cent, take place over predominantly urban development which is susceptible to damage in the event of a vortex reaching ground level. On that basis, it may be expected that there will be a relatively high probability of events being recorded at Heathrow Airport where they occur.

Given the broad similarity of the fleet mixes operating at Heathrow Airport and anticipated at WSI, the above statistics for Heathrow Airport provide a reasonable basis for assessing the potential for wake vortex impact at WSI, with the caveat that possible differences in meteorological conditions at the 2 locations may influence the relative rates of occurrence and spread of locations at them. For the 226,000 annual movements projected at WSI in 2055, the Heathrow Airport record would suggest of the order of 50 wake vortex events per annum with the potential to cause roof damage, if the vortices were to meet a suitable structure that is susceptible to damage.

Referring to the historical incident record at Heathrow Airport, it can be expected that that most events will be contained within a funnel with its origin at threshold extending to 4 km and diverging with an angle of 14 degrees either side of the approach path. The regions covered by those funnels are shown in Figure 8.1. From inspection of the available satellite imagery, it appears that there are no residential properties or other properties with tiled roofs that may be susceptible to wake vortex damage in the zone identified for Runway 05 approach. There are several buildings towards the southern limit of this zone at around 1.4 km from threshold and several low-level buildings at around 3.3 km or more from threshold close to the approach path. There is an area of residential development to the north of the zone identified for Runway 23 at a distance around 3.1 km or more from threshold. Whilst most of this residential development lies outside this zone, one property at around 3.4 km from threshold is located just inside it. There are several buildings associated with apparent minerals extraction activities at around 2.7 km from the Runway 23 threshold.

It is evident from this review that there are a limited number of buildings only within the wider zones where wake vortex damage is identified as a possibility and very few in areas within the wider zones where damage is expected to be more concentrated. Whist some confirmation by closer inspection of roof construction may be appropriate, it appears from the available satellite images that there is only one building with a tiled roof that may be susceptible to wake vortex damage within the wider zones and that building is located towards the periphery where the probability of impact is expected to be low.

NASF principles and guidelines Guideline B refers to wake vortex as a component of overall turbulence impacts and provides some high-level guidance for building design to minimise future impacts, in the event of new development in the identified wake vortex area. At WSI, there are no off-airport planning controls that relate specifically to the management of risk to buildings due to wake vortex with Western City Parklands SEPP. However, in regard to most land uses, other planning controls are already in place which would serve to reduce development within the wake vortex area and minimise impacts to buildings from turbulence. This includes the Obstacle Limitation Surface, PSAs and the ANEC contours which restrict certain land use types within the ANEC 20 and above contours (refer to Technical paper 6: Land use and planning) (Technical paper 6). These are all in proximity to the wake vortex area identified for WSI and will to some extent address the associated impacts.

8.3.3 Conclusions

It may be concluded that, due to the limited number of buildings located in areas where wake vortex damage is identified as a possibility, the type of roof construction adopted for most of the buildings and the low probability of impacts in the area where potentially susceptible roofs are located, there will be a low risk of wake vortex damage associated with single runway operations (05/23) at WSI. In the unlikely event of damage occurring where it is identified as a remote possibility, this can be effectively addressed by the compensation scheme operated by Airservices Australia.

Figure 8.1

Wake vortex contours

Legend

- WSI Runway
- Western Sydney International (Nancy-Bird Walton) Airport land boundary
- Wake vortex

0 1 2 km

Coordinate system: GDA 1994 NSW Lambert

Scale ratio correct when printed at A4

1:100,000 Date: 10/05/2023

Data sources: - DITRDC, DCS, Nearmap, Geoscience Australia
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

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8.4 Meteorological hazards

The extent to which potential adverse meteorological conditions may represent hazards to aircraft operations at WSI and to lead to real risks to operational safety has been assessed by reference to the ATSB occurrence database and to the site-specific assessment of local conditions at WSI provided by the Western Sydney Airport Usability Report (Bureau of Meteorology, 2015).

The ATSB database identifies 5,097 weather-related occurrences that occurred since 2003, broken down into events associated with turbulence and windshear (3,471), lightning strike (1,303), other weather (200), unforeseen weather (135) and icing (78). Of those 5,097 occurrences, the vast majority were classified as incidents, 49 were identified as serious incidents and 28 were identified as accidents, 2 of which resulted in fatalities. Both accidents that resulted in fatalities involved relatively small piston-engine powered aircraft operating charter passenger flights. In one occurrence a Cessna C210 suffered in-flight breakup after experiencing severe turbulence in stormy weather conditions. The other fatal accident is understood likely to have been caused by disorientation and loss of situational awareness, resulting in controlled flight into terrain in severe weather in a mountainous area.

Of the 28 occurrences identified as accidents, 7 involved turbo-fan powered aircraft and 5 involved turbo-prop powered aircraft in flight in Australian airspace. All except 2 of these 12 occurrences were classified in the "Turbulence/Windshear/Microburst" category. Seven of these 10 turbulence-related occurrences involved serious injury (e.g., fractured limbs) to a single aircraft occupant that was not restrained by seat belt use when the event took place and 3 involved additional minor injuries. A single aircraft occupant suffered a leg fracture in another wind-related occurrence. The remaining accident involved ditching in the sea of an aircraft that was unable to land at Norfolk Island due to bad weather, a scenario that developed under circumstances that would not arise at WSI.

Weather-related occurrences are reported across the full range of phases of flight. Around 20 per cent of the identified in flight occurrences for which the flight phase is specified were in the cruise phase with the remaining 80 per cent spread across, take-off, initial climb, climb, descent, approach and landing. This distribution between flight phases evidently reflects the range of altitudes across which potentially significant weather phenomena occur with adverse conditions being less likely at higher altitude. A further factor influencing this distribution may be the greater options for avoiding areas subject to adverse weather during the cruise.

It is clear from the above review of occurrences that weather-related factors have potentially significant implications for the safety and efficiency of aircraft operations, especially in the general vicinity of airports in areas supporting departures and arrivals. The most significant weather-related factor in that respect is identified as turbulence and windshear. However, it is also clear that the severity of the consequences of these occurrences is normally relatively limited. Turbo-fan and turbo-prop aircraft of the types that will operate at WSI can normally be expected to be resilient to turbulence and windshear. The historical record provided by the ATSB occurrence database indicates that the consequences of such encounters are typically limited to injuries to low numbers of aircraft occupants who are not protected using seat belts. Nevertheless, it is evident from the wider international dataset that such weather phenomena may lead to aircraft crashes when they are encountered relatively close to the ground, near airports.

Weather phenomena that may adversely affect operations at WSI have been considered in detail in the Western Sydney Airport Usability Report (Bureau of Meteorology, 2015). Meteorological characteristics considered in the usability report include wind, temperature, rainfall, fog and low cloud, turbulence and thunderstorms. For the most part, the report focuses on the operational implications of meteorological conditions at WSI, based on recent historical weather records. It concludes that it is expected that the current runway configuration proposed will be usable approximately 99.5 per cent of the time based on crosswinds alone. It concludes further that other weather phenomena such as fog, low cloud and low visibility conditions may lower the usability of the airport but that these impacts may be mitigated through navigational systems and aids. The general working assumption in respect of these weather factors is that operations will cease if appropriate conditions for safe operation are not provided and that will affect operational efficiency rather than compromise safety.

The usability report considers turbulence and wind shear in some details by comparison with conditions at Sydney (Kingsford Smith) Airport and RAAF Base Richmond. Consideration is given to the possibility of severe turbulence associated with air movement over the Great Dividing Range and to the possibility of rotors, rotating systems of air that may form as friction drags air down the leeward side of a mountain. Overall, the report concludes that WSI will be less susceptible to turbulence and wind shear than Sydney (Kingsford Smith) Airport and identifies no particular concerns about these weather phenomena. It notes that a Doppler LIDAR system at Badgerys Creek would be able provide the necessary information for observing wind movement in the lower atmosphere including detection of wind shear and rotors but notes further that a Doppler LIDAR system would be costly and therefore that a cost-benefit analysis would be recommended before any decision is made to adopt this mitigating measure.

The usability report recognises explicitly that thunderstorms are hazardous to aviation and disruptive to the management of air traffic. It identifies the following aviation hazards encountered in and near thunderstorms: severe wind shear and turbulence, severe icing, downbursts, hail, lightning, heavy rain, tornadoes, low cloud, poor visibility, and rapid air pressure fluctuations. The report notes that most thunderstorms that may affect WSI develop over the Great Dividing Range and move eastwards into the Sydney Basin. The proximity (around 20 km) of the Airport Site to the Great Dividing Range (Blue Mountains) means that a short lead time for thunderstorm aerodrome warnings will be available at WSI. Having regard to the anticipated frequency of thunderstorms in the vicinity of WSI and the identified short lead time for thunderstorm warnings, it has been recommended that an ATSAS is implemented at WSI to improve the accuracy of thunderstorm forecasting for the airport.

In summary, the potential for adverse meteorological conditions, in particular turbulence, wind shear and thunderstorm activity is evident. However, the available historical evidence indicates that the extent to which these types of occurrences can be expected to lead to a real threat to aircraft safety is limited. Compared with other airports which have been shown by the historical record to operate with an acceptable level of safety, there are no exceptional meteorological conditions at WSI that might lead to significant risks to operational safety. Measures to identify and avoid adverse weather conditions are applied generally in the air transport industry to limit the risk to aircraft safety. It is anticipated that implementation of ATSAS at WSI will mitigate the identified site-specific susceptibility to potential thunderstorm activity. Whilst these measures are primarily directed towards the provision of aircraft safety, they will support the achievement of acceptable levels of safety for third parties in the vicinity of WSI. The generic aircraft crash risk model that has been employed to determine the level of risks to third parties takes account of a wide range causal factors, including weather-related accident scenarios. No specific weather-related risks to aircraft operations at WSI were identified that would suggest that the risk estimates provided by the available generic model do not adequately represent the risk to third parties in the vicinity of WSI.

8.5 Wildlife hazards

The general and WSI site-specific characteristics of wildlife hazards to aircraft operations have been comprehensively described in Technical paper 5. Such details are not repeated here. The key point to be drawn from that document are that whilst wildlife presents a potentially significant threat to aircraft safety, this hazard can be and is effectively managed so that, for the most part, wildlife-related occurrences primarily represent a significant financial cost to the commercial civil aviation industry in respect of the repair of damaged engines and airframes.

To a large extent, commercial civil aircraft are resilient to bird strikes. Commercial air transport operations are typically served by twin-engine aircraft with the capability of safe flight following the loss of a single engine to bird strike. There are certification requirements relating to engine resistance to bird strike. As a result, most bird strikes will not lead to a significant threat to aircraft safety. Multiple strikes associated with larger flocking species may lead significantly compromise aircraft safety, as demonstrated by the well-publicized Hudson River accident in 2009 (NTSB, 2010). Further possibilities of major loss from less severe bird strike events cab be envisaged under some circumstances, as illustrated by the example in the Wildlife Strike Risk Assessment Technical Paper from 2008 of an overrun after rejected take-off following a strike with a single medium sized bird that led to the total loss of a Boeing B747 freighter. However, the historical accident record shows that such events can be expected to be very rare, since the introduction of effective wildlife hazard management programmes following fatal accidents in the earlier years of post-war commercial civil aviation.

The general picture outlined above is confirmed by reference to the ATSB database which identifies 22,526 wildlife related occurrences that affected turbo-fan and turbo-prop aircraft performing commercial air transport operations since 2003. One of these occurrences was classified as an accident and 3 were classified as serious incidents. The accident involved a multiple kangaroo strike on landing that caused substantial aircraft damage and no injuries. The accident classification relates to the scale of damage rather than the safety impacts. Two of the serious injuries involved wildlife strikes on landing. One of the incidents was associated with a single kangaroo strike and the other involved a multiple galah strike. Both incidents resulted in minor aircraft damage and no injuries. The remaining serious incident did not relate to a strike but was associated with an airspeed indicator malfunction due to obstruction of a pitot probe by an insect nest.

Most of the reported incidents involved bird strikes and resulted in minor or no aircraft damage and no injuries. Of the inflight occurrences for which the flight phase is identified, 75 per cent took place during take-off and landing, 22.5 per cent took place during the initial climb and approach. It is evident from these statistics that the bird strike hazard which has potential implications for third party safety is very much concentrated at and in the immediate vicinity of airport.

The focus of wildlife strike management measures, as covered in the Technical paper 5 is on maintaining aircraft safety, primarily from the perspective of the safety of aircraft occupants. The assessment concludes that acceptable wildlife strike risk mitigation for WSI is achievable, but this will require that a rigorous and integrated wildlife management program is implemented. In essence, this means that the wildlife hazard to aircraft safety will account for no more than a very small contribution to the total risk associated with aircraft operations at WSI.

From the perspective of risks to third parties, any contribution from the wildlife hazard can similarly be expected to be very small. The likelihood of a wildlife strike leading to a ground impact in the vicinity of WSI will negligible, compared with the overall crash probability which is itself very small. In the unlikely event of a wildlife strike compromising aircraft safety to the extent that a ground impact were to occur, the most likely locations affected will be within or close to the runway strip where harm to third parties would not arise.

In accordance with the findings set out in Technical paper 5, it may be concluded that wildlife strike risk mitigation for WSI providing an acceptable level of safety is achievable, provided that an appropriate site-specific wildlife management program is implemented. Details concerning recommendations for mitigation in respect of priority species and habitats is provided elsewhere (Avisure, 2022).

Chapter 9 Facilitated impacts

The EPBC Act Guidelines require that this Draft EIS should identify, and address facilitated impacts on operations at Sydney (Kingsford Smith) Airport and other aerodromes and aviation activities in the region as a direct result of arrival and departure paths into and out of the airport and associated airspace control zone.

As has already been noted, operating the new airport will require changes to the current Sydney Basin airspace and its airspace classification structure through the introduction of a new controlled airspace volume and flight paths which will determine where and how aircraft arrive and depart the airport. Additional routes and flights will be introduced into what is an already busy airspace serving Sydney (Kingsford Smith) Airport and other aerodromes in the Sydney Basin and facilitating changes to the flight paths and operating procedures at those aerodromes. These changes may inevitably have impacts on the existing operations with implications for safety if the new operating environment is not appropriately designed.

The potential for the introduction of additional risks to existing operations within the Sydney Basin airspace from the changes is well-recognised. The process that has been described in Chapter 6 seeks to implement the required changes in a manner that ensures that an appropriate level of safety is achieved throughout the revised airspace. Provided that the identified process is implemented effectively, it can be expected that there will be no significant risk impacts on those existing operations. In accordance with the approach set out earlier in Chapter 6, the risks associated with operation of the system should be ALARP and an acceptable level of safety should be achieved.

Chapter 10 Cumulative impacts

There are existing risks associated with the operation of the existing aerodromes and airspace in the Sydney Basin, including risks to third parties of the nature described in Chapter 7. In accordance with the historical accident record and the third party risk model based on it that was employed to assess the third party risks associated with WSI operations, third party risks associated these other operations were concentrated along flight paths closer to each runway end. In these areas, just as in those closer to the runway at WSI, individual risks may reach levels that would be considered potentially significant when assessed against the criteria described in Section 3.1.3. Outside these areas risks will be at levels that can be regarded as negligible. Further from each runway end the risks associated with existing operations more generally in the Sydney Basin airspace can be expected to be very considerably lower than these level of 1 in a million per annum individual risk level below which risks are considered to be acceptable and of no regulatory concern.

The risks that were determined for WSI and that are shown in the risk contour plots in Chapter 7 will be introduced into an area that is a substantial distance from the existing aerodromes and where the existing background risk will be very low in comparison with the WSI-related risks. Closer to WSI, the cumulative risk associated with the new and existing operations will therefore be dominated entirely by the risks associated with WSI operations. That is to say, the background risk in the vicinity of WSI associated with existing operations will be so small (very much lower than 1 in a million per annum) that it will not add significantly to the WSI-related risks which are adequately represented by the estimates made for WSI operations alone.

The areas that are currently subject to elevated risk levels associated with existing operations may be subject to an additional risk from WSI operations. Given the substantial distance from WSI and its associated flight paths to these areas of existing elevated crash risk, that additional risk can be expected to be very small indeed and the cumulative impact can therefore be expected to only very marginally above the existing risk level.

Overall, the project will introduce new potentially significantly elevated crash risks only into areas that are currently subject to entirely negligible risk from existing operations. It will introduce no more than a trivial additional crash risk into areas that are currently subject to potentially significant risk from existing operations. The cumulative risk impacts can therefore be regarded to be trivial and acceptable.

Chapter 11 Management and mitigation measures

11.1 Outline

In accordance with the general assessment approach followed earlier, consideration has been given to management and mitigation measures in respect of the following hazards which are addressed in turn below:

- airspace conflicts
- residual off-airport aircraft crash risks to third parties and critical infrastructure
- aircraft fuel jettisoning
- objects falling from aircraft
- aircraft wake vortex strikes
- local meteorological hazards
- local bird and bat strike hazards.

11.2 Airspace conflicts

As described in Chapter 6, airspace conflicts are mitigated in the first instance by system design, in particular by systemic separation of aircraft through the physical layout of the system and by air traffic controller workload minimization. The continuing design process seeks to identify any potentially significant residual risks which can then be addressed by refinement of the system design and the development of operational controls to be implemented by air traffic control. After implementation of the new airspace design, residual risks can be identified by ongoing monitoring of the system performance. This approach is expected to achieve a level of safety that is ALARP and for which the residual risks will be minimal and acceptable. The costs of these mitigation measures are part of the design process costs and the costs of the subsequent implementation of the associated air traffic control services.

11.3 Residual risks to third parties and critical infrastructure

Considerable effort is directed towards ensuring the safety of aircraft, to minimise the risks to passengers and crew. From that perspective, the residual risks of aircraft crash are small and acceptable. The measures in place to minimise those risks will play a role in limiting the risks to third parties and critical infrastructure. Given the concentration of crash risk along flight paths and close to runway ends, risks to third parties and critical infrastructure can be further minimised by locating runways and the associated flight paths to minimise the potential targets at risk. Compared with many existing airports, including those in the Sydney Basin, the runway location selected for WSI provides for an inherently low risk. That inherently low risk is further mitigated by the location flight paths, in particular departure routes, in areas where relatively low numbers of people will be exposed to operational impacts. The selection of the runway and flight path locations away from areas in which higher levels of exposure would arise is driven largely by the objective to minimise noise impacts and meeting those noise-related objectives serves to limit crash risks to third parties. As described in Chapter 7, detailed quantitative risk assessment has demonstrated that the risks to third parties is generally low and acceptable, when judged against defined criteria that reflect the risks to which people are exposed in their daily lives and the requirement to manage such risks to be ALARP.

As noted in Section 3.1.3 and discussed in further detail in Appendix B, 7 operational scenarios for use of the flight path network have been identified. These are based on different options for the RMO in terms of the preference of runway direction in use and the use of RRO that gives preference to a Runway 05 arrival and a Runway 23 departure during night-time hours only (11 pm to 5:30 am) on flight paths to the south-west of the runway. The different RMO vary slightly with regard to the frequency of operations in areas where development is predominantly located, to the north and east of the runway. Accordingly, there may be scope for further risk mitigation through the choice of RMO but the scope for risk mitigation by this means can be expected to be limited. The choice of RMO will require that a balance is struck between operational efficiency and safety objectives on the one hand and the minimisation of noise and risk impacts on the other. The quantitative risk assessment that has demonstrated an acceptable level of residual risk was based on a single RMO, selected on the basis that it represents a worst-case in terms of the use of flight paths closer to areas of where development is predominantly located, to the north and east of the runway. Given the limited residual risk determined for that worst-case, further risk minimization through choice of RMO is judged not to be an over-riding consideration but a matter to be balanced with other safety and environmental objectives. Overall, it may be concluded that an acceptable level of safety with respect to third party risk can be achieved by use of the mitigation options identified and that no further management and mitigation measures are required.

The frequency of events giving rise to risks to critical infrastructure are determined to be low. There may be scope of limiting the scale of the associated impacts by contingency planning, for example to respond to fuel spillage water contamination events. These possibilities are identified for further consideration by the airport operator, in collaboration with other authorities, as appropriate, having regard to the frequency and scale of consequences of the events concerned. It is noted that international regulations require that search and rescue provisions are made in respect of aircraft and occupants. It may be appropriate to confirm that the provisions in place adequately cover the third party impacts identified in this assessment.

11.4 Aircraft fuel jettisoning

As described in Section 8.1, if required for operational safety purposes, the jettisoning of aircraft fuel is undertaken in a controlled manner and in accordance with the Manual of Air Traffic Services (section 4.2.11 – Fuel Dumping) to eliminate any risk to sites on the ground. The Australian and wider international incident record demonstrates the established procedures ensure risks associated with fuel jettisoning are very small and can therefore be considered acceptable, without the need for any further management and mitigation measures at WSI.

11.5 Objects falling from aircraft

As described in Section 8.2, the risks to people and property on the ground associated with objects falling from aircraft is generally very small and acceptable. Notwithstanding that low level of risk, there would appear to be scope for some improvement to reduce the frequency of these occurrences, for example through mandatory reporting and feedback intended to reduce the future event likelihood, in accordance with the general approach to safety management improvement adopted across the aviation industry. Given the location of flight paths with respect to people and property in the vicinity of WSI and the relatively low level of exposure there compared with other airports, falling object risks associated with operations at WSI can similarly be expected to be very small and acceptable. Accordingly, no need for any further site-specific management and mitigation measures at WSI to address this hazard are required.

11.6 Aircraft wake vortex strikes

As described in Section 8.3, aircraft wake vortex strikes arise can be expected to arise over a limited area close to approach flight paths near runway ends. Damage in the event of a wake vortex impact with a building is generally quite limited and confined to the lifting of tiles on roofs. Very few buildings that would be susceptible to this sort of damage are located in areas where aircraft wake vortex strikes are to be expected and occurrences involving building damage are therefore expected to be very infrequent. In the unlikely event of building damage from a wake vortex strike, mitigation is available through the compensation scheme operated by Airservices Australia which provides for repairs.

11.7 Meteorological hazards

For the most part, aircraft operating at WSI can be expected to be able accommodate the meteorological conditions encountered there without aircraft operational safety and efficiency being significantly compromised. The Western Sydney Airport Usability Report (Bureau of Meteorology, 2015) identifies 2 mitigation measures that could be implemented to assist in the identification of adverse weather. The report identifies the possibility of severe turbulence associated with air movement over the Great Dividing Range but concludes that WSI will be less susceptible to turbulence and wind shear than Sydney (Kingsford Smith) Airport and identifies no particular concerns about these weather phenomena. Nevertheless, it notes that a Doppler LIDAR system at the Airport Site would be able provide the necessary information for observing wind movement in the lower atmosphere including detection of wind shear and rotors but notes further that a Doppler LIDAR system would be costly and therefore that a cost-benefit analysis would be recommended before any decision is made to adopt this mitigating measure.

The usability report identifies a concern in respect of thunderstorms, noting that most thunderstorms that may affect WSI develop over the Great Dividing Range and move eastwards into the Sydney Basin. The proximity of the Airport Site to the Great Dividing Range means that a short lead time for thunderstorm aerodrome warnings will be available at WSI. Having regard to the anticipated frequency of thunderstorms in the vicinity of WSI and the identified short lead time for thunderstorm warnings, it has been recommended that an ATSAS is implemented at WSI to improve the accuracy of thunderstorm forecasting for the airport. This service would be provided by the BoM which should be consulted about costs. It appears from the unequivocal recommendation for ATSAS implementation in the usability report that the BoM consider that is would be cost beneficial at WSI. That view is apparently based on the experience of the BoM of the implementation of ATSAS at other international airports in Australia.

11.8 Wildlife strike hazards

As outlined in Section 8.5 and described in further detail in Technical paper 5, wildlife strike is a well-recognised hazard to aircraft operations that receives considerable attention to minimise the associated risk. Mitigation is provided in 2 primary ways: through resilience of aircraft to strikes, for example the capacity for multi-engine civil aircraft to withstand engine strikes without compromising aircraft safety and through site-specific wildlife management programmes to limit the likelihood of strikes, in particular with respect to more hazardous species. Based on a review of wildlife hazards at and in the vicinity of WSI (Avisure, 2022), it has been concluded that wildlife strike risk mitigation for WSI providing an acceptable level of safety is achievable, provided that an appropriate site-specific wildlife management program is implemented. Details concerning recommendations for mitigation in respect of priority species and habitats is provided elsewhere (Avisure, 2022). The costs of the development and implementation of an appropriate wildlife management program are expected to be substantial but should be regarded as an integral to the overall costs of operating a major international airport. Given the scope, scale and variability in the mitigations recommended, specific costs associated with the required measures cannot be estimated at this time.

11.9 Summary of proposed mitigation measures

Risk mitigation is provided by a wide variety of general measures and standard procedures adopted across the aviation industry that will apply to operations at WSI. Project specific recommendations for mitigation are identified in Table 11.1 and supported by the proposed monitoring program in Table 11.2.

Table 11.1 Summary of proposed mitigation measures

ID No.	Issue	Mitigation measure	Owner	Timing
HR1	Airspace conflicts	Airservices Australia will continue to address hazard identification and risk mitigation during the remainder of the design process and prioritise ongoing safety performance monitoring.	Airservices Australia	**Pre-operation** (Detailed design, 2024–2026)
HR2	Contingency planning	WSA Co will implement contingency planning to respond to the impacts of crash events as per Part 139 Aerodromes Manual of Standards 2019.	WSA Co	**Operation** (Implementation, 2026–ongoing)
HR3	Aircraft fuel jettisoning	Airservices Australia will apply existing procedures to deal with aircraft fuel jettisoning occurrences as per Manual of Air Traffic Services (MATS) Section 4.2.11.	Airservices Australia	**Operation** (Implementation, 2026–ongoing)
HR4	Local meteorological hazards	Automated Thunderstorm Alert Service (ATSAS) will be implemented by the Bureau of Meteorology (BoM) to provide improved thunderstorm forecasting. Implementation of a Doppler LIDAR, if required, to support the identification of turbulence and wind shear (subject to the conclusions of an appropriate cost-benefit study).	WSA Co (in coordination with BoM)	**Operation** (Implementation, 2026–ongoing)
HR5	Wildlife strike	WSA Co will monitor and control the presence of birds and other wildlife on or in the vicinity of WSI in accordance with Civil Aviation Safety Regulations (CASR) Part 139 MOS 2019 requirements and National Airports Safeguarding Framework (NASF) Guideline C.	WSA Co	**Operation** (Implementation, 2026–ongoing)
HR6	Wildlife strike	WSA Co will liaise with planning authorities on matters related to the development of, or modifications to, off-airport land uses that have the potential to attract hazardous numbers or types of wildlife.	WSA Co	**Pre-operation** (Detailed design 2024–2026) and **Operation** (Implementation, 2026–ongoing)
HR7	Wildlife strike	WSA Co will establish a WSI Wildlife Hazard Management Committee (WHMC) that will likely comprise Western Sydney local government representatives, NSW Department of Planning and Environment and other relevant aviation stakeholders.	WSA Co	**Operation** (within 6 months of implementation, 2026–ongoing)

ID No.	Issue	Mitigation measure	Owner	Timing
HR8	Wildlife strike	The WHMC will contribute to the preparation of regional species management programs (including Australian White Ibis) as required. Regional species management plans will build on any existing management programs (e.g., the Canterbury-Bankstown Council Australian White Ibis Management Program). The regional programs will aim to: • reduce species impacts on aviation and the community in general • provide advice to landowners on how they can contribute to species management programs on non-council land • establish measurable targets for species management • maintain the long-term sustainability of the local species populations.	WSA Co	**Operation** (Implementation, 2026–ongoing)

Table 11.2 Proposed monitoring program

ID No.	Issue	Monitoring measure	Owner	Timing
M2	Wildlife Strike	A bird and bat strike monitoring program will be conducted to monitor for the presence of wildlife on the WSI site and in the vicinity of WSI. The monitoring program will: • identify wildlife hazards which must be addressed to reduce potential risk to aircraft operations • be conducted in accordance with relevant Commonwealth and State guidelines and standards including any recovery plans for threatened species • carried out under the direction of a suitably qualified person • be carried out in liaison with local government in relation to plans for proposed developments within 13 km of WSI that are likely to increase bird and bat strike • identify locations where reasonable and feasible mitigation measures to manage wildlife strike risk are required • be reviewed annually to determine its effectiveness.	WSA Co	**Operation** (Implementation, 2026–ongoing)

Chapter 12 Conclusion

The following conclusions may be drawn from the assessment of the various hazards and risks described in this technical paper:

- ***Airspace conflicts***. Operation of WSI will introduce additional flights into the existing busy Sydney Basin airspace, requiring substantial airspace redesign. If not appropriately conducted, that process has the potential to introduce additional hazards and risks to existing Sydney Basin aircraft operations as well as introducing new hazards and risks associated with WSI operations. The design process that has been followed can be expected to provide a revised airspace design that meets operational needs and for ”Safety by Design”, meeting the key goals of being ALARP and achieving an acceptable level of safety, due to the following key features:
  - the airspace design has been delivered within a safety regulatory and management framework in which the safety of air navigation is regarded as the most important consideration and where management systems are in place to ensure that such a commitment is met
  - the airspace design is underpinned by defined goals established at the outset that all risks will be managed to be ALARP and that any residual risk will be acceptable
  - the airspace design is further underpinned by 2 design principles supporting inherent safety: systemic separation of aircraft and air traffic controller workload minimisation
  - the identification and evaluation options for airspace design and the selection of the preferred concept option has followed a rigorous process which can be expected to deliver an optimum solution within the inherent constraints of the existing operational requirements that is safer by design
  - the subsequent development of the preliminary airspace design from the selected concept option follows established industry good practice and has delivered a more detailed operational specification that can be expected to deliver an eventual outcome meeting the identified objectives, minimising airspace conflicts and maximising system safety and operability
  - continued attention is being given to hazard identification and risk mitigation during the remainder of the design process and on-going attention safety performance monitoring post-implementation should provide further mitigation of any residual risks.
- ***Off-airport aircraft crash risks to third parties.*** Whilst aircraft crashes are rare events, the majority during take-off and landing operations such crash risks are more concentrated along flight paths close to runway ends. Accordingly, people and critical infrastructure located in vicinity of airports cab be expected to be exposed to an elevated risk above the background levels that apply more generally. Quantitative risk assessment using an empirical crash risk model informed by the historical accident record demonstrates that the risks associated with single runway operations at WSI approaching capacity in 2055 can be expected to be low and within acceptable levels. For the most part, residential and other properties are subject to individual risks that are below the level of a 1 in 1,000,000 per annum fatality risk that is normally considered to be negligible in the context of the regulation of public safety. These generally low levels of risk reflect the siting of the runway and associated flight paths within the proposed airspace design which limits the extent to which areas of development are overflown which has been largely driven by the objective of minimising noise impacts. There are a limited number of exceptions to the above general observation: 32 properties are estimated to be subject to individual fatality risks in excess of 1 in 1,000,000 per annum and for 2 of these the risk is estimated to be above 1 in 100,000 per annum but below the criterion for more significant risk of 1 in 10,000 per annum. On that basis, the risks cannot be considered to be entirely trivial but there are nevertheless identified as “slight” and, given the unavoidable constraints associated with runway and flight path siting, these risk levels can be considered to be ALARP. Similar conclusions are reached on the basis of the societal risk estimates. Crashes involving one or more third party fatalities are estimated to be 1 in 4,245 year and 1 in 1,416 year events in 2033 and 2055, respectively and the average number of fatalities anticipated is estimated to be around 10. The potential for incidents giving rise to a hundred or more third party fatalities on the ground is identified where larger aircraft crash in more densely populated areas but such events are predicted to be very uncommon, with estimated rates of 1 in 7.3 million years and 1 in 1.3 million years for 2033 and 2055 movement levels, respectively. When assessed against appropriate societal risk criteria, these risks are determined to be ALARP. Scope for further mitigation of this risk, for example by choice of the future runway mode of operation, is found to be limited.

- ***Off-airport aircraft crash risks to critical infrastructure.*** Various scenarios for aircraft crashes into infrastructure have been identified, for example involving transport links, hospitals, DEOH facility, the Warragamba Dam, Burragorang Lake and Prospect Reservoir. The typical event frequencies and scale of fatalities associated with these events are consistent with risks that would be considered acceptable when assessed against the societal risk criteria that have been employed more generally to evaluate the significance of third-party fatality risks. These general conclusions can be expected to apply to a wider range of scenarios that have not been explicitly assessed but which are broadly comparable with those that have been analysed. Specific criteria for the evaluation of the significance of infrastructure loss and damage have not been defined but given the low frequencies of occurrence of these events, it appears that these risks can be considered acceptable. For example, the likelihood of an aircraft impact leading to potentially significant structural damage to the Warragamba Dam barrage is estimated to be somewhat less than 1 in 13 million years. Notwithstanding the potential scale of the consequences of such an event, the associated risk may be judged acceptable at such a low frequency. A higher probability of water contamination from aircraft impact across a wider area than the barrage is to be expected but the estimated frequency of one in 87,000 years may still be considered acceptable. There may be scope of limiting the scale of these impacts by contingency planning if it were to be considered beneficial.
- ***Aircraft fuel jettisoning.*** Reference to the available incident data shows that fuel dumping is a relatively uncommon non-standard operational requirement that will have no impacts at ground level if carried out in accordance with appropriate procedures, as has always been the case historically in Australia. There are limited occurrences only of impacts at ground level associated with fuel jettisoning in the wider international incident record, confirming that this is a very small risk indeed. It may therefore be concluded that there will be no significant adverse impact associated with fuel dumping associated with WSI operations, provided that existing procedures (specifically MATS Section 4.2.11) are followed.
- ***Objects falling from aircraft.*** The historical incident record shows that occurrences involving objects falling from aircraft are uncommon and typically involve small objects with limited hazard potential. Taking account of the relative size of the objects concerned and frequency of these occurrences compared with aircraft crashes, it may readily be concluded that the risks to people and sites on the ground are very small compared with the risks associated with aircraft crashes. Given that the risks associated with aircraft crashes have been shown to be low and acceptable, it may be concluded that the lesser risks associated with objects falling from aircraft can similarly be low and acceptable.
- ***Aircraft wake vortex strikes.*** Vortex damage incidents are confined to a relatively small area close to approach paths near the ends of landing runways used by large aircraft. Damage is generally confined to the lifting of small-format roofing elements, such as tiles and slates. Given the size of aircraft that will operate at WSI, vortex damage is identified as a possibility in principle. However, the number of properties located in areas where vortex damage would be expected is very limited indeed. Accordingly, risks of wake vortex damage due to operations at WSI in practice are determined to be negligible. If any strikes were to occur, the damage caused would be covered by the compensation scheme operated by Airservices Australia which can be adequate mitigation.
- ***Local meteorological hazards.*** The historical incident record shows that weather-related factors have potentially significant implications for the safety and efficiency of aircraft operations, especially in the general vicinity of airports in areas supporting departures and arrivals. The most significant weather-related factor in that respect is identified as turbulence and windshear. However, the severity of the consequences of these occurrences is normally relatively limited, in particular for turbo-fan and turbo-prop powered aircraft of the types that will operate at WSI that can normally be expected to be resilient to turbulence and windshear. The risks to safety and operational efficiency can be mitigated by provision of improved forecasting. Following a detailed review of meteorological conditions at WSI, the BoM has recommended that ATSAS should be implemented to provide improved thunderstorm forecasting and that consideration should be given to implementation of a Doppler LIDAR to support the identification of turbulence and wind shear, subject to the conclusions of an appropriate cost-benefit study.

- ***Local bird and bat strike hazards.*** Whilst wildlife strikes represent a potentially significant threat to aircraft safety, this hazard can be and is effectively managed so that, for the most part, wildlife-related occurrences primarily give rise to financial costs to the commercial civil aviation industry in respect of the repair of damaged engines and airframes rather than significant safety risks. The general and WSI site-specific characteristics of wildlife hazards to aircraft operations have been comprehensively described in Technical paper 5. Taking account of the site- and species-specific characteristics of wildlife hazards to operations at WSI, that study concluded that wildlife strike risk mitigation for WSI providing an acceptable level of safety is achievable, provided that an appropriate site-specific wildlife management program is implemented.

Chapter 13 References

AECOM 2020 Dublin Airport North Runway Relevant Action Application Environmental Impact Assessment Report, Main Report, Chapter 6, Major Accidents and Disasters, prepared by Eddowes Aviation Safety Limited.

Airservices Australia 2019 Safety Management System Framework C-FMK0012 Version 1 Effective 14 June 2019.

Airservices Australia 2023 Manual of Air Traffic Services version 64.3 Effective: 15 June 2023 to 6 September 2023 NOS-SAF-2000 (airservicesaustralia.com).

Airservices Australia 2021a Western Sydney Airport Airspace Plan and Design Safety Plan Version 2.0 Effective 11 August 2021.

Airservices Australia 2021b Western Sydney International Airport Airspace Concept Safety Assessment Report Version 1.0 Effective 10 December 2021.

Byrne JP 1997 The Calculation of Aircraft Crash Risk in the UK. Report prepared by AEA Technology (Byrne, J. P.) for the UK Health and Safety Executive, Contract Research Report 150/1997.

Bureau of Meteorology, 2015 Western Sydney Airport Usability Report.

CASA 2014 Safety Risk Management SMS 3 2nd Edition.

CASA 2020a CASR Part 139 (Aerodromes) Manual of Standards 2019 (as amended).

CASA 2020b CASR Part 121 (Australian Air Transport Operations—Larger Aeroplanes) Manual of Standards.

CASA 2020c CASR Part 172 (Air Traffic Services) Manual of Standards.

CASA 2022 CASR Part 5 Safety Management Systems – under development – see https://www.casa.gov.au/search-centre/rules/part-5-casr-safety-management-systems accessed July 2022.

Commonwealth of Australia 2016 Western Sydney Airport Environmental Impact Statement: Chapter 14 Hazard and Risk, pp 200-217.

Cowell P G, Foot P B, Gerrard R J, Kent D, Mason SM & Rivoire A 2000 A Methodology for Calculating Individual Risk Due to Aircraft Accidents near Airports, , NATS R&D Report 0007.

DITRDCA 2022 National Airports Safeguarding Framework principles and guidelines, accessed July 2022 at https://www.infrastructure.gov.au/infrastructure-transport-vehicles/aviation/aviation-safety/aviation-environmental-issues/national-airports-safeguarding-framework/national-airports-safeguarding-framework-principles-and-guidelines.

DITRDCA 2018 NASF Guideline I: Managing the Risk in Public Safety Areas at the Ends of Runways, November 2018 https://www.infrastructure.gov.au/infrastructure-transport-vehicles/aviation/aviation-safety/aviation-environmental-issues/national-airports-safeguarding-framework/national-airports-safeguarding-framework-principles-and-guidelines.

DNV Technica 1988 Interim Victorian Risk Criteria – Risk Assessment Guidelines, prepared for the Altona Chemical Complex and the Victorian Government.

EPBC 2022/9143 Guidelines for the content of a draft environmental impact statement: Western Sydney International Airport airspace and flight path design.

ERM 2005 Public Safety Zones Main Report, prepared by ERM on behalf of the Department of Transport and the Department of Environment, Heritage and Local Government https://www.gov.ie/en/publication/29d232-public-safety-zones/.

Evans A W, Foot P B, Mason, S M, Parker I G & Slater K 1997 R&D Report 9636 Third Party Risk Near Airports and Public Safety Zone Policy https://saeninfo.files.wordpress.com/2013/05/dpartyrisknearairportsan2989.pdf.

ICAO 2018a Annex 14 - Aerodromes - Volume I - Aerodromes Design and Operations, 8th Edition.

ICAO 2018b Procedures for Air Navigation Services (PANS) - Aircraft Operations - Volume I Flight Procedures (Doc 8168) 6th Edition.

ICAO 2018c Annex 6 – Operation of Aircraft – Part I – International Commercial Air Transport – Aeroplanes 11th Edition.

ICAO 2018d Annex 11 – Air Traffic Services 15th Edition.

ICAO 2018e Safety Management Manual Fourth Edition Doc 9859 AN/474.

ICAO 2020 Procedures for Air Navigation Services (PANS) - Aircraft Operations - Volume II Construction of Visual & Instrument Flight Procedures (Doc 8168) 7th Edition.

Melbourne Airport 2022 Melbourne Airport Third Runway Major Development Plan Environmental Impact Statement Chapter C5 Airspace hazards and risks.

NTSB 2010 NTSB/AAR-10/03 PB2010-910403 Loss of Thrust in Both Engines After Encountering a Flock of Birds and Subsequent Ditching on the Hudson River US Airways Flight 1549 Airbus A320-214, N106US Weehawken, New Jersey January 15, 2009.

Piers M A 1998 Methods and Models for the Assessment of Third Party Risk Due to Aircraft Accidents in the Vicinity of Airports and Their Implications for Societal Risk in Technology, Risk, and Society Volume 12, Quantified Societal Risk and Policy Making pp 166-204 https://doi.org/10.1007/978-1-4757-2801-9_17.

Pikaar A J, Piers M A & Ale B 2000 External Risk Around Airports: A Model Update, Presentation at the 5th International Conference on Probabilistic Safety Assessment and Management, Osaka, Japan, December 2000 https://core.ac.uk › download › pdf.

r2a Due Diligence Engineers 2016 Western Sydney Airport Environmental Impact Statement 2016 Volume 4 Appendix H: Western Sydney Airport EIS Hazard and Risk Review.

ROI HSA 2010 Policy & Approach of the Health & Safety Authority to COMAH Risk-based Land-use Planning.

Safe Work Australia 2012 Guide for Major Hazard Facilities, Safety Case: Demonstrating the adequacy of safety management and control measures.

State of NSW (through the Department of Planning) 2011a Hazardous Industry Planning Advisory Paper No 10 Land Use Safety Planning.

State of NSW (through the Department of Planning) 2011b Hazardous Industry Planning Advisory Paper No 4 Risk Criteria for Land Use Safety Planning.

State of NSW (through the Department of Planning) 2011c Hazardous Industry Planning Advisory Paper No 3 Risk Assessment.

UK HSE 1989 Quantified risk assessment: Its input to decision making.

UK HSE 1992 The tolerability of risk from nuclear power stations, http://www.onr.org.uk/documents/tolerability.pdf.

UK HSE 2001 Reducing risks, protecting people, HSE's decision-making process http://www.hse.gov.uk/risk/theory/r2p2.pdf.

Vince, I., 2011 Societal Risk Criteria in Land Use Planning – the Scale of 'Scale Aversion' IChemE Symposium Series 156 Hazards XXII.

Appendix A

Risk modelling assumptions review

A1 Review outline

As summarised in Section 3.1.2 of the main report, site-specific risks in the vicinity of airports can be estimated quantitatively by using an empirical modelling approach, based on historical accident data that characterises risk by reference to 3 key parameters as follows:

- the likelihood or probability (frequency per annum) of an aircraft crash occurring during landing or take-off operations, anywhere in the vicinity of an airport, having regard to the number of movements and the inherent reliability of different aircraft types, as determined from the available crash statistics
- the probability of impact at any specific location at or near an airport relative to the runway ends and the flight paths beyond them, as described by the crash location distribution, determined by reference to crash locations in the historical accident data set, and
- the severity of the consequences of an impact on the ground, according to the size of the aircraft concerned and again determined by reference to the historical accident data set.

The initial development of these modelling approaches up to the mid-1990s is well-described by Byrne (1997). The crash of a Boeing B747 transport aircraft into an apartment block near Amsterdam Schiphol Airport in 1992 (Piers 1998, Pikaar at al. 2000) stimulated development of the next generation of these sorts of models in the 1990s in the Netherlands. In the UK, concerns about the adequacy of PSZ policy around that time raised by a proposed new runway development (Eddowes, 1994; Purdy 1994) similarly stimulated the further development of this modelling approach support of PSZ policy review (Evans at al. 1997, Cowell et al. 2000). Equivalent models have been developed elsewhere in Europe (GfL, 2003) and, more recently, in the US (Shirazi, et al. 2016).

These different models use the same general architecture, as outlined above. Given the low frequency of accidents across particular regions, in order to develop statistically reliable modelling parameters, it is usual to employ data from a wider geographical area where operations can be considered equivalent to those of interest. The different models are therefore based on broadly the same empirical accident and operational data. Accordingly, although there are differences in their details, these models provide broadly similar risk predictions. For the purposes of this assessment, the UK DfT risk model has been employed. This model is the most practical choice. The method has been fully described in the literature, in terms of the key equations that describe crash location distributions and the relation between crash consequence and aircraft mass. The published model provides crash rates per movement for different aircraft types which can be used as a default in any application and, if needed, crash rates can be tailored for specific operations where appropriate local accident and operational data is available. In that respect, it is practical to implement this model. A further factor supporting the choice of this model is its previous adoption in Australia, as noted in NASF Guideline I.

Any empirical model of this sort may have potential limitations, for example relating to the availability of data and the need to make practical assumptions when developing mathematical descriptions of accident characteristics. The potential limitations of the UK DfT model have therefore been reviewed in some detail to confirm that it can be considered sufficiently reliable and appropriate for its intended use and to identify any modifications that might be made to improve its suitability. The findings of that technical review are set out in this appendix to support the modelling approach that has been adopted. The review considers crash rates, crash location distributions and crash consequences, in turn.

A2 Aircraft crash rates

The UK DfT Model employs historical accident rates per take-off and landing movement of different aircraft types as the basis for estimating the future probability of a crash for a defined fleet mix operating at any given airport. Several criteria are employed for characterising the crash rates of different aircraft types. In the first instance, aircraft types are split according to the 3 engine types, as follows:

- jet engine
- turbo-prop
- piston engine.

The second main division is then made according to the age of the aircraft. Western-built jet airliners are divided into the following categories:

- Class I: First Generation Jets, e.g., Comet, Boeing 707
- Class II: Second Generation Jets, e.g., Boeing B727, VC-10
- Class III: Early WBJs, e.g., Boeing B747, Tristar, and
- Class IV: Subsequent Types, e.g., Airbus A310, Boeing B757.

In addition to identifying crash rates for those categories of western-built jet airliners, the UK DfT model identifies crash rates for executive jets and “eastern jets”, the latter comprising those jet airliners aircraft built in the former Soviet Bloc. Turbo-prop driven aircraft are split into 2 categories as follows:

- those first delivered in or after the 1970s (T1), and
- those first delivered earlier (T2).

Finally, a distinction is made between passenger and cargo operations for some aircraft types. The forecast fleet mixes at WSI supporting this assessment are best represented by Class IV category jet airliners and T1 category turbo-prop aircraft, including passenger and non-passenger operations.

When the UK DfT model was first developed and published in 1997, the crash rate estimates for the aircraft within the different categories were made publicly available. To take account of the improvements in the safety performance in civil aviation since those estimates were first made, the crash rate estimates have been up-dated periodically. The most recent estimates currently available for use in this assessment for the relevant aircraft types are summarised in Table A.1. Taking account of the established trends towards lower crash rates, estimates determined using the most up-to-date accident and movement statistics may be slightly lower than those identified in the table. Statistical studies undertaken in relation to a previous new runway development programme at Frankfurt (GfL 2003) have indicated an annual reduction, year-on-year, of around 0.732 per cent. Based on that value, the decline in accident rates over the 15-year period since those rates were identified can be expected to be relatively small and of the order of 10 per cent. On that basis, the available estimates given in the table can be expected to be slightly conservative.

Table A.1 Estimates for crash rate per million movements (UK DfT model dataset)

Aircraft category	Crash rate per million movements
Class IV Jets (passenger)	0.082
Class IV Jets (non-passenger)	0.531
Turbo-props T1 (passenger)	0.254
Turbo-props T1 (non-passenger)	1.68

As has been noted earlier, it is usual for crash rates to be based on accident and operational data from a wider area than that to which the model is being applied, to improve the statistical reliability of the estimates of what are quite rare events. The UK DfT model estimates are based on data that are expected to be representative of Australian operations, derived from comprising European, US and Pacific Rim operations. To confirm that the identified estimates provide a reasonable basis for the assessment of Australian operations, reference has been made to the Australian historical accident record, as set out in the ATSB database, focusing on off-airfield incidents involving jet and turbo-prop commercial air transport operations.

A total of 16 off-airfield incidents with the potential to cause third party damage involving scheduled operations have been identified from the ATSB database over a period since 1966 to the present day of which 8 involved turbo-prop aircraft. The remaining incidents involved piston-engine aircraft. None involved jets. These accidents are summarised in Table A.2. In addition to these accidents, further accidents involving scheduled operations contained within the airfield boundary have been identified, including some involving jet aircraft. These accidents, which include runway excursions and one incident in which an aircraft became airborne after a tail strike in the clearway, serve to demonstrate the potential for serious off-airfield accidents in Australia but have not been considered further in the determination of the off-airfield crash rate.

Table A.2 Summary of Australian off-airfield accidents

Date	Location	Operation category	Aircraft model	Propulsion	MTOW	Flight phase	Injury
22/09/1966	Near Winton, QLD	Scheduled public transport	Viscount 832	Turbo-prop	30,617	En-route	Fatal
31/12/1968	Near Port Hedland, WA	Scheduled public transport	Viscount 720C	Turbo-prop	30,617	Descent	Fatal
06/05/1969	Warracknabeal, VA	Air Transport Low Capacity	Aero Commander 500	Twin piston	3,060	Approach	Serious
24/04/1970	Renner's Rock, NT	Air Transport High Capacity	Beech 50	Twin piston	2,858	En-route	Minor
20/01/1972	Alice Springs, NT	Air Transport High Capacity	Beech 65	Turbo-prop	3,992	Climb	Fatal
31/05/1974	Bathurst, NSW	Air Transport High Capacity	Fokker 27	Turbo-prop	19,773	Go-around	Minor
21/02/1980	Sydney (Kingsford Smith) Airport, NSW	Air Transport Low Capacity	Beech 200	Turbo-prop	5,670	Take-off	Fatal
12/04/1985	Port Macquarie, NSW	Air Transport Low Capacity	Piper PA-31	Twin piston	2,948	Take-off	Serious
07/08/1985	37 km NE of Biloela, QLD	Air Transport Low Capacity	Beech 65	Turbo-prop	3,992	En-route	Fatal
07/04/1988	Coffs Harbour, NSW	Air Transport Low Capacity	Piper PA-31	Twin piston	2,948	Approach	Fatal
28/11/1990	30 km E of Mainoru, NT	Air Transport Low Capacity	Cessna 182	Single piston	1,406	En-route	None
08/02/1991	Kiana Station, NT	Air Transport Low Capacity	Cessna 210	Single piston	1,814	Take-off	None
11/06/1993	Young Airport, NSW	Air Transport Low Capacity	Piper PA-31	Twin piston	2,948	Approach	Fatal
31/05/2000	28 km SE Whyalla Airport, SA	Air Transport Low Capacity	Piper PA-31	Twin piston	2,948	Descent	Fatal
07/05/2005	11 km NW Lockhart River, QLD	Air Transport Low Capacity	Fairchild SA227	Turbo-prop	6,920	Approach	Fatal
22/03/2010	Darwin, NT	Air Transport Low Capacity	Embraer EMB-120	Turbo-prop	11,500	Take-off	Fatal
04/09/2000	65 km ESE Burketown, QLD	Charter	Beech 200	Turbo-prop	5,670	En-route	Fatal
27/11/2001	Toowoomba, QLD	Charter	Beech C90	Turbo-prop	4,580	Take-off	Fatal

Date	Location	Operation category	Aircraft model	Propulsion	MTOW	Flight phase	Injury
09/04/2008	Sydney Airport SE 19 km, NSW	Charter	Fairchild SA227	Turbo-prop	6,920	En-route	Fatal
28/01/2016	11 km Net Hamilton Island Airport	Charter	Cessna 208 Caravan	Turbo-prop	3,538	Go-around	Minor
21/02/2017	Essendon Airport	Charter	Beechcraft B200	Turbo-prop	5,670	Take-off	Fatal
30/05/2017	4 km west of Renmark Airport, SA	Charter	Cessna 441	Turbo-prop	4,468	Climb	Fatal

Relevant off-airfield accidents involving air transport operations within the charter category are found to be more common than those involving scheduled operations. A total of 6 off-airfield accidents involving turbo-prop charter operations over the period since 2000 have been identified, as also summarised in Table A.2. These more recent accidents provide a reasonable basis for establishing a statistically reliable crash rate for these operations and detailed consideration has therefore not been given to earlier accidents involving aircraft within this category.

To estimate crash rates per movement, reference has been made to ATSB data for flight operations of the relevant aircraft types. The ATSB provides data for hours flown and the number of landings per annum for aircraft with different propulsion types, including jet and turbo-prop, over the period 2014 to 2020, covering scheduled and non-scheduled operations separately, as summarised in Table A.3. The data available for operations in earlier periods do not provide the same breakdown into those types of operation and propulsion type but total hours flown for different operational categories from 1985 to 2020 are available, as summarised in Table A.4. Using these data as a guide and if the breakdown according to propulsion type from 2014 to 2020 is broadly applicable to operations for any period from 1985 to 2020, estimates for movement numbers throughout that period for jet and turbo-prop aircraft can be made. Whilst it should be recognised that these estimates will be approximate and subject to some uncertainty they will nevertheless serve as a useful basis for assessing the general consistency of the Australian historical accident record with the crash rate assumptions supporting the UK DfT model.

Table A.3 Turbo-prop and jet commercial air transport operations (thousands) 2014–2020

	Year	Jet		Turbo-prop	
		Hours	Landings	Hours	Landings
Scheduled	2014	1 228.5	501.6	150.8	164.0
	2015	1 236.1	500.4	197.1	214.4
	2016	1 130.3	473.3	235.9	256.3
	2017	1 181.2	492.9	224.1	250.8
	2018	1 187.5	492.2	213.5	235.5
	2019	1 289.3	514.6	223.5	239.7
	2020	407.1	177.5	109.1	116.1
	Total	7 659.8	3 152.5	1 353.8	1 476.8
Non-scheduled	2014	42.5	26.5	123.6	120.0
	2015	51.4	33.4	137.9	137.5
	2016	40.6	24.1	122.1	119.1
	2017	63.6	32.3	127.7	128.2
	2018	62.4	37.5	145.6	142.3
	2019	47.6	30.2	144.5	145.0
	2020	83.8	51.2	162.4	150.0
	Total	391.9	235.1	963.8	942.2

Table A.4 Annual hours flown 1985–2020

Year	Total scheduled	Other VH-registered aircraft	Year	Total scheduled	Other VH-registered aircraft
1985	494,807	1,568,098	2003	969,020	1,645,944
1986	518,938	1,558,604	2004	1,090,430	1,644,975
1987	556,392	1,597,410	2005	1,144,087	1,722,807
1988	600,053	1,762,615	2006	1,156,701	1,694,964
1989	554,884	1,927,642	2007	1,191,600	1,831,842
1990	613,065	1,930,757	2008	1,250,542	1,857,704
1991	692,800	1,754,741	2009	1,241,447	1,807,469
1992	750,272	1,650,970	2010	1,325,677	1,847,728
1993	781,187	1,703,889	2011	1,347,406	1,771,362
1994	838,667	1,715,708	2012	1,382,059	1,704,912
1995	899,570	1,761,328	2013	1,410,700	1,741,815
1996	938,501	1,799,029	2014	1,402,080	1,526,375
1997	969,837	1,839,296	2015	1,439,953	1,552,294
1998	958,216	1,877,947	2016	1,389,439	1,608,799
1999	963,518	1,842,164	2017	1,427,107	1,600,368
2000	1,074,165	1,714,822	2018	1,423,866	1,642,281
2001	1,044,314	1,702,868	2019	1,526,290	1,719,700
2002	926,038	1,687,696	2020	524,197	1,585,376

The relevant crash statistics and movement number estimates for various periods are summarised in Table A.5. To take account of the statistical uncertainty in the rate of crashes, estimates at defined confidence limits based on Poisson statistics have been made, in accordance with previously established practice (Byrne, 1997). This approach allows estimates of likely rates to be estimated for comparison with the wider international dataset, even where there have been no events in any given period. Essentially, it provides a basis for establishing the extent to which the actual crash rates observed in the limited Australia can be considered consistent with the wider dataset, given the smaller size of the Australian dataset.

Table A.5 Crash, movement and crash rate statistics for Australian operations

Aircraft type and operating period	Crashes	Movements	Crash rate per movement at confidence level		
			5%	50%	95%
Jet scheduled aircraft since 1985	0	25,417,211	2.02×10^{-9}	2.73×10^{-8}	1.18×10^{-7}
Turbo-prop scheduled since 2014	0	2,953,630	1.74×10^{-8}	2.35×10^{-7}	1.01×10^{-6}
Turbo-prop scheduled since 2000	2	8,307,326	9.84×10^{-8}	3.22×10^{-7}	7.58×10^{-7}
Turbo-prop scheduled since 1985	2	11,907,045	6.87×10^{-8}	2.25×10^{-7}	5.29×10^{-7}
Turbo-prop charter since 2000	4	5,299,917	3.72×10^{-7}	8.81×10^{-7}	1.73×10^{-6}
Turbo-prop charter since 2014	3	1,884,360	7.25×10^{-7}	1.95×10^{-6}	4.11×10^{-6}

The 50th percentile estimate for scheduled jet aircraft based on movement estimates from 1985 to 2020 and no accidents over that period, at 2.73×10^{-8} per movement, is slightly lower than the jet aircraft value of 8.2×10^{-8} per movement identified for use in the UK DfT model. The UK DfT model value relates to all hull loss accidents, including those within the airfield boundary, comprising crashes inside the runway strip and overrun events. Taking account of those on-airfield events included within that statistic, the off-airfield estimate for Australian operations can be seen to be in very good agreement. On that basis, use of the value of 8.2×10^{-8} per movement in this assessment is appropriate.

Various estimates have been made for scheduled turbo-prop operations, based on different periods for which data are available, and the 50th percentiles fall in the range of 2.25 to 3.22×10^{-7} per movement. These values can be seen to be in good agreement with the value of 2.54×10^{-8} per movement identified for use in the UK DfT model. The 50th percentile value for charter turbo-prop operations, at 0.88 to 1.95×10^{-6} per movement, is seen to be consistent with the turbo-prop non-passenger value of 1.68×10^{-7} per movement. Whilst “non-passenger” operations under the UK DfT model classification cannot necessarily be equated directly with “charter” operations under the ATSB classification, these observations of differences in scheduled and charter operations in Australia clearly support the use of specific crash rates for different types of operation and not just for different aircraft frame types. Crash rates may be as much if not more dependent upon the way aircraft are flown than on the aircraft type. Criteria that relate to the nature of the operation and the way an aircraft is flown and may be usefully considered include the following:

- whether the airport is licensed or unlicensed
- the quality of available navigational aids
- whether there are one or 2 pilots on board, and
- the quality of the operational procedures followed by the pilot(s).

The overall conclusion to be drawn from the review of the Australian historical aircraft accident record is that, taking account of the size of the sample of what are quite uncommon events, the observed crash rates are consistent with those derived from the wider international recent historical accident dataset. Use of the crash rates identified in Table A.1 is therefore considered to be appropriate.

A3 Crash location modelling

A3.1 Introduction

The UK DfT crash location model provides for the determination of the probability, in the event of a crash anywhere in the vicinity of the airport, of the crash being centred at any given location, defined in terms of rectilinear coordinates by the distance relative to the runway end and the runway extended centreline. The model consists of a set of 4 probability density functions (pdfs) which represent the crash distributions associated with 4 separate accident scenarios as follows:

- ground impacts from flight during take-off
- ground impacts from flight during landing
- take-off overruns and
- landing overruns.

These empirical distributions were determined by fitting mathematical functions to the crash locations identified in the historical accident record. They have been employed as described in the identified references. Some comment on the mathematical functions employed and their potential limitations and reliability is provided here.

Four primary limitations in the UK DfT crash location model, discussed in turn below, are identified as follows:

- the over-concentration of crash locations on the runway extended centreline
- the approach to the treatment of overruns
- the use of the departure end of runway as the coordinate system origin for take-off accidents, and
- the assumption that departure routes are confined to the runway extended centreline.

A3.2 Over-concentration of crash locations on the runway extended centreline

As noted earlier, the crash location model consists of probability distribution functions that fit the accident locations reported for historical accidents. A Weibull distribution was selected to fit the variation of the probability laterally from the runway extended centreline (the x direction according to the convention adopted in the UK DfT model) for the reported historical accident locations. The Weibull distribution tends to infinity at x = 0 which can be seen to be physically unrealistic for the crash location distribution. The crash location probability at the centreline can be expected to reach a maximum at x = 0 but must, under any physically realistic representation, be finite at that point.

From the perspective of model development, there appears to be a problem associated with the nature of the reporting of accident locations. Where the historical accident locations were close to the runway extended centreline, it appears that they were often reported as being exactly on the centreline (i.e., at x = 0) whilst in practice they will have been displaced some distance laterally from it. The reported accident locations will therefore be over-concentrated at the centreline and, to fit these reported locations closely, a function such as the Weibull distribution that tends to infinity at x = 0 is required to achieve a good fit. The model based on these reported crash locations and associated Weibull pdfs can therefore be expected to over-estimate the crash risks along and close to the runway extended centreline. There will be a corresponding under-estimation of the crash risks across the immediately adjacent region slightly further from the runway centreline. Further still from the runway centreline the use of the Weibull distribution can be expected to provide an effective and realistic fit to the true accident location distributions.

Studies of aircraft track keeping during normal operations provide a reference point for assessing the potential impact on the reliability of the predictions of the model that employs these physically unrealistic Weibull distributions. The observed tracks follow physically realistic distributions, broadly in accordance with the normal distribution function, that are finite at x = 0. Given the nature of the functions employed in the DfT model, there is inevitably a region across which the crash risk is more concentrated than the distribution of aircraft in flight. In effect, aircraft are predicted to crash more accurately along the runway extended centreline than they can fly.

This somewhat unrealistic scenario is found to apply over a relatively limited distance from the extended centreline only. to determine the crash risk, account is taken of the area on the ground that is expected to be destroyed in the event of an accident, in accordance with the crash consequence model assessed further in Section A4. The values for the predicted “destruction area” for the fleet mixes under the relevant scenarios are of the order of 0.5 hectares. According to the standard approach adopted in the UK DfT model for the determination of individual risk, this destruction area is represented by a square which, for the identified destruction area, has a side length of around 70 metres. The risk at any single location is determined by summing the probabilities of impact within this area by integration over this destruction area. The integration of the risk over this sort of distance smooths out the over-concentration of risk along the centreline, to some extent at least. The approach adopted for societal risk estimation also involves an element of integration that will smooth out these effects. Overall, it is concluded that, whilst there may be an element of over-estimation of risk close to the runway extended centreline, this limitation of the model and reported accident location data upon which it is based is unlikely to have any significant impact on the reliability of the risk predictions of the model.

A3.3 Treatment of overruns

The DfT model employs the landing threshold as the basic reference point for landing accident locations. In the case of impacts from flight, the pdf describing the accident location distribution is based on the impact location. This approach is entirely appropriate. For landing overruns, the pdf describing the accident location distribution is based on the final resting location of the wreckage. There are 2 fundamental concerns regarding this modelling approach.

The first key point to note in this respect is that landing operations are matched to the available runway length. Aircraft will land at a given runway only where they can stop, under normal circumstances and with an appropriate margin of safety, in the landing distance available, taking account of the performance characteristics of the aircraft, its weight and relevant external parameters (wind velocity, runway surface condition). In a small proportion of cases, aircraft are unable to complete the landing manoeuvre in the nominal distance required and overrun beyond the distance in which it was intended that the landing be completed.

Other studies (Eddowes et al. 2001, Hall et al. 2008) have developed overrun models referenced against the end of the available landing runway and this approach is more appropriate than the use of landing threshold. The DfT model landing overrun dataset includes a significant number of overruns that come to rest 3,000 m or more from the landing threshold. The vast majority of these will have involved large and heavy aircraft landing on runways of around 3,000 m or more in length and typically overrunning beyond the end of the landing distance available by no more than a few tens of metres. Conceptually the DfT model is physically unrealistic and will therefore tend to over-estimate the landing overrun risk, especially for shorter runways.

The second concern is that the UK DfT overrun model employs accident location data without any consideration of the influence of the obstacle environment. Conceptually, this approach may be reasonably appropriate for crashes from flight but is flawed in the case of the overrun. What is observed during overrun events is dependent upon the obstacle environment and may be characterised by 2 primary outcomes:

- the aircraft decelerates in the open space beyond the runway end and comes to a halt before hitting any obstacle, and
- the aircraft fails to stop in the available open space beyond the runway and is arrested by the first substantial obstacle it meets.

Only those accidents involving a total hull loss that will fall into the second category are employed in the DfT model whilst other studies (Eddowes et al. 2001, Hall et al. 2008) clearly demonstrate that overrun events that do not result in major damage are common. This modelling approach is not representative of the risk scenario concerned.

The extent to which these overrun modelling assumptions may lead to unrealistic risk predictions has been investigated in the context of previous studies (Eddowes, 2021). Those studies indicate that, for runway lengths of the order of 3 kilometres, risks may noticeably over-stated at distances closer to the runway end, for example of the order of a kilometre or so, but not at distances of several kilometres from the runway end.

These observations raise the question whether off-airfield risks are better assessed using the complete UK DfT model, including the overrun model, or by a modified approach that excludes the overrun model and employs the crashes from flight elements only of the UK DfT model. Given that this flaw in the model can be expected to have a limited impact on risk contour estimates at distances relatively close to runway ends only, this aspect of the model is not particularly critical in determining the overall risks associated with operations, given the lack of public use of the areas concerned. It is quite straightforward to drop the overrun element of the model and base the assessment on the crashes from flight elements only. That approach is recommended here.

A3.4 Coordinate system origin for take-off accidents

The UK DfT model essentially employs the end of the declared runway as the reference point for the pdfs that describe take-off accident locations. However, the available description of the model development states that the take-off accident locations are referenced against the threshold nearest the take-off end of runway. That is understood to mean that the nearest landing threshold to the departure end of runway was employed as the reference point when determining the crash locations that were used to develop the take-off accident pdfs. This reference point for take-off accidents is less unambiguous than the threshold as a reference point for landing accidents.

In some cases, there may be a displaced threshold and the chosen reference point may therefore not correspond with a specific take-off-related reference point. In some cases, clearway will be available such that take-off distance available from an operational perspective will not correspond with the paved surface. Finally, it may be noted that different aircraft have different inherent take-off distance requirements and the runway length provision in relation to those requirements will vary between different airports. Two crashes with identical operational characteristics may therefore be identified as being located at different distances from the runway end if they were to occur at runways of different lengths. As a result, there is no clear-cut reference point for use in relation to take-off accidents.

When using the departure end of runway as a reference and pdfs of the type employed in the UK DfT model, a potential problem arises in relation to accidents that occur before that reference point has been reached. It is evident that there can be no crashes during take-off that occur at locations prior to the start of take-off run. This physical reality of the process is not accommodated by the model. The crash probability is not constrained to zero at locations before the start of take-off run but varies according to the pdfs selected to fit the data points before the departure end of runway: i.e., the model places a component of take-off risk behind the point at which the take-off run commences. This component of take-off risk should be accounted for somewhere by the modelling process but in a different location. In practice, this misplaced component of the risk can be expected to be relatively small and not to have a major impact on the locations of the estimated risk contours.

Overall, whilst recognising these uncertainties and the possible benefits associated with using the alternative reference of the start of take-off run, the view adopted is that the departure end of runway represents a convenient and pragmatic coordinate system origin for the current purposes and the UK DfT modelling approach has been followed in this respect.

A3.5 Runway-aligned departure routes

The UK DfT model assumes flight paths are runway-aligned whilst some other models (DNVT, 1994; Piers, M.A. 1998; Pikaar et al., 2000; GfL, 2003) take account of flight paths that deviate from runway alignment. Approach and landing operations are typically runway-aligned for a considerable distance before the landing threshold, as is the case for the proposed WSI flight paths.

In the case of departures, turns are often initiated somewhat closer to the runway ends. Turns shortly after take-off may be initiated for noise abatement and for improved air traffic management. Several relatively early turns are envisaged under the proposed WSI flight path design.

The description of the DfT model development states the following in relation to departure routes:

> *4.25 No attempt to 'bend' the distributions around the arrival and departure routes was made for this model and all crash locations were measured relative to the runway ends and the extended runway centreline. The reason for this decision was that only a small proportion of crash reports record in detail the intended route of the aircraft prior to an accident. Even when this is recorded it is not always clear how to relate the intended route of the aircraft to the eventual accident location. For example, on departure a serious problem (which ultimately causes a crash) may arise before the intended route deviates from a straight path. In this case, the pilot would not attempt to follow the intended curved route, and therefore the actual crash location would be the same irrespective of whether the intended route was curved or straight.*
>
> *4.26 The fact that aircraft do not always follow straight routes will to some extent be implicit in the NATS model [i.e. the UK DfT model], as some of the historical crashes would have occurred while aircraft were on curved routes. Thus the 'average' effect of aircraft routeing on crash location is taken into account in the NATS model. The effects of curved routes are likely to be small, where the risk is greatest, close to the runway ends.*

Whilst the comments relating to the quality of the information concerning the intended route in paragraph 4.25 may be true, that does not validate the approach adopted in the UK DfT model. Some of the crash locations may relate to specific flight paths at certain airports that are not runway-aligned. The use of these locations in a runway-aligned model may lead to a greater degree of dispersion being predicted than would arise in practice for runway-aligned routes. The observation in para 4.26 that the "average" effect of aircraft routeing on crash location is considered is not helpful in this respect since the accurate prediction of areas of higher crash probability at any individual airport will be dependent on the specific details of routeing at that airport and not on the average. The observation that the effects of curved routes are likely to be small, where the risk is greatest, close to the runway, would appear to be reasonable. For the implementation of UK PSZ policy which refers to the 1 in 100,000 per annum risk contours which are typically located relatively close to runway ends, this modelling approach is adequate.

However, for the purposes of this assessment, consideration is being given to crash risks across a wider area that extends further from the runway ends and where these effects may be more substantial. In that context, a modified approach has been employed in this assessment in which the risks at any given point relative to the flight paths were determined on the basis of the identified distribution functions where the y value (distance from the threshold) is measured along the line of the curved flight path and the x value (displacement from the flight path) is measured perpendicular to the tangent of the curve of flight path at the appropriate y value. Accordingly, the distribution functions are bent around the flight paths in use in a manner consistent with that employed in the NLR model (Piers, M.A. 1998; Pikaar et al., 2000). In practice, whether straight or curved departure routes are employed makes no significant difference to the predicted risks, at least in areas subject to more significant risks closer to runway ends. The more refined modelling approach may relocate areas subject to higher probability of air crash but only slightly. However, since these areas are predominantly unpopulated, the risks to people on the ground will be very similar to that using the simpler assumption of runway-aligned flight paths.

A4 Accident consequence model

The UK DfT consequence model is based on the empirical relationship between the area destroyed and the size of the aircraft, characterised in terms of the maximum take-off weight allowed (MTOWA), as determined by reference to the historical accident record. The original DfT consequence model identified the following logarithmic relationship:

$$\log_e(\text{Area destroyed}) = -6.36 + 0.49 \log_e (\text{MTWA})$$

This relationship was subsequently revised slightly as follows:

$$\log_e(\text{Area destroyed}) = - 6.16 + 0.474 \log_e (\text{MTWA})$$

The historical accident record indicates a clear dependence of the size of the area affected in the event of a ground impact on aircraft size. The identified logarithmic relationship lacks an element of physical realism in that it does not provide for the prediction of an area destroyed of zero for a weight of zero. However, it is found to provide a better fit to the available empirical data across the range of aircraft sizes encountered in practice.

Theoretical considerations based on dimensional analysis suggest that a linear dependence is not to be expected. For simplicity, consideration is given to a simple rectilinear object of length, l, width, w and height, h. The volume will be given by $V = l \times w \times h$. Volume is proportional to mass: $V \propto M$. On impact with a surface, a constant force for deceleration per unit area over which the impact takes place is assumed. The contact area will be proportional to the square of the linear dimension. For an object sliding across a surface the contact area will be $l \times w$ and for impact with a wall, the contact area will be $w \times h$. On that basis the contact area will be proportional to Mass to the power 2/3. The kinetic energy to be dissipated will be directly proportional to mass. Accordingly, the distance travelled to arrest the Mass due to the identified deceleration force will be proportional to Mass to the power 1/3. Assuming that the consequence area is given by the object width multiplied by the distance travelled it would therefore be expected to be proportional to mass to the power 2/3.

The above dimensional analysis based on a rectilinear object may not be entirely representative of aircraft behaviour in the event of an accident, but it does provide some theoretical basis for the identification of the nature of the relationship between aircraft size and the scale of the impact consequences. The UK DfT logarithmic model is found to agree reasonably well with the Mass to the power 2/3 relationship, although, empirically, a square root relationship appears to provide a better basis for correlation with the identified logarithmic relationship. The available accident dataset includes a limited number of accidents involving larger aircraft and there is therefore some uncertainty as to whether the observed empirical logarithmic relationship provides a sound basis for predicting crash consequences for larger aircraft. The theoretical Mass to the power 2/3 relationship would indicate somewhat larger areas destroyed for larger aircraft than the empirical logarithmic relationship of the UK DfT model. However, larger aircraft for which limited empirical crash consequence data is available (i.e., those of around 200 tonnes or more) make up a relatively small proportion of the operations (less than 7.6 per cent). The estimated risks will be dominated by the contribution made by smaller aircraft for which the empirical logarithmic model is expected to provide reliable crash consequence estimates. Overall, it is concluded that the logarithmic UK DfT crash consequence model is an appropriate model for use in the current assessment in relation to ground impacts in areas of general urban development.

It is noted that mechanistic models have previously been developed (Byrne, 1997) to support the assessment of crash consequences arising from impacts with specific large structures and could be adopted to address specific features of the built environment if considered appropriate.

A5 Conclusions

Overall, it is concluded based on this review that, with limited modification, the UK DfT model represents a suitable modelling approach to support the current assessment. Key findings are as follows:

- Aircraft crash rates: taking account of the more limited size of the dataset, the available Australian historical accident record is generally consistent with the crash statistics identified from the wider “first world” international experience and the crash rates developed to support the UK DfT model are therefore considered appropriate for use in the current assessment.
- Crash location distribution modelling: whilst some flaws are evident in this aspect of the UK DfT model, the primary concerns, relating to the treatment of overrun scenarios the failure to address curved flight paths can readily be addressed by minor modifications to the model.
- Crash consequence modelling: the UK DfT model is confirmed to provide estimates for the area impacted in the event of a ground collision dependent on aircraft mass that are consistent with the historical data by means of an empirical relationship that is supported by theoretical considerations. The model is considered appropriate for general application to the assessment of crash consequences following ground impacts in areas of typical urban development.

A6 References

Byrne JP 1997 The Calculation of Aircraft Crash Risk in the UK. Report prepared by AEA Technology (Byrne, J. P.) for the UK Health and Safety Executive, Contract Research Report 150/1997.

Eddowes, M., 1994, Risk of Ground Fatalities from Aircraft Crash Accidents at Manchester Airport. Proof of Evidence submitted to the Manchester Airport Second Runway Public Inquiry.

Eddowes M., Hancox, J. and MacInnes, A., 2001, Final Report on the Risk Analysis in Support of Aerodrome Design Rules, report produced by AEA Technology on behalf of the Norwegian Civil Aviation Authority, December 2001.

Eddowes, M., 2021, Chapter 8 Major Hazards and Disasters prepared by Eddowes Aviation Safety Limited in Dublin Airport North Runway Relevant Action Application Environmental Impact Assessment Report Volume 2 - Main Report, AECOM, September 2021.

Hall, J. et al. 2008, ACRP Report 3: Analysis of Aircraft Overruns and Undershoots for Runway Safety Areas, US Transportation Safety Board, 2008.

GfL, 2003 Externes Risiko für den Flughafen Frankfurt Main. Gessellschaft für Luftverehrsforschung mbH, 2003.

Piers, M.A. 1998 Methods and Models for the Assessment of Third Party Risk Due to Aircraft Accidents in the Vicinity of Airports and Their Implications for Societal Risk in Technology, Risk, and Society Volume 12, Quantified Societal Risk and Policy Making pp 166-204, 1998.

Pikaar, A.J., Piers M.A. and Ale, B., 2000 External Risk Around Airports: A Model Update, , Presentation at the 5th International Conference on Probabilistic Safety Assessment and Management, Osaka, Japan, December 2000.

Purdy, G., 1994 Manchester Airport Second Runway, Third Party Risk Proof of Evidence, Grant Purdy, DNV Technica, August 1994.

Shirazi, H. Etal., 2016 Runway Protection Zones (RPZs) Risk Assessment Tool Users Guide (2016) ACRP Research Report 168.

National Academies of Sciences, Engineering, and Medicine 2016. Runway Protection Zones (RPZs) Risk Assessment Tool Users Guide. Washington, DC: The National Academies Press. https://doi.org/10.17226/24662.

Appendix B

Flight path, flight schedule and runway use specifications

B1 Runway and flight path specification

The runway threshold locations provide the primary reference points for the runway system and these are given in UTM coordinates in Table B.1. For the purposes of the assessment, it is convenient to work in terms of runway-aligned rectilinear coordinates referenced against the runway thresholds. The Runway 05 and Runway 23 departure ends of runway (DERs) are assumed to coincide with the Runway 23 and Runway 05 thresholds, respectively.

Table B.1 Runway threshold coordinates

Threshold	UTM coordinates (m)		Threshold to threshold distance (m)
	Easting	Northing	
05	286914.061	6247443.790	3,700
23	290067.115	6249379.830	

A series of flight paths for Runway 05 and Runway 23 have been provided covering arrivals and departures at both runways in day and night operations, comprising a total of 51 separate routes. *(Presumably these are identified elsewhere and do not need to be repeated here – is there a document reference for this?)*

To support the assessment flightpaths coordinates were specified in a kmz file (13147_WSAd_Merged tracks.kmz) which identifies the 51 separate flightpaths, as follows:

05 Departures	05 Arrivals	23 Departures	23 Arrivals
GDA94_W.D.05.EAST	GDA94_W.A.05.MARLN	GDA94_W.D.23.EAST	GDA94_W.A.23.WEST
GDA94_W.D.05.NJ_NORTH	GDA94_W.A.05.NORTH	GDA94_W.D.23.NJ_NORTH	GDA94_W.A.23.NORTH
GDA94_W.D.05.NJ_NORTH_EAST	GDA94_W.A.05.NORTH 2	GDA94_W.D.23.NJ_SOUTH	GDA94_W.A.23.MARLN
GDA94_W.D.05.NJ_SOUTH	GDA94_W.A.05.NORTH 2.RNPAR	GDA94_W.D.23.NORTH	W.A.23.MARLN.NIGHT
GDA94_W.D.05.NORTH	GDA94_W.A.05.WYATT	GDA94_W.D.23.SOUTH	W.A.23.NORTH.NIGHT
GDA94_W.D.05.NORTH_TRANS	W.A.05.MARLN.NIGHT	GDA94_W.D.23.SOUTH_HOT	W.A.23.NW.NIGHT
GDA94_W.D.05.SOUTH	W.A.05.MARLN.NIGHT.RRO	GDA94_W.D.23.WEST	W.A.23.WYATT.NIGHT
GDA94_W.D.05.SOUTH_HOT	W.A.05.NORTH.NIGHT	W.D.23.NE.NIGHT	
GDA94_W.D.05.WEST	W.A.05.NORTH.NIGHT.RRO	W.D.23.NE.NIGHT.RRO	
GDA94_W.D.05.WNW	W.A.05.WYATT.NIGHT	W.D.23.NORTH.NIGHT	
W.D.05.NE.NIGHT	W.A.05.WYATT.NIGHT.RRO	W.D.23.NORTH.NIGHT.RRO	
W.D.05.NORTH.NIGHT_A		W.D.23.SE.NIGHT	
W.D.05.NORTH.NIGHT_B		W.D.23.SE.NIGHT.RRO	
W.D.05.SE.NIGHT		W.D.23.SOUTH.NIGHT	
W.D.05.SOUTH.NIGHT		W.D.23.SOUTH.NIGHT.RRO	
W.D.05.WEST.NIGHT		W.D.23.WEST.NIGHT	
		W.D.23.WEST.NIGHT.RRO	

For the purposes of risk contour estimation, flightpaths are modelled out to a distance that encompasses the 1 in 1,000,000 per annum risk contour. Based on experience gained from undertaking similar assessments, it is expected that for the traffic volume and fleet mix identified for the 2055 reference year, the 1 in 1,000,000 per annum risk contour will not extend beyond a distance of around 13.5 km. That experience indicates that the extents of the contour along any non-runway aligned departure route will be substantially less than that distance. This experience informs the approach to the treatment of different routes in the modelling process in which different flight paths following the same route out to these distances were combined.

All Runway 05 arrivals follow the extended centreline from a minimum of 15 km before threshold. With the exception of GDA94_W.A.05.NORTH 2.RNPAR, all Runway 05 arrivals follow the extended centreline from a minimum of 22 km before threshold. All Runway 23 arrivals follow the same path from a minimum of circa 22 km before threshold and the last 14 km are runway aligned. Prior to runway alignment this common flight path follows a heading of c. 150 degrees, at 90 degrees to the runway axis, and involves a final 90 degree turn to align with the runway. On that basis, the initial working assumption in the modelling process is that the 1 in 1,000,000 per annum contour will be contained with the runway-aligned portion of the arrivals routes at both runway ends and hence that all Runway 05 arrivals can be treated together for modelling purposes, as can all Runway 23 arrivals.

Working through the above 05 departures list, various sets of flight paths are identified as being coincident out to a distance of 13.5 km or more and can therefore be treated as a single flight path for the purposes of risk contour estimation. These combined routes comprise the following flight paths:

- D05-1: GDA94_W.D.05.EAST, GDA94_W.D.05.SOUTH, GDA94_W.D.05.SOUTH_HOT
- D05-2: GDA94_W.D.05.NJ_NORTH, GDA94_W.D.05.NJ_NORTH_EAST
- D05-3: GDA94_W.D.05.NORTH, GDA94_W.D.05.NORTH_TRANS, GDA94_W.D.05.WEST, GDA94_W.D.05.WNW, W.D.05.NORTH.NIGHT_B
- D05-4: W.D.05.NE.NIGHT, W.D.05.NORTH.NIGHT_A
- D05-5: W.D.05.SE.NIGHT, W.D.05.SOUTH.NIGHT, W.D.05.WEST.NIGHT.

GDA94_W.D.05.NJ_SOUTH is not common with any other of the flightpaths and was treated separately.

On that basis, the Runway 05 departures may be simplified to a total of 6 flight paths nearer to threshold. Two sets of flight paths, D05-1 and D05-3, are almost identical until circa 6 km from THR and 1 km laterally from the extended centreline which can be expected to cover the area of interest in respect of contour determination. These sets of routes may therefore also be combined also, giving a total of 5 distinct Runway 05 departure routes for contour modelling purposes.

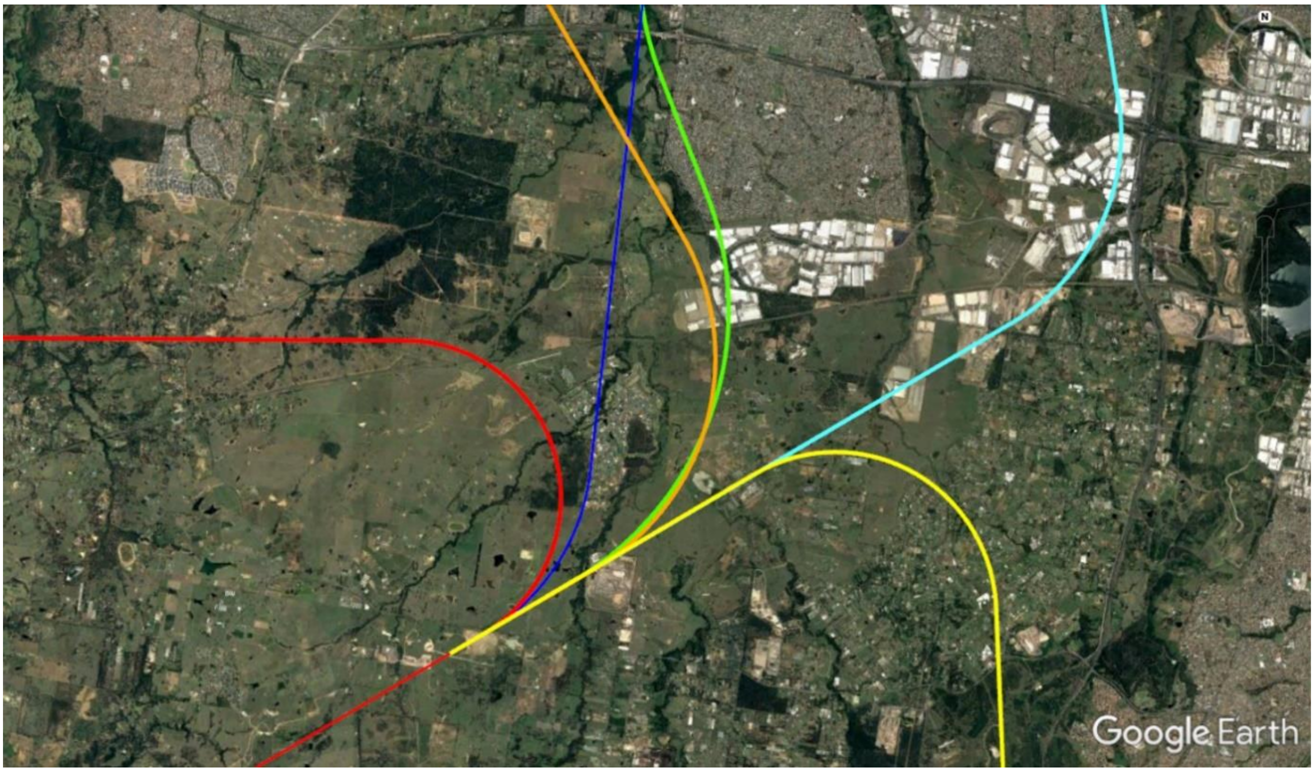
Working similarly through the Runway 23 departures list the following combined routes, numbered D23-1 to D23-5 are identified:

- D23-1 : GDA94_W.D.23.EAST, GDA94_W.D.23.NORTH, GDA94_W.D.23.SOUTH, GDA94_W.D.23.WEST
- D23-2: GDA94_W.D.23.NJ_SOUTH, W.D.23.SE.NIGHT, W.D.23.SOUTH.NIGHT, GDA94_W.D.23.SOUTH_HOT
- D23-3: W.D.23.NE.NIGHT, W.D.23.NORTH.NIGHT, W.D.23.WEST.NIGHT
- D23-4: W.D.23.NE.NIGHT.RRO, W.D.23.NORTH.NIGHT.RRO, W.D.23.WEST.NIGHT.RRO
- D23-5: W.D.23.SE.NIGHT.RRO, W.D.23.SOUTH.NIGHT.RRO.

GDA94_W.D.23.NJ_NORTH (Figure 15) is not common with any other of the flightpaths and has been treated separately.

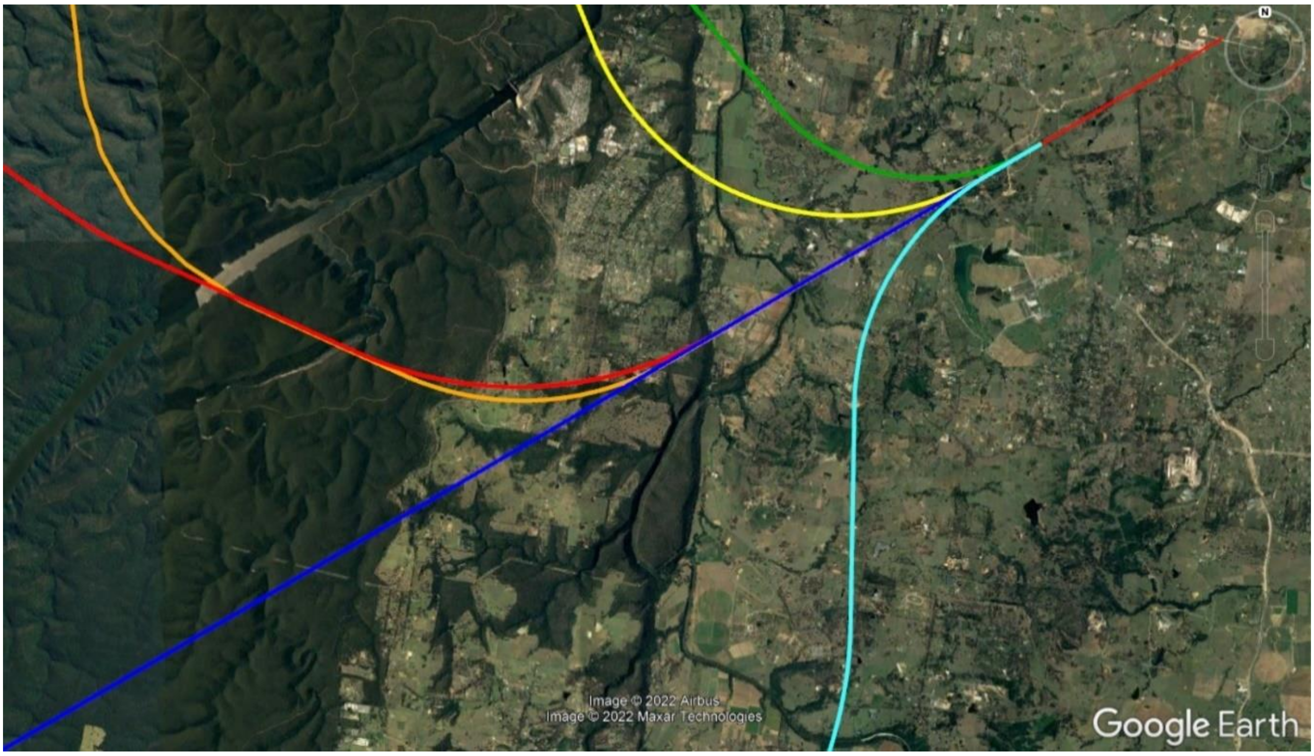
On that basis, the Runway 23 departures may be simplified to a total of 6 flightpaths nearer to threshold. Two sets of flight paths, D23-1 and D23-3, are almost identical until circa 6 km from THR and 1 km laterally from the extended centreline which can be expected to cover the area of interest in respect of contour determination. These sets of routes may therefore also be combined also, giving a total of 5 distinct Runway 23 departure routes for contour modelling purposes.

These consolidated flight path specifications which cover the regions in the vicinity of WSI subject to potentially significant risk were employed in the further assessment of the fleet mix and runway use and in the subsequent modelling of risk contours. They provide an initial visual impression of areas potentially subject to elevated risk.



D05-1: Orange; D05-2: Light blue; D05-3: Green; DO5-4: Dark blue; D05-5: Red; GDA94_W.D.05.NJ_SOUTH: Yellow

Figure A.1 Combined near threshold 05 Departure routes



D23-1: Orange; D23-2: Dark blue; D23-3: Red; D23-4: Yellow; D23-5: Light blue; GDA94_W.D.23.NJ_NORTH: Green

Figure A.2 Combined near threshold 23 Departures

B2 Movements, fleet mixes and runway use scenarios

The assessment is based on average daily movement schedules, for different aircraft types, as summarised in Table A.2. Annual movements used in the assessment were 365.25 times the identified value for the average day.

Table A.2 Movements numbers and fleet mixes for the average day

Aircraft type	2033	2055
7878	3.43	30
7879	2.57	30.86
73H	12	
77300		16
7478F	0.57	1.43
773ER	2	
77F	3.43	2.57
A221	21.14	19
A321	29.43	67.43
A32N	46	125.86
A332	4	
A333	6.57	35.43
A338	1.43	9.71
A33F	3.14	4.29
A359	2	46.57
A35F		2.57
B3M8	8.57	127.14
B738	59.14	63.14
B779		16
DASH8	12.86	12.86
SF34	4	12
Total	**222.29**	**622.86**

Seven different operating scenarios were defined for the projected fleet mixes in the 2033 and 2055 reference years representing different options for runway use and use of the associated flight paths. The scenarios are as follows:

- S1 No preference (day) and no preference (night) (No preference)
- S2 No preference (day) and prefer RRO (night)
- S3 Prefer Runway 05 (day) and prefer RRO (night) (Prefer Runway 05)
- S4 Prefer Runway 23 (day) and prefer RRO (night) (Prefer Runway 23)
- S5 Prefer Runway 05 (day) and prefer RRO (night), limited peak time change
- S6 Prefer Runway 23 (day) and prefer RRO (night), limited peak time change
- S7 Preference Runway 23 during non-peak, no preference during peak (day) and preference RRO (night).

Reciprocal runway operations (RRO) refer to "head-to-head" runway operations in which Runway 05 is used for landing and Runway 23 is used for take-off which leads to a greater number of movements to the south-west of the runway than to the north-east. These options have been identified as a basis for providing flexibility in air traffic control provision in the future and no single option has been identified at this stage to support future operation.

Flight path use varies according to the chosen option and the third party risks in specific areas in the vicinity of WSI will vary to some extent according to which option is employed. Runway and flight path use was reviewed for the different options to determine the option that is most representative overall of all the options. This review considered the relative use of both runway directions (Runway 05 or Runway 23) and operation over the north-east runway end (Runway 05 take-off and Runway 23 landing) as compared with operation over the south-west runway end (Runway 23 take-off and Runway 05 landing). As summarised in Table A.3 and Table A.4, the different options involve quite different proportions of use of runway direction with extremes of 21.4:78.6 and 69.3:30.7 in the use of Runway 05 to use of Runway 23. However, the proportion of operations using the north-east and south-west ends of the runway for the different scenarios cover a narrower range from 43.0:57.0 to 48.9:51.1. These findings reflect the fact that prioritising one runway direction over another leads to take-offs more predominantly at one runway end and landings more predominantly at the other end. In terms of the risk characteristics, one runway direction will be more exposed to take-off crashes and the other runway direction will be more exposed to landing crashes but neither runway end will be significantly more exposed to risk than the other. Conversely, where RRO are in use, this will lead to a concentration of operations in one runway direction (the south-west) and to a higher level of risk at that end compared with a more balanced use of the runway. Concomitantly, risk levels will be lower in the north-east if RRO are employed.

From the perspective of risk levels over more developed areas in the vicinity of WSI, RRO offer a benefit by reducing flight activity levels over those areas and hence reducing the associated crash risk. On that basis, the No preference scenario can be seen to be a worst case from the perspective of the location of flight paths closer to areas of development. Given that the No preference scenario represents the most balanced runway use scenario, that it sits in the middle of the range of runway direction use and is a worst-case from the perspective of the proximity of flight paths in the vicinity of developed areas, the assessment was based on that operating scenario. The movement numbers by aircraft type and flight path that were used in the individual risk assessment are summarised in Table A.5 and Table A.6 for the 2033 and 2055 reference years, respectively.

Table A.3 2033 runway use for operating scenarios

Scenario	RWY 05	RWY 23	North-east	South-west
S1	47.65%	52.35%	48.91%	51.09%
S2	46.01%	53.99%	43.03%	56.97%
S3	69.26%	30.74%	44.07%	55.93%
S4	21.41%	78.59%	43.74%	56.26%
S5	66.05%	33.95%	43.48%	56.52%
S6	24.26%	75.74%	44.08%	55.92%
S7	31.61%	68.39%	43.36%	56.64%
Average	43.75%	56.25%	44.38%	55.62%

Table A.4 2055 runway use for operating scenarios

Scenario	RWY 05	RWY 23	North-east	South-west
S1	47.37%	52.63%	49.40%	50.60%
S2	45.86%	54.14%	43.48%	56.52%
S3	69.07%	30.93%	43.85%	56.15%
S4	22.10%	77.90%	44.57%	55.43%
S5	66.18%	33.82%	43.76%	56.24%
S6	24.57%	75.43%	44.70%	55.30%
S7	32.11%	67.89%	45.32%	54.68%
Average	43.90%	56.10%	45.01%	54.99%

Table A.5 2033 No preference scenario movements by aircraft type and flight path for the average day

Aircraft type	D05-1/3	D05-2	D05-4	D05-5	GDA94 _W.D.0 5.NJ_ SOUTH	D23-1/3	D23-2	D23-4	D23-5	GDA94 _W.D.2 3.NJ_ NORTH
7878	0.243	0.000	0.000	0.543	0.000	0.928	0.000	0.000	0.000	0.000
7879	0.475	0.000	0.000	0.000	0.000	0.810	0.000	0.000	0.000	0.000
73H	2.276	0.000	0.000	0.493	0.000	2.724	0.507	0.000	0.000	0.000
7478F	0.119	0.000	0.000	0.000	0.000	0.167	0.000	0.000	0.000	0.000
773ER	0.000	0.000	0.000	0.537	0.000	0.463	0.000	0.000	0.000	0.000
77F	1.003	0.000	0.000	0.000	0.000	0.712	0.000	0.000	0.000	0.000
A221	4.797	0.000	0.000	0.000	0.000	5.774	0.000	0.000	0.000	0.000
A321	4.102	0.000	1.323	1.553	0.000	6.432	1.304	0.000	0.000	0.000
A32N	10.102	0.000	0.000	0.551	0.000	11.898	0.449	0.000	0.000	0.000
A332	0.775	0.000	0.000	0.000	0.000	1.225	0.000	0.000	0.000	0.000
A333	0.610	0.000	0.395	0.540	0.000	1.741	0.000	0.000	0.000	0.000
A338	0.307	0.000	0.000	0.000	0.000	0.408	0.000	0.000	0.000	0.000
A33F	0.414	0.000	0.000	0.481	0.000	0.300	0.376	0.000	0.000	0.000
A359	0.543	0.000	0.000	0.000	0.000	0.457	0.000	0.000	0.000	0.000
B3M8	1.418	0.000	0.537	0.000	0.000	2.331	0.000	0.000	0.000	0.000
B738	11.781	0.000	0.388	1.540	0.000	14.884	0.979	0.000	0.000	0.000
DASH8	0.249	2.040	0.000	0.000	0.679	0.000	0.749	0.000	0.000	2.712
SF34	0.345	0.000	0.000	0.000	0.598	0.000	0.402	0.000	0.000	0.655

Table A.6 2055 No preference scenario movements by aircraft type and flight path for the average day

Aircraft type	D05-1/3	D05-2	D05-4	D05-5	GDA94_W.D.05.NJ_SOUTH	D23-1/3	D23-2	D23-4	D23-5	GDA94_W.D.23.NJ_NORTH
7878	0.243	0.000	0.000	0.543	0.000	0.928	0.000	0.000	0.000	0.000
7879	0.475	0.000	0.000	0.000	0.000	0.810	0.000	0.000	0.000	0.000
73H	2.276	0.000	0.000	0.493	0.000	2.724	0.507	0.000	0.000	0.000
7478F	0.119	0.000	0.000	0.000	0.000	0.167	0.000	0.000	0.000	0.000
773ER	0.000	0.000	0.000	0.537	0.000	0.463	0.000	0.000	0.000	0.000
77F	1.003	0.000	0.000	0.000	0.000	0.712	0.000	0.000	0.000	0.000
A221	4.797	0.000	0.000	0.000	0.000	5.774	0.000	0.000	0.000	0.000
A321	4.102	0.000	1.323	1.553	0.000	6.432	1.304	0.000	0.000	0.000
A32N	10.102	0.000	0.000	0.551	0.000	11.898	0.449	0.000	0.000	0.000
A332	0.775	0.000	0.000	0.000	0.000	1.225	0.000	0.000	0.000	0.000
A333	0.610	0.000	0.395	0.540	0.000	1.741	0.000	0.000	0.000	0.000
A338	0.307	0.000	0.000	0.000	0.000	0.408	0.000	0.000	0.000	0.000
A33F	0.414	0.000	0.000	0.481	0.000	0.300	0.376	0.000	0.000	0.000
A359	0.543	0.000	0.000	0.000	0.000	0.457	0.000	0.000	0.000	0.000
B3M8	1.418	0.000	0.537	0.000	0.000	2.331	0.000	0.000	0.000	0.000
B738	11.781	0.000	0.388	1.540	0.000	14.884	0.979	0.000	0.000	0.000
DASH8	0.249	2.040	0.000	0.000	0.679	0.000	0.749	0.000	0.000	2.712
SF34	0.345	0.000	0.000	0.000	0.598	0.000	0.402	0.000	0.000	0.655

Appendix C

Societal risk modelling

C1 Outline

Societal risks have been determined by reference to the following parameters:

- the likelihood of a crash at any given location relative to the runway and associated flight paths
- the area impacted on the ground in the event of a crash for each different aircraft type
- the density of occupancy at any given location subject to crash risk.

This modelling approach provides estimates for the frequency (f) of scenarios causing a wide range of numbers of fatalities (n) up to a maximum number associated with an impact of the largest aircraft type into the area of highest population density. These estimates are then employed to derive estimates for different societal risk measures for comparison with appropriate acceptability criteria. In accordance with the approach set out in Section 3.1.3 of the main report, 3 different societal risk measures have been employed in this assessment:

- the FN curve where F is the cumulative frequency of events leading to up to N fatalities
- the expectation value, $\sum_{i=1}^{n_{max}} f_i \, n_i$, representing the average number of fatalities per annum
- the scaled risk integral.

The crash risk frequency and area impacted are determined using the available empirical models, as described in further detail in the following sections of this appendix. The density of occupancy has been estimated by reference to the available census data. This approach considers residential areas only and assumes that all individuals are permanently resident at those locations. In practice, individuals will leave these residential areas for periods of time and so the risk associated with crashes into them will be over-stated. On the other hand, there will be additional crash scenarios involving impacts into work place and other sites that are not explicitly covered by this approach. These 2 factors can be expected to balance one another to some extent such that the overall estimate of residential impacts will provide a reasonable representation of the true situation. This simplified approach is therefore considered adequate for the current purposes and is preferred due to the ready availability of residential data to support it.

C2 Airport-related societal risk modelling

The majority of accidents occur in the more immediate vicinity of airports during take-off and landing operations and the risk associated with them may be estimated quantitatively by use of the airport-related crash risk model that has been outlined in Section 3.1.3 and reviewed in further detail in Appendix A. Whilst the UK DfT model employed to support this assessment was initially developed primarily to support the estimation of individual risks it is equally applicable to the estimation of societal risks. As described in detail in Appendix A, this empirical model comprises 3 distinct elements as follows:

- the likelihood or probability (frequency per annum) of an aircraft crash occurring during landing or take-off operations, anywhere in the vicinity of an airport, having regard to the number of movements and the inherent reliability of different aircraft types, as determined from the available crash statistics
- the probability of impact at any specific location at or near an airport relative to the runway ends and the flight paths beyond them, as described by the crash location distribution, determined by reference to crash locations in the historical accident data set, and
- the severity of the consequences of an impact on the ground, according to the size of the aircraft concerned and again determined by reference to the historical accident data set.

The annual probability of a crash at any given location with respect to the runway and associated flight paths was estimated by reference to the aircraft crash rate and the crash location distribution elements of the model, using an appropriate specification for operations. The annual crash probabilities were estimated within each 200 x 200 m grid square from an overall runway-aligned grid, centred on the runway and covering 40 km laterally and 45 km longitudinally. These annual crash probabilities per square, p_s, were determined by reference to the different fleet mixes using the different take-off and landing flight paths, in accordance with the specifications presented earlier in Appendix B. Risks within the grid associated with the departure and arrival routes described in Appendix B were modelled longitudinally out to a distance along the flight paths that ensured coverage of all but the more sparsely populated areas for which the contributions to societal risk will be negligible, having further regard to the limit of the applicability of the crash location distribution element of airport-related crash risk model. The latter limit is determined in accordance with the crash locations in the database on which the model is based which extend to around 40 km from the runway.

To determine the likely number of fatalities in the event of a crash, reference was made to the consequence model which provides an estimated destruction area (DA) for the different aircraft types under consideration. Further reference was made to the 2021 Census data to determine the population density in each 200 x 200 m grid square. The 2021 Census provides population data in terms of the number of persons, the number of dwellings and the size of individual census areas from which 2 key parameters employed as inputs to the assessment were derived: the number of persons per dwelling (PpD) and the area per dwelling (ApD). For grid squares in which the area per dwelling is less than the crash destruction area (DA), it is expected that one or more (DA/ApD) dwellings will be affected on average in the event of an impact. The number of fatalities, n, expected in this case is the number of dwellings affected, multiplied by the number of persons per dwelling: n = PpD x DA/ApD. The event frequency, f, for the incident causing those n fatalities is the probability of a crash in the grid square concerned, p_s.

For grid squares where the area per dwelling is greater than the destruction area, there is a possibility that a crash will not impact on any dwelling. If the impact is on a dwelling, the number of fatalities is expected to be the number of persons per dwelling. Allowing for crashes in which dwellings are not impacted, the fatality event frequency, f, is reduced by a factor DA/ApD below the grid square crash probability: f = p_s x DA/ApD.

Values for the individual event frequencies, f, and the number of fatalities, n, are determined for all combinations of grid squares and aircraft types with different DA values. These values are then combined to provide the FN curve in terms of the cumulative probabilities, F, of events causing N or more fatalities.

C3 Airways-related societal risk modelling

Beyond the limit of the area across which the airport-related risk model has been applied, as described in the previous section, the network of airways providing access to and from WSI involves flight predominantly over sparsely populated areas. Given the low crash rates per unit area in these locations and their low population densities, the contribution to the total societal risk from crashes in these areas can be expected to be small compared with the estimate provided by the airport-related risk model. However, some of these airways pass over some more densely populated areas of Sydney. The proximity of the airways network to populated areas has therefore been reviewed to determine the extent to which flight in such areas might contribute to the overall societal risk associated with WSI operations.

On the basis of the flight path review, 5 flight paths involving flight over more densely populated areas were identified that are not covered by the societal risk assessment using the airport-related model described above. Those routes are the Runway 05 arrival from the north (GDA94_W.A.05.NORTH), the Runway 05 and 23 departures to the east (GDA94_W.D.05.EAST and GDA94_W.D.23.EAST) and the Runway 05 and 23 arrivals from the east (GDA94_W.A.05.MARLN and GDA94_W.A.23.MARLN), as shown in Figure C.1. The relative densities of population are evident from the census area boundaries shown in red in this figure: areas with higher population densities have smaller census areas and therefore have higher densities of area boundaries. These 5 routes were identified initially as priorities for determining the scale of the contribution of airways-related risks to the total societal risks compared with the airport-related contribution. This modelling approach demonstrated that the risk associated with these priority airways is small compared with the risk determined using the airport-related model. On that basis, it can be concluded that the remaining airways make a negligible additional contribution to the total societal risk and so need not be modelled explicitly.

Risks along these routes were modelled using a similar approach to that employed in the airport-related societal risk assessment. Crash risks per flight kilometre identified by Byrne (1997) of 4.7×10^{-11} and 3.8×10^{-10} were employed for large and small commercial transport aircraft, respectively. To determine the number of fatalities in the event of a crash, population densities, as characterised in terms of the number of persons per dwelling and the area per dwelling, were sampled from the available census data at 100 m intervals along the routes. Making further reference to the destruction areas (DA) associated with different aircraft types, these population density estimates were then applied to determine the number of fatalities in accordance with the methodology applied to airport-related societal risk modelling.

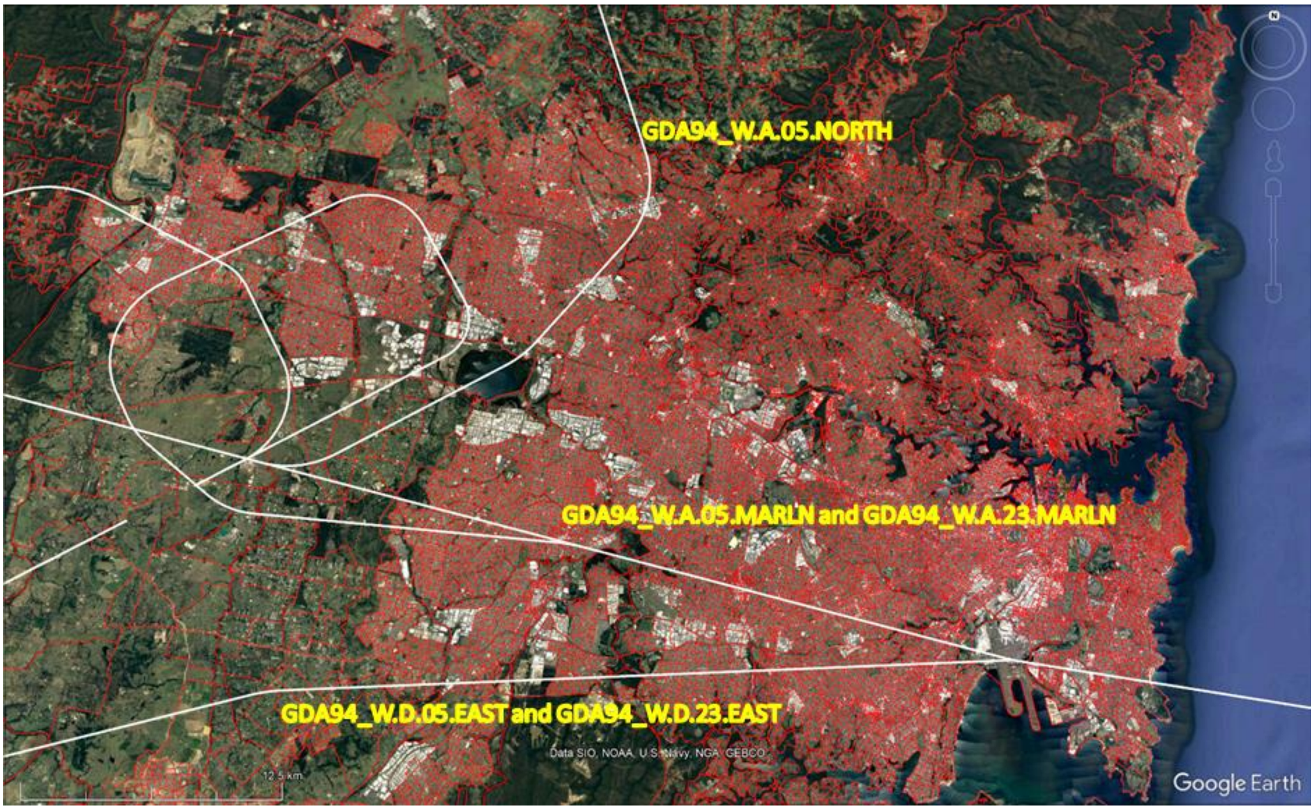


Figure C.1 Flight paths over populated areas outside the airport-related model limit

The airways model has also been applied to the estimation of the impact rate in the Blue Mountains area, including the associated World Heritage area. Based on a review of flight paths, it is estimated that around 50% to 60% of flights at WSI involve flight over the Blue Mountains, typically involving paths of 50–60 km across that area. For the identified fleet mix, application of the identified airways crash model gives a crash rate of 7.3×10^{-11} per km. On that basis, the annual rate of impacts in the Blue Mountains is estimated to be 1 in 1,700 to 1 in 2,400 years.

C4 Societal risk estimates

The societal risk estimates for 2033 determined in accordance with the approach outlined earlier in this appendix are summarised by the FN curve shown in Figure C.2. The risk estimates are shown separately for the airport-related element, the airways-related element and the total of these 2 components. At lower values of N, the airport-related risk estimate makes the dominant contribution to the total risk. At higher values of N, the contributions from airport-related and airways-related risk estimates are comparable. This outcome reflects the implementation of the airways-related model for flight over more densely populated areas only, compared with the implementation of the airport-related model which is implemented over a areas with a wider range of population densities. In practice, if the airways model were to be applied more generally across all areas, including relatively sparsely populated areas a higher estimate for the rate of occurrence of events involving lower numbers of fatalities would be expected. These findings indicate that the risk contribution estimated sing the airport-related model will be representative of the risk overall and that the FN curve shown in Figure C.2 will provide a reliable estimate for the total risks. It can be seen that the risks for 2033 are above the level of negligible risk identified according to UK criteria and well below the identified UK quantitative criterion for significant risk. The FN curve essentially meets the more stringent criteria for additional aversion to high fatality incidents identified in NSW and Safe Work Australia guidance.

For 2033 the rate of occurrence of incidents giving rise to one or more fatalities is estimated to be 1 in 4,245 years and the average number of fatalities expected for the range of scenarios identified is estimated to be 9.6. The expectation value for the anticipated range of crash scenarios at the estimated frequency of occurrence is 0.0027 per annum, equivalent to 1 fatality in 444 years. The scaled risk integral value determined for 2033 according to the Republic of Ireland specification is 6,770. These risk estimates are summarised in Table C.1.

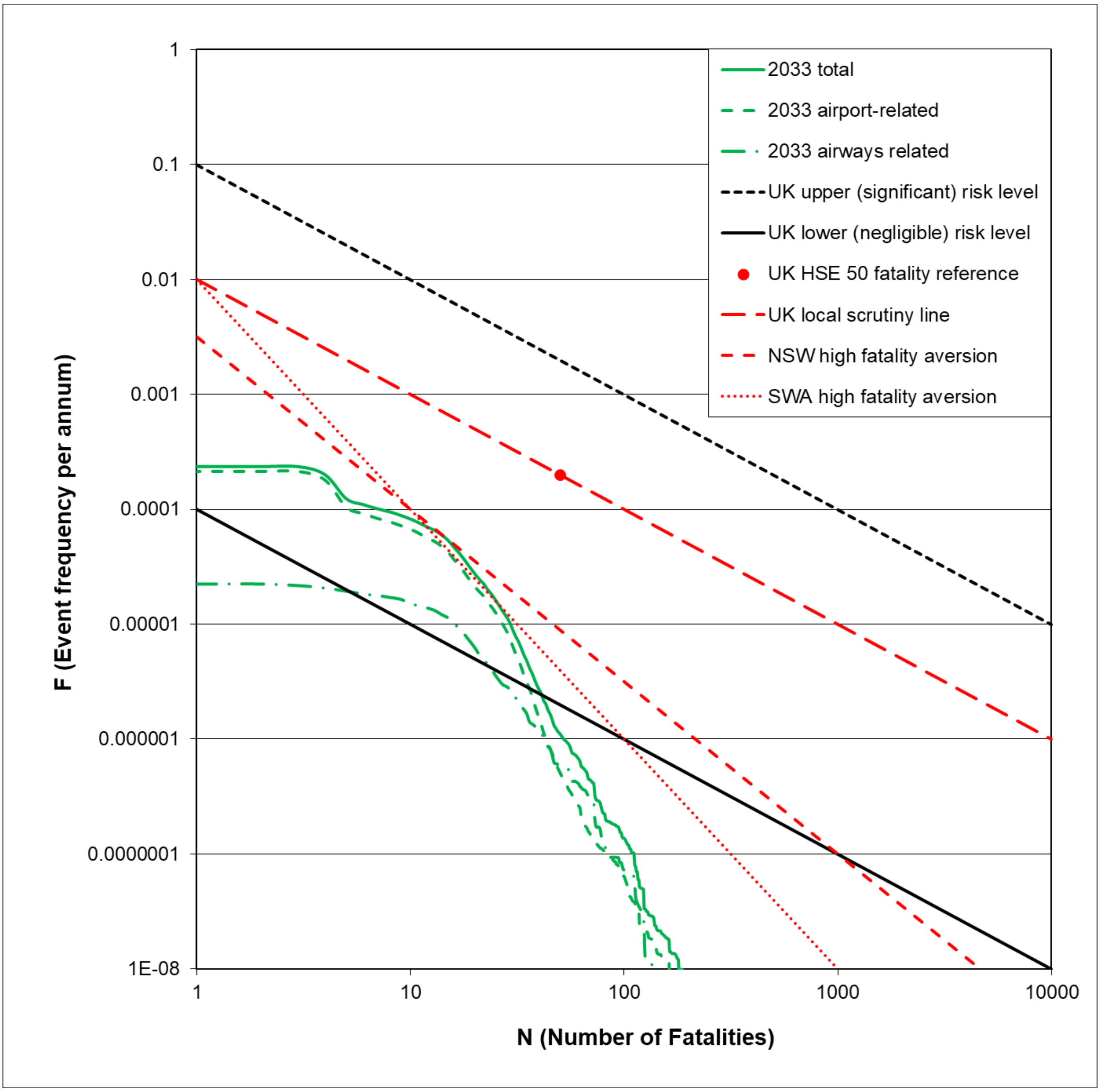


Figure C.2 2033 FN curve

The societal risks estimates for 2055 are broadly similar to those estimated for the 2033 but somewhat greater, reflecting the larger number of movements. As shown by the FN curve in Figure C.3, the risks are above the level of negligible risk identified according to UK criteria and well below the identified UK quantitative criterion for significant risk. The FN curve exceeds the more stringent criteria for additional aversion to high fatality incidents identified in NSW and Safe Work Australia guidance over the range covering around 5 to 50 fatalities.

The rate of occurrence of incidents giving rise to one or more fatalities is estimated for 2055 to be 1 in 1,416 years and the average number of fatalities expected for the range of scenarios identified is estimated to be 10.7. The expectation value for the anticipated range of crash scenarios at the estimated frequency of occurrence is 0.0076 per annum, equivalent to 1 fatality in 132 years. The scaled risk integral value determined for 2055 according to the Republic of Ireland criterion is 24,244. These risk estimates for 2055 are summarised in Table C.1, together with the comparable estimates for 2033.

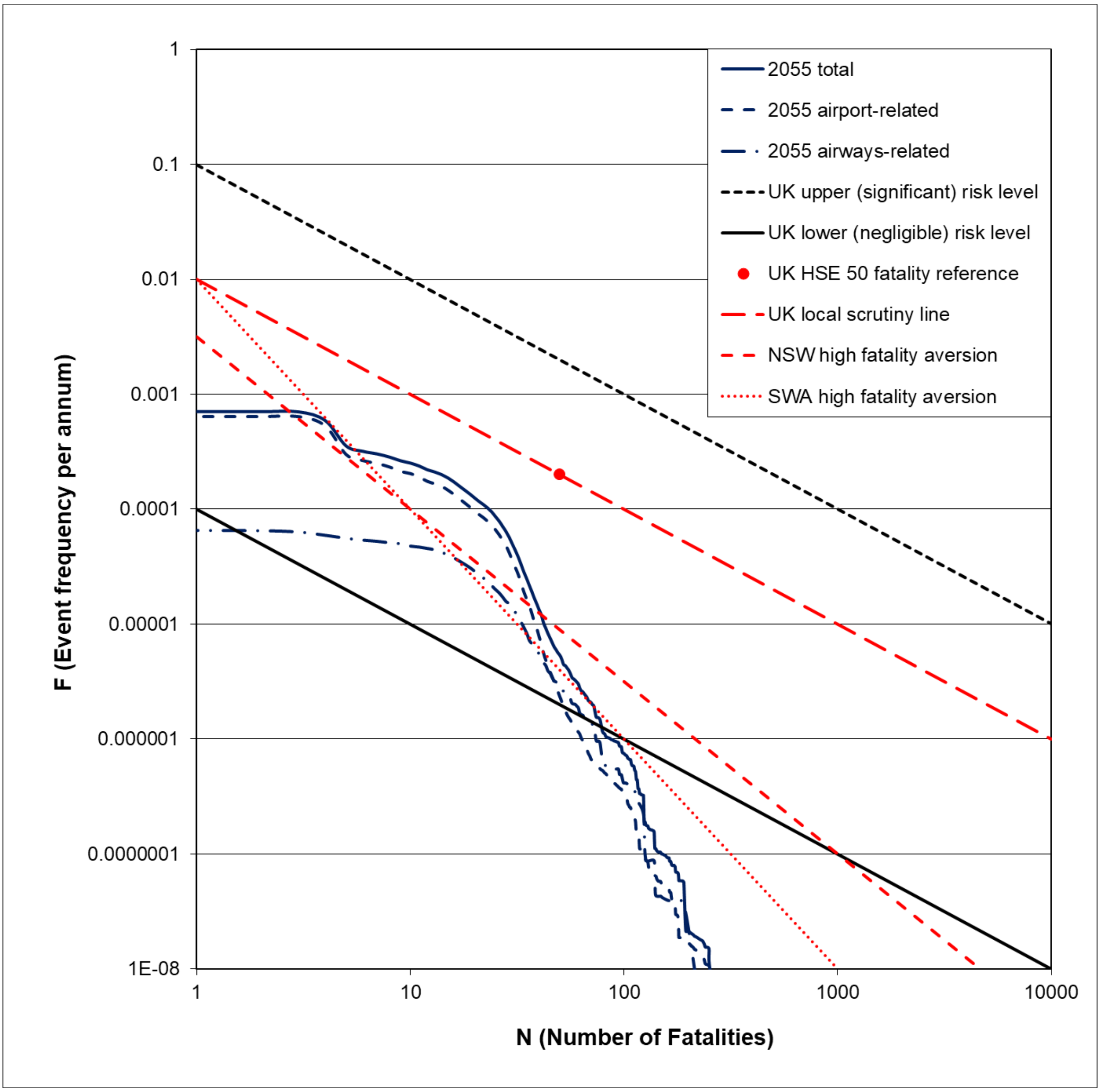


Figure C.3 2055 FN curve

Table C.1 Summary of societal risk estimates for 2033 and 2055

Risk measure	2033	2055
Crashes involving 1 or more fatalities per annum	2.36×10^{-4}	7.06×10^{-4}
Crashes involving fatalities (return period in years)	1 in 4,245	1 in 1,416
Average number of fatalities per crash	9.6	10.7
Expectation value (fatalities per annum)	2.27×10^{-3}	7.55×10^{-3}
Expectation value (return period in years)	1 in 441	1 in 132
Scaled risk integral value	6,770	24,244

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