



MARSHALL DAY
Acoustics 

GUIDELINES FOR MINIMISING AIRCRAFT
OVERFLIGHT IMPACTS

Rp 001 20170310 | 21 July 2017

Project: **Guidelines for Minimising Aircraft Overflight Impacts**
Reference F03800-17/46669

Prepared for: **Blue Mountains City Council**
2 Civic Place
Katoomba NSW 2780
Australia

Attention: **Mr Tony Middleton**

Report No.: **Rp 001 20170310**

Disclaimer

Reports produced by Marshall Day Acoustics Pty Ltd are based on a specific scope, conditions and limitations, as agreed between Marshall Day Acoustics and the Client. Information and/or report(s) prepared by Marshall Day Acoustics may not be suitable for uses other than the specific project. No parties other than the Client should use any information and/or report(s) without first conferring with Marshall Day Acoustics.

The advice given herein is for acoustic purposes only. Relevant authorities and experts should be consulted with regard to compliance with regulations or requirements governing areas other than acoustics.

Copyright

The concepts and information contained in this document are the property of Marshall Day Acoustics Pty Ltd. Use or copying of this document in whole or in part without the written permission of Marshall Day Acoustics constitutes an infringement of copyright. Information shall not be assigned to a third party without prior consent.

Document Control

Status:	Rev:	Comments	Date:	Author:	Reviewer:
draft		Issued for comment	8 June 2017	A. Morabito & J. Adcock	J. Adcock & A. Morabito
final		Issued	21 July 2017	A. Morabito & J. Adcock	J. Adcock & A. Morabito

EXECUTIVE SUMMARY

The planned Western Sydney Airport at Badgerys Creek could cause a significant increase in the number of aircraft movements over the Greater Blue Mountains World Heritage Area and National Park area.

A literature review was carried out to identify Australian and international guidance that is relevant to the subject of aircraft noise impacts in sensitive wilderness areas.

Comprehensively managing overflight noise impacts on the Greater Blue Mountains World Heritage Area and National Park area will require a range of actions through both the airspace design and operating stages of the planned Western Sydney Airport.

Based on the findings of the literature review, the recommended actions comprise:

- Quantitative noise assessments that should be carried out to assess alternative operating strategies;
- Operational noise mitigation measures that should be evaluated as part of the airspace design; and
- Longer term measures for managing the noise impacts of aircraft overflights.

Each of the recommendations is described in further detail below.

Quantitative noise assessments

To compare and assess alternative operating strategies, quantitative noise assessment should be carried out on the basis of noise metrics that are selected to reflect the type of impact that could occur as a result of aircraft overflight; i.e. a degradation in the experience of visitors to the area as a result of regular audible aircraft noise intrusion. The data to be obtained will therefore need to describe both the natural sound environment and aircraft noise intrusion.

These assessments are recommended to be based on three types of metrics for rating aircraft noise intrusion:

- Maximum sound pressure levels of individual aircraft overflights;
- The number of audible aircraft overflights; and
- Time-based metrics which provide an indication of the amount of time that aircraft noise is audible.

Importantly, determining these metrics will involve modelling noise at low sound pressure levels that are below the validated range of practical noise modelling tools. Validation work is therefore recommended to improve the reliability of predicted noise level data for this purpose.

Operational noise mitigation measures

The assessment of aircraft noise impacts during the design stage should consider, in order of priority, the following:

- Overflight avoidance of Blue Mountains.

Areas within the Blue Mountains where natural soundscapes are prioritised, should be identified at an early stage. Consideration should also be given to avoiding overflights during sensitive time periods.

There are however practical challenges, for example, redirected flights will then have impacts in other potentially sensitive locations. This therefore requires a balance of the benefits afforded to the areas that are avoided and the newly impact areas.

- Overflight dispersion.

Where aircraft overflight cannot be practically avoided, flight tracks should be dispersed across the widest practical range to avoid concentration of audible aircraft overflights. This has the added benefit of maximising the period between audible aircraft overflights at a given location.

- Overflight mitigation procedures.

Flight procedures and operations should be selected to reduce noise experienced at ground level. As an example, procedures should be considered which enable the aircraft to reach or maintain the greatest possible altitude over sensitive areas. This may involve using reduced thrust procedures during arrival operations, or requiring departure flight paths to climb straight along the runway centreline, before turning to their destination.

Longer term noise impact management measures.

Monitoring is recommended to be carried out to enable aircraft noise impacts as a result of the introduction of Airport aircraft operations to be proactively identified and addressed where issues arise. This should comprise a combination of:

- Surveys of visitor and park user experiences – the viability, practicality and utility of this type of survey has been demonstrated by extensive work carried out in the US and New Zealand; and
- Surveys of aircraft noise levels at key sensitive wilderness locations to quantify noise levels using the recommended metrics presented in the preceding sections.

These surveys should ideally be conducted concurrently to enable a dose-response relationship between aircraft noise levels and visitor experiences to be developed for the Blue Mountains which would provide an objective reference for ongoing airspace management of the planned Airport.

TABLE OF CONTENTS

1.0	INTRODUCTION	1
2.0	BACKGROUND.....	1
3.0	LITERATURE REVIEW	4
3.1	Publications	4
3.2	Summary	6
4.0	OVERFLIGHT NOISE IMPACTS	8
5.0	RECOMMENDATIONS	10
5.1	Quantitative Noise Assessments	10
5.2	Operational Noise Mitigation Measures.....	12
5.2.1	Overflight Avoidance.....	12
5.2.2	Overflight Dispersion	12
5.2.3	Overflight Procedures	13
5.3	Long Term Noise Impact Management Measures.....	13

APPENDIX A GLOSSARY OF TERMINOLOGY

APPENDIX B REFERENCES

APPENDIX C LITERATURE REVIEW

1.0 INTRODUCTION

The planned Western Sydney Airport at Badgerys Creek could result in a significant increase in the number of aircraft movements over the Greater Blue Mountains World Heritage Area (GBMWhA) and National Park. The Blue Mountains City Council (Council) is concerned about the impacts associated with the location and operation of the Airport, including the potential for overflight noise to detrimentally affect natural areas within the Blue Mountains.

Through a public consultation process, the Council are providing input into the airspace and flight path design for the Airport. This is being facilitated through the community and stakeholder reference group, *Forum on Western Sydney Airport*, established as part of the development approval conditions for the operation of the Airport.

This document presents the findings of a study commissioned by the Council to:

- Review national and international practices and policies on mitigation and management of aircraft overflight noise in natural areas;
- Consider potential aircraft noise impacts based on the findings of the literature review; and
- Develop evidence-based guidelines for the management of aircraft noise impacts within the GBMWhA and National Park that can be used by the Council throughout the flight path design phase as a guide to minimise detrimental impacts.

In parallel with this study, a sample baseline survey of existing aircraft overflight noise in quiet areas of the Blue Mountains is being carried out. The findings of the baseline survey will be documented in a separate report and present results using the aircraft noise metrics discussed in these guidelines.

2.0 BACKGROUND

A new Western Sydney Airport (Airport) is planned at Badgerys Creek, approximately 65 km west of Sydney, NSW. The Airport is proposed as a staged development and, as demand increases, expand to accommodate greater numbers of passengers and aircraft movements.

The Stage 1 development of the Airport, expected to commence operations in the mid-2020s, includes a single northeast-southwest runway and associated facilities to cater for approximately 10 million annual movements. Operations at the Airport are forecast to increase as demand increases beyond 10 million passengers a year. There has therefore been consideration for a long-term development of the airport when demand approaches 37 million passengers annually. This long-term development, forecast to occur around 2050 will necessitate the need for a second parallel runway.

The Airport is subject to environment and development requirements under both the *Federal Airports Act 1996* and the *Environment Protection and Biodiversity Conservation Act 1999*. An Environmental Impact Statement (EIS) for the Airport was completed in 2015.

As part of the preparation of the EIS for the Airport, Airservices Australia developed a suite of indicative flight paths. For areas of the GBMWhA directly under these flight paths, the EIS concluded that the potential noise impacts were not significant due to the high altitude of operating aircraft. Specifically, while it is acknowledged in the EIS that the amenity of wilderness areas within the GBMWhA has the potential to be impacted by an increase in aircraft overflight noise, the impacts are noted as limited in nature, given the aircraft are expected to be higher than 5,000 feet (approximately 1.5 km), with the majority more than 10,000 feet (approximately 3 km) above sea level when passing over the GBMWhA. The EIS notes predicted aircraft noise levels would be below 55 dB L_{Amax} and that these levels are comparable to typical ambient sounds of similar levels (the EIS cites vehicle movements in suburban areas, conversational voice levels or a bird call within a wilderness setting as example sounds for comparison).

Following the release of the draft EIS prepared for the Airport, a peer review of the assessment methodology and findings was carried out, including the noise related aspects of the assessment. The peer review determined that the noise modelling generally provided an accurate representation of the extent of noise impacts for the development description and operating scenarios that were proposed.

However, it also identified a number of limitations which related to both the extent to which the airspace management's design had progressed, and the assessment of the noise modelling outcomes. In addition, it was identified that the draft EIS may *not have adequately reflected the potential impact within the GBMWA and National Park*. The following summary from the peer review is provided for context.

The draft EIS presents information to evaluate the potential impacts of aircraft operations on the acoustic amenity of the GBMWA. The assessment indicates the potential for a large number of audible aircraft events within the GMWA. While the levels are predicted to be relatively low (below 50 – 55 dB L_{Amax}), aircraft over flights would be expected to be audible and represent a significant and widespread impact for a World Heritage Area where natural soundscapes are likely to be a valued feature of the areas amenity. Accordingly, the assertion within draft EIS chapter that noise levels below 50 and 55 dB L_{Amax} are 'not significant' is not considered to have been sufficiently justified, and the assessment may therefore not adequately reflect the potential impact to the values of tranquillity within the World Heritage Area.

Subsequent to the peer review, it is understood that the Council made a submission on the draft EIS, that drew upon the findings of the review, and detailed, amongst other issues, the potential impacts to the GBMWA and National Park.

The final EIS concluded that noise impacts *within the GBMWA and National Park* were not expected to be significant and in December 2016, the Airport received approval for the construction and operation of Stage 1.

The approval conditions (Australian Government 2016) include requirements to minimise the impact of aircraft overflight impacts to these locations, through the flight path design process. Specifically, Approval Conditions 16(2) and 16(5), state the following:

16. Airspace design process

- (2) *The airspace and flight path design are to be developed by a steering group led by the Infrastructure Department and involving Airservices Australia and the Civil Aviation Safety Authority. After an Airport Lease is granted the ALC will also be invited to participate in the steering group. The Infrastructure Department must establish a community and stakeholder reference group (Forum on Western Sydney Airport) which will operate until the end of the detailed design stage identified in Table 10 in Part 2 of the Airport Plan.*
- (3) *In developing the airspace and flight path design, the steering group must conduct public consultation with stakeholders who include the aviation industry, the community and state and local government authorities.*
- (5) *The airspace and flight path design must take account of the following principles, in addition to the principles in section 2.2.5 of the Airport Plan:*
 - (d) *airspace and flight path design must minimise to the extent practicable the impact of Aircraft Overflight Noise on the following:*
 - (i) *residential areas;*
 - (ii) *Sensitive Receptors;*

(iii) the Greater Blue Mountains World Heritage Area – particularly areas of scenic or tourism value; and

(iv) Wilderness Areas

By way of example, the indicative flight paths presented in the draft EIS included the proposal for a single merge point for all arriving aircraft over a single town in the Blue Mountains. It is understood that objections to this proposal resulted in the approval conditions also dictating no single merge point. Given these conditions, the flight paths are not currently known beyond the indicative paths shown in the EIS. They will be further developed through the Forum on Western Sydney Airport and the steering group.

Accordingly, these conditions establish the GBMWhA and associated sensitive areas as locations which must be addressed for the control of noise prior to commencement of Stage 1 operations of the airport. This is to be achieved through development of appropriate planning and design of airspace management strategies.

As per the approval conditions, part of the process includes ongoing community consultation, with a key focus on minimising overflight noise of residential and sensitive areas, including the GBMWhA.

One of the most important methods of managing aircraft noise is to avoid or reduce overflight of populated areas by directing traffic over uninhabited or lower population density areas where possible. However, in the case of the planned Western Sydney Airport, these uninhabited areas include the GBMWhA and National Parks, also valued for their quiet. Given the approval conditions do not set prescriptive noise targets to be achieved, it is also not clear or defined how these impacts in different sensitive areas are to be balanced.

3.0 LITERATURE REVIEW

3.1 Publications

A literature review was carried out to identify current Australian and international guidance that is relevant to the assessment of aircraft overflight impacts in sensitive areas such as those found in the Blue Mountains, including the GBMWhA and National Park.

Current Australian policies and guidelines do not directly address noise in park and wilderness areas. Instead, publications concerning aircraft noise have been primarily focused on impacts in urban environments or areas near airports. In contrast, visitors to national parks or wilderness areas are not at home or in a residential setting, nor are they necessarily exposed to aircraft noise for long periods of time, or levels of noise that would be experienced at locations near airports.

From the review of Australian publications, no legislation, policies or guidelines exists that specifically set out obligations for the control of aircraft noise in national parks, or indeed for the preservation of natural soundscapes.

However, aircraft noise intrusion in wilderness and tranquil areas, including national parks, has been a topical subject in a number of countries. In particular, considerable research has been carried out in the US to quantify the impact of aviation activity on highly valued natural soundscapes within national park areas. This has included noise monitoring and modelling over large areas as part of quantifying and protecting tranquil areas of national parks. That said, the subject of noise impacts in such areas is a developing field. For example, the international standard, *ISO/DIS 12913-2 Acoustics - Soundscape - Part 2: Data collection and reporting requirements* is still in development, once completed, is to provide a framework for defining and assessing highly valued soundscapes.

Noting the absence of available literature in Australia, it has been necessary to review publications from other jurisdictions, including the United States, New Zealand and the European Union. A summary of the publications reviewed is provided Table 1. Further detail on these publications is provided in Appendix C.

Table 1: Publications Reviewed

Document	Author	Description
<i>Australia</i>		
Expanding Ways to Describe and Assess Aircraft Noise	Department of Infrastructure and Regional Development	Collectively, these documents provide a comprehensive discussion of the importance of environmental noise information to assist land use planning, manage aircraft operations and inform affected communities.
Guidance Material for Selecting and Providing Aircraft Noise Information	Department of Infrastructure and Regional Development	They also highlight the need for, and benefits of, alternative ways to more effectively communicate environmental noise information from airport operations.
Going Beyond Noise Contours – Local Approaches to Land Use Planning Around Smaller Australian Airports – Discussion Paper	Department of Infrastructure and Regional Development	
Fly Neighbourly Advice (FNA) Guidelines	Civil Aviation Safety Authority	Provides advice on the form and content in the development of a FNA.

Document	Author	Description
Aircraft activity and sound levels relative to recreation opportunity spectrum settings in the Great Barrier Reef Marine Park: A case study from Whitehaven Beach, Whitsunday Island	On behalf of Great Barrier Reef Marine Park Authority	Provides quantitative information including aircraft activity and noise levels along Whitehaven Beach and in particular, four (4) nominated recreational areas. Conducted to complement a visitor survey, though not in parallel.
Seaplanes at Green Island: A study for the Great Barrier Reef Marine Park Authority	On behalf of Great Barrier Reef Marine Park Authority	A study aimed at determining how seaplanes affect people's experience on Green Island, Great Barrier Reef.
United States		
Airport Cooperative Research Program (ACRP) Synthesis 9: Effects of Aircraft Noise: Research Update on Select Topics	United States Transportation Research Board	A comprehensive review of aircraft noise related issues conducted, with a section dedicated to a review on the effects of aviation noise on parks, open space and wilderness areas.
Airport Cooperative Research Program (ACRP) report 15: Aircraft Noise: A Toolkit for Managing Community Expectations	United States Transportation Research Board	A guidebook designed to help airport managers improve their communications with the public about issues related to aircraft noise.
Study of Visitor Response to Air Tour and Other Aircraft Noise in National Parks	United States Department of Transportation, Federal Aviation Authority	A study which analysed nearly 2500 aircraft noise dose and visitor response data collected in National Parks throughout the US, at four National Parks between 1992 and 1999.
Protecting National Park Soundscapes	National Park Service (NPS)	The NPS has a mandate to protect the soundscape in its 400-plus properties and actively manages noise in its properties.
New Zealand		
The impact of noise on recreationists and wildlife in New Zealand's natural areas: a literature review	Department of Conservation	A review of the available literature regarding noise effects on recreationists and wildlife in New Zealand's natural areas. Also focuses on the general nature of noise impacts, factors that influence them, response to noise impacts and how to monitor these, as well a number of key theoretical concepts.
Europe		
EEA Technical Report No 4/2014: Good practice guide on quiet areas	European Environment Agency	Environmental Noise Directive aims to define a common approach intended to avoid, prevent or reduce health effects from exposure to high environmental noise. Also highlights the need to preserve environmental noise quality in quiet areas, which are the focus of this guide.
WHO Guidelines for Community Noise	World Health Organization	Establishes a relationship between the onset of health effects from levels of community noise exposure.

3.2 Summary

The literature review demonstrates a substantial amount of evidence exists that support aircraft noise intrusion in quiet areas, such as would be found in the Blue Mountains, could represent a significant impact. Importantly, the literature review indicates that these impacts can occur as a result of relatively low noise levels associated with high altitude jet aircraft overflights. This is due to factors such as the prominence of the noise of the intrusion in areas with low background noise levels and, importantly, the amount of time the intrusion is audible (and conversely the amount of time when the environment is free from audible intrusion from non-natural sound sources).

The key findings of the review are summarised below:

- Aircraft overflights and the associated noise in national parks is an environmental management issue. The protection of natural quiet is considered important, as evidenced by legislative measures in the US and guidance provided by European jurisdictions;
- Quantifying the value of natural soundscapes in wilderness settings is complex and subject to significant uncertainty. With the present level of knowledge about these impacts, reliable methods of setting performance targets or design requirements cannot presently be defined that could be directly applied in consideration of the airspace design for the Western Sydney Airport;
- As an indication of the level of importance that has been attached to the protection of these soundscapes in quiet areas, the US recognises the need to protect natural soundscapes for both their inherent value as a physical resource as well as for the enjoyment of visitors;
- A number of objective studies have been carried out to quantify the value of natural soundscape preservation, including dose response studies, noise mapping and monitoring studies. These studies have considered a range of variables, including a number of noise metrics, and correlating these with visitor surveys to provide an objective management tool;
- A number of factors influence the effect of noise on visitors to natural park areas. The physical properties, e.g. level, frequency and variation, and environmental factors including weather, topography and the existing levels of ambient noise, affect the perception when it reaches the listener's ear. The perception of intrusiveness noise is also subject to an individual's characteristics, including their physiological hearing capability and their sensitivity to sound. For visitors to natural park areas, factors such as their attitudes, expectations, values and past experiences can also influence their response in either a positive or negative way;
- In terms of assessing the level of noise intrusion and associated impacts, measurements based solely on equivalent sound levels (L_{Aeq}) do not adequately characterise most noise environments, nor do they adequately assess the health impacts of noise on human wellbeing. The maximum noise level during a noise event and the number of events are also important factors. The Time Above Ambient (TAA) noise level metric is also often used in the assessment of impacts on national parks.

The literature review clearly establishes the importance of preserving natural soundscapes in high value wilderness settings, such as would be expected in the GBMWhA. Importantly, the potential significance of impacts that can occur as a result of relatively low levels of noise intrusion in wilderness areas is evident. However, the current level of understanding of these impacts is not sufficient to define prescriptive targets or impact assessment criteria.

Further research is required and a number of complicating factors include:

- The measured average level of a noise source is difficult to relate to everyday experiences or how it is perceived for the public;
- Conventional urban-area noise assessment methodologies are generally impractical to apply to sensitive wilderness areas;
- Whether lower noise levels for a longer period is less of an impact than greater noise levels but over a shorter period;
- What people perceive can differ greatly from what they actually hear. There is a need to develop a better understanding of visitor's values, expectations and preferences associated with the natural areas;
- The varying nature of ambient noise levels and the associated impact of a given noise level; for example, a set threshold level may be acceptable for one setting where high ambient noise levels exist, but would be considered intrusive in a setting of low ambient noise level; and
- Trying to define the natural soundscape can often be as challenging as defining the noise intrusion and potential effects.

Notwithstanding these limitations, the literature indicates that the most appropriate means of assessing impacts is likely to rely on assessing noise levels using a variety of metrics tailored to gauge the extent which the natural soundscape may be altered by periodic aircraft noise intrusion. Furthermore, the review indicates that visitor surveys and park-specific dose response relationships are a practical and feasible method of monitoring intrusive noise impacts in wilderness settings. This type of survey can provide an objective basis for identifying and prioritising areas to be protected as part of the detailed flight path design

4.0 OVERFLIGHT NOISE IMPACTS

Ambient noise levels within the GBMWhA and national park areas would be expected to be very low in locations that are remote from roads and water courses. For example, underlying background levels in the range of 20 to 40 dB L_{Aeq} would be expected to occur regularly in many areas. The EIS notes predicted aircraft noise levels would be below 55 dB L_{Amax} when flying at high altitude over the GBMWhA and national park areas. These levels of overflight noise would generally be considered relatively low in an urban context, where ambient levels can vary between 40 dB L_{Aeq} and 60 dB L_{Aeq} . However, amidst the low ambient noise levels expected across large parts of the GBMWhA and national park areas, an aircraft overflight would be clearly distinguishable and potentially prominent. As the Airport is proposed to operate 24 hours per day, these impacts could occur during both the day and night.

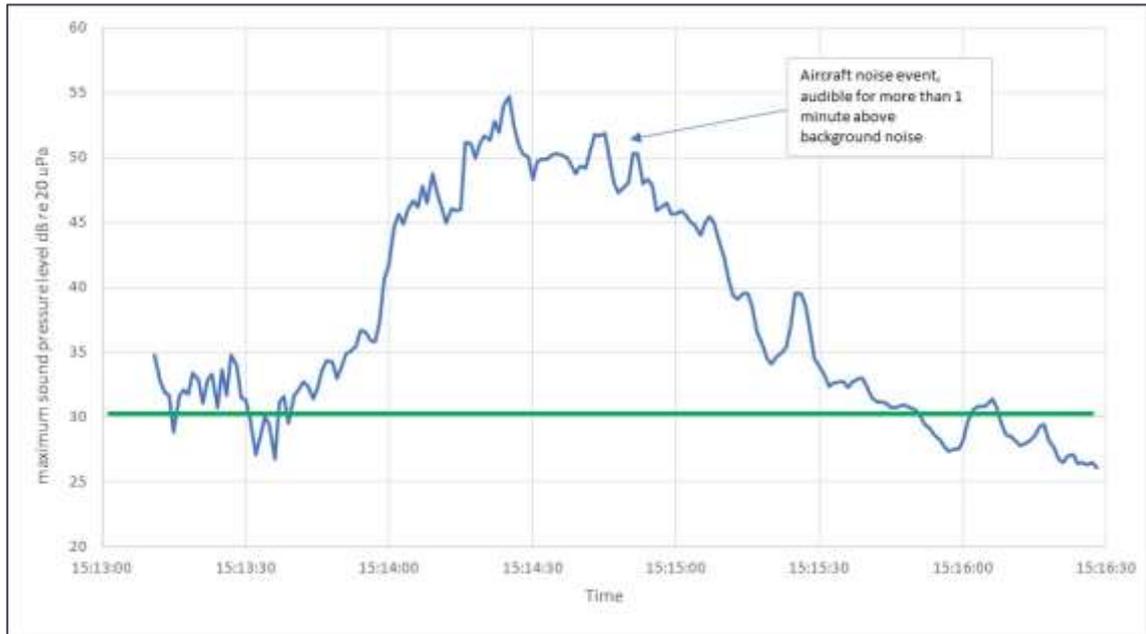
The literature review, particularly in relation to studies of user and visitor surveys of national park or tranquil areas, indicates that noise impacts in national park or tranquil areas are not determined solely by the level of the noise and are likely to relate to:

- Audible aircraft noise altering the perceived character of the area, i.e. a change from natural soundscape to a soundscape overlaid with regular man-made sources of intrusion;
- Increased awareness and sensitivity to noise intrusion in areas of the park which are valued for their tranquillity and natural soundscapes (e.g. areas where there is little to no intrusion from artificial sources of noise); and
- A reduction in the duration of periods that are free from audible artificial noise intrusion as a result of an increase in the number of aircraft movement.

These factors mean that the duration that an aircraft overflight is audible becomes more important when assessing the impact of aircraft overflights which result in relatively low noise levels. This is in contrast to impact assessments for urban areas that involve addressing relatively high noise levels which occur for briefer periods. It is therefore particularly important to account for the duration of the noise when assessing low noise level intrusion in quiet areas, as aircraft noise is present at these low noise levels but for a longer period.

This is described in Figure 1, and is an example of the existing level of aircraft noise present in the Glenbrook area of Blue Mountains National Park. This example demonstrates the noise resulting from an aircraft overflight at an altitude of approximately 13,000 ft. The event is audible for a period more than one minute above the background noise level (shown in green, 30 dB L_{A90}), that rises to a maximum level of 55 dB L_{ASmax} , which although low compared with aircraft noise levels in urban areas, is approximately 25 dB above the background level. These noise levels and aircraft altitudes are comparable to those predicted in the EIS for overflights above the GMWhA and National Park, associated with the planned Western Sydney Airport.

Figure 1: Example demonstration of aircraft noise intrusion – Blue Mountains National Park



Although the proposed number of average daily aircraft movements for Stage 1 of the Airport is relatively low compared with other Australian international airports, there is still potential that during a ‘peak’ day, up to 100 overflights could occur over particular areas of the Blue Mountains. This is projected to increase to 200 overflights per day in the future, as part of the long-term development of the Airport. This could therefore lead to a significant increase in the number of events of which would be audible in large areas over the Blue Mountains, and conversely, a significant decrease in the time periods in which the soundscape is unaffected by aircraft noise intrusion.

As an example, during these peak periods associated with Stage 1 of the Airport, there could be 10 overflights of the Blue Mountains per hour, leading to approximately 4 minutes of quiet between audible aircraft events. With the long-term development of the Airport, this increases to a peak of 40 overflights of the Blue Mountains per hour, of which aircraft noise could be audible for the entire hour.

5.0 RECOMMENDATIONS

This section presents recommended noise studies and mitigation actions for addressing aircraft overflight noise impacts in the GBMWhA and national park areas.

The findings of the literature review indicate that assessing intrusive noise impacts on high value natural soundscapes is complex and subject to considerable uncertainty. Comprehensively managing aircraft overflight impacts will therefore require a range of actions through both the airspace design and operating stages of the Airport.

The recommendations for addressing aircraft noise overflight impacts in the GBMWhA and national park areas are defined in three distinct categories, which are further described in subsequent sections:

- Quantitative noise assessments:

The type of noise metrics that should be considered when assessing the impact, and the methods which should be used to develop this information.

- Operational noise mitigation measures:

Aircraft flight procedures, flight path and flight distribution options which should be evaluated during the development and detailed design of the airspace management strategy for the airport.

- Long term noise impact management measures:

The way that residual aircraft overflight noise impacts in the GBMWhA and national park are monitored after the airport starts operating and the number of overflights increase with time.

5.1 Quantitative Noise Assessments

Noise data in the form of a variety of noise metrics will need to be collated and compared to assess the aircraft noise overflight impacts of alternative airspace designs and operating strategies.

The type of noise data used to compare and assess alternative operating strategies must be selected to reflect the type of impact that could occur as a result of aircraft overflight; i.e. a degradation in the experience of visitors to the Blue Mountains as a result of regular audible aircraft overflight noise intrusion on the natural soundscape. Data will therefore be needed to describe both the natural sound environment and aircraft noise intrusion.

In relation to the natural sound environment, A-weighted background sound pressure levels represent the most common method of quantifying an environment which may be affected by the introduction of a new sound source. Background sound levels do not provide a measure of the intrinsic value of a soundscape that is composed entirely of natural sound sources. However, background sound levels are used in policies throughout Australia, including NSW noise policies, as a baseline metric for gauging the intrusiveness of a new or altered noise source. The background sound level therefore has relevance when assessing the potential for aircraft noise to impact on quiet areas within the Blue Mountains. For consistency with established NSW policies, it is recommended that the background sound pressure levels are established at representative locations within the GBMWhA and national park areas using the $L_{A90,T}$ noise metric – the sound level that is exceeded for 90 % of a measurement period of duration, T.

In relation to aircraft noise levels, consistent with the findings of the literature review, and established Commonwealth guidelines for the assessment of aircraft noise in urban areas, no single aircraft noise metric can be relied upon in isolation to provide a complete representation of the potential impact. A range of aircraft noise metrics should therefore be collated and considered as part of the assessment.

The selected metrics should account for:

- The level of aircraft noise overflights;
- The duration of audible noise associated with individual aircraft overflights; and
- The regulatory of aircraft overflight noise.

The above factors are commonly accounted for through the use of exposure metrics (e.g. average or equivalent noise levels) which combine the total sound energy of the noise in question, and therefore implicitly account for the noise levels, event durations and event frequency. However, the literature review indicates that exposure metrics are unlikely to be suitable for this type of assessment. Similarly, experience in aircraft noise assessment in Australia has shown that exposure metrics are not well suited to describing the noise in a way that individuals experience the noise or in a way that stakeholders can readily interpret. For these reasons, we do not recommend the use of exposure metrics for assessing aircraft noise overflight impacts in the GBMWH and national park. Instead, the following metrics are recommended:

- Maximum sound pressure levels:

The maximum noise levels L_{Amax} of aircraft overflights, as presented and considered in the EIS for the Airport. However, maximum levels significantly lower than the ranges considered in the EIS would need to be assessed (i.e. well below 50 dB L_{Amax}) to account for events at sound pressure levels which, although would generally be considered low in a typical urban setting, have the potential to significantly alter the character of the soundscape in quiet wilderness areas.

- Event numbers:

A measure of the number of audible aircraft events expected within key periods - as a minimum, the day, evening and night periods and also periods of expected visitor duration to the areas. This type of metric is similar to the Number Above metric used in the EIS (e.g. the N60 and N70), but rather than present the number of aircraft events above a sound pressure level that is defined as a threshold for disturbance or annoyance, this should indicate the number of times that aircraft noise intrudes on the natural soundscape. In practice, generating this type of information will require defining a practical sound pressure level threshold, based on a measure of background noise conditions, above which audible aircraft noise is likely to be audible for a significant portion of an overflight (i.e. as opposed to momentarily audible).

- Time-based metrics (event duration and respite periods):

A measure of the amount of time that aircraft noise will be audible (e.g. the TAA or %TAA), or conversely a measure of the time between overflights when aircraft noise is not audible, as contemplated in research proposals referred to in the literature review. The TAA or %TAA relate to audibility as judged by comparisons with the ambient sound level. The ambient sound level is generally taken to represent an average of all sound sources other than the source being investigated. However, in natural soundscapes, average parameters are highly prone to variations and higher frequency sound sources which are less relevant when judging the audibility of intrusive transportation type sounds. For this reason, the background sound level referred to earlier is recommended to be adopted as a representation of the underlying ambient level during quiet periods.

Preparing the above types of aircraft noise data will involve prediction of aircraft noise in terms of metrics, and at sound pressure levels, beyond the intended scope of application of practical noise modelling tools. In particular, at the low sound pressure levels that need to be considered for this assessment, the noise modelling is subject to considerable uncertainties. Validation work is therefore recommended to improve the reliability of predicted noise level data for this purpose.

This should be based on comparison of measured and predicted data, in terms of sound pressure levels and event duration data, for aircraft altitudes and procedures that are comparable to potential future aircraft operations over the Blue Mountains area.

Measurement data for existing aircraft movements in the vicinity of the Blue Mountains area, similar to that which is being obtained as part of the parallel sample monitoring data project, can also enable the duration of audibility for high altitude jet aircraft overflights to be quantified and used to inform the assessment of overall time-based metrics.

5.2 Operational Noise Mitigation Measures

It is recommended that during development of the airspace management strategy, the following airspace management strategies for the control of aircraft noise impacts in the GBMWHA and national park areas should be considered. These are in order of priority:

- Overflight avoidance;
- Overflight dispersion; and
- Overflight mitigation procedures.

5.2.1 Overflight Avoidance

Given that the impacts in sensitive wilderness locations relate to audible changes to the soundscape, rather than exceedance of acceptability thresholds, the preferred method of managing aircraft noise intrusion is to avoid overflying sensitive locations at a noise level which is audible.

Inevitably there are practical challenges to implementing this strategy in all instances; redirected flights will have impacts in other potentially sensitive locations and these alternative impacts must be weighed against the benefits afforded to the areas that are avoided. It is recommended that consideration is given to identifying the areas where natural soundscapes are likely to be most highly valued, and therefore the locations where avoidance of overflight should be prioritised.

The GBMWHA and national park and recreation areas cover extensive areas. The size of the areas to be ideally avoided is therefore likely to be large. Nonetheless, the most sensitive areas should be identified with consideration to the following, but not limited to, factors:

- Typical sensitivity of use (e.g. areas sought after for their natural heritage, character and environment);
- Background sound levels;
- Remoteness from transportation and other anthropogenic noise sources; and
- Consultation with relevant stakeholders including the National Parks Authority, Destination NSW, Aboriginal representatives and the Blue Mountains City Council.

As well as avoidance of locations, consideration should be given to how avoidance of sensitive time periods could be practically implemented – in terms of sensitive times of the day, as well as potential weekly and seasonal changes in sensitivity associated with variations in visitor numbers and park usage.

5.2.2 Overflight Dispersion

If and where aircraft overflight of sensitive wilderness areas cannot be practically avoided, flight tracks are recommended to be dispersed across the widest practical range to avoid concentration of audible aircraft overflights in particular areas, and to maximise the period between audible aircraft overflights at any given location. As the impacts relate to audible noise at relatively low levels, relatively large distances between dispersed tracks will be needed to result in subjectively meaningful changes to the noise at ground level.

Quantifying the magnitude of these separating distances based on predictions alone is subject to significant uncertainties associated with the limitations of modelling aircraft noise at relatively low levels. Validation work based on measurement and prediction comparisons, as described in Section 5.1, is therefore recommended.

5.2.3 Overflight Procedures

If and where aircraft overflight of sensitive wilderness areas cannot be practically avoided, flight procedures should be selected to reduce the noise experienced at ground level. These procedures are broadly similar to those which may be considered for urban areas, but the following specific options for the GBMWhA and national park areas should be evaluated:

- Flight routing in combination with departure and arrival procedures which enable the aircraft to reach or maintain the greatest possible altitude over sensitive wilderness areas; and
- Adoption of reduced thrust procedures and maximising altitude of overflights where safety permits, e.g. for arriving aircraft, the adoption of constant descent procedures, and for departing aircraft, climb straight along the runway centreline as far as practical before turning to their destination. However, assessing these procedures will require a trade off, i.e. while reducing thrust leads to reducing noise levels, there is the potential to increase the duration that the aircraft event is audible.

5.3 Long Term Noise Impact Management Measures

The assessment and mitigation measures should ideally be used to minimise the regularity and level of aircraft noise in the GBMWhA and national park areas.

The extent to which aircraft noise intrusion can be minimised is likely to be determined by the balance between the competing interests of sensitive wilderness areas and densely populated urban areas in the vicinity of the Airport. As a result, it is unlikely that audible aircraft noise intrusion can be entirely avoided.

Recognising the complexities and uncertainties associated with the assessment of aircraft noise intrusion in wilderness areas, the magnitude of the residual impact cannot be reliably quantified. In addition, problematic impacts, or intensification of impacts as aircraft movement numbers increase, may not be readily apparent to regulators or the Airport operators. This is in contrast to noise impacts which occur in urban areas where community dissatisfaction may be more vocal or monitored as a matter of course.

To address these issues, monitoring is recommended so that aircraft noise impacts as a result of the introduction of Airport aircraft operations are proactively identified and addressed where issues arise. This should comprise a combination of:

- Surveys of visitor and park user experiences – the viability, practicality and utility of this type of survey has been demonstrated by extensive work carried out in the US and New Zealand; and
- Surveys of aircraft noise levels at key sensitive wilderness locations to quantify noise levels using the recommended metrics presented in the preceding sections.

Ideally, these surveys should be conducted concurrently to investigate the possibility of establishing a dose-response relationship between aircraft noise levels and visitor/experiences that is specific to the context of the Blue Mountains which can be used as an objective reference for ongoing airspace management of the planned Airport. Again, the feasibility and utility of these types of studies has been demonstrated by extensive work carried out in the US and New Zealand as part of the management and preservation of high value soundscapes in wilderness and national park settings.

APPENDIX A GLOSSARY OF TERMINOLOGY

Ambient	The ambient noise level is the noise level measured in the absence of the intrusive noise or the noise requiring control. Ambient noise levels are frequently measured to determine the situation prior to the addition of a new noise source.
A-weighting	The process by which noise levels are corrected to account for the non-linear frequency response of the human ear.
dB	Decibel. The unit of sound level.
dBA	A-weighted decibel. The A-weighting approximates the response of the human ear
Frequency	Sound can occur over a range of frequencies extending from the very low, such as the rumble of thunder, up to the very high such as the crash of cymbals. Sound is generally described over the frequency range from 63Hz to 4000Hz (4kHz). This is roughly equal to the range of frequencies on a piano.
Hertz (Hz)	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
L_{A90}	The noise level exceeded for 90% of the measurement period, measured in dBA. This is commonly referred to as the background noise level.
L_{Aeq}	The equivalent continuous sound level. This is commonly referred to as the average noise level and is measured in dBA.
L_{Amax}	The A-weighted maximum noise level. The highest noise level which occurs during the measurement period.
TAA	Time Above Ambient. A noise metric to describe the time that aircraft noise is audible above ambient noise levels.

APPENDIX B REFERENCES

- Australian Government, 2016, *Conditions for the Stage 1 Development of a Western Sydney Airport*
- Berglund B, Lindvall T and Schwela DH, 1999. *World Health Organization Guidelines for Community Noise*. World Health Organization, Geneva
- Brown, A, 1986. *Seaplanes at Green Island: A study for the Great Barrier Reef Marine Park Authority*. Institute of Applied Environmental Research, Griffith University, Australia
- Cand et al, 2009. *Comparison of measurements of aircraft noise levels and their variability with model results*, presented at Euronoise 2009, Edinburgh, Scotland.
- Civil Aviation Safety Authority, 2017. *Fly Neighbourly Advice*. Available at: <https://www.casa.gov.au/standard-page/fly-neighbourly-advice>. [Accessed 5 June 2017]
- Department of Infrastructure and Regional Development (then Department of Transport and Regional Services), 2000, *Discussion Paper: Expanding Ways to Describe and Assess Aircraft Noise*. Canberra, Australia
- Department of Infrastructure and Regional Development (then Department of Infrastructure, Transport, Regional Development and Local Government), 2009, *National Aviation Policy White Paper 2009: Flight Path to the Future*. Canberra, Australia
- Department of Infrastructure and Regional Development (then Department of Transport and Regional Services), 2003, *Guidance Material for Selecting and Providing Aircraft Noise Information*
- Department of Infrastructure and Regional Development (then Department of Transport and Regional Services), 2003, *Going Beyond Noise Contours – Local Approaches to Land Use Planning Around Smaller Australian Airports – Discussion Paper*. Canberra, Australia
- European Environment Agency, 2014. *EEA Technical report No 4/2014: Good practice guide on quiet areas*. Publications Office of the European Union, Luxembourg
- Fleming, G, 2013. *Protecting National Park Soundscapes*, National Academies Press, Washington, D.C.
- Hamilton, M, 2003. *Aircraft activity and sound levels relative to recreation opportunity spectrum settings in the Great Barrier Reef Marine Park: A case study from Whitehaven Beach, Whitsunday Island*. Great Barrier Reef Marine Park Authority, Townsville, Queensland
- Harbrow M, Cessford G and Kazmierow B, 2011. *The impact of noise on recreationists and wildlife in New Zealand's natural areas: a literature review*. Science for Conservation 314, Wellington, Department of Conservation
- Horonjeff, R, 2005. *Queuing for Quiet—The Natural Soundscape from a Visitor Perspective*, presented at the ASA (Acoustical Society of America)/Noise-Con 2005 Meeting, Minneapolis
- Mestre, V, 2008. *ACRP Synthesis Report 02-01, Effects of aircraft noise: research update on selected topics*. United States Transportation Research Board, Washington, D.C.
- National Park Service, 1994. *Report on Effects of Aircraft Overflights on the National Park System*. Prepared Pursuant to Public Law 100-91, The National Parks Overflights Act of 1987
- Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948
- Rapoza et al, 2005. *Study of Visitor Response to Air Tour and Other Aircraft Noise in National Parks*. United States Department of Transportation, Federal Aviation Authority, Washington, D.C.
- Woodward, J, 2009. *ACRP Report 15, Aircraft Noise: A Toolkit for Managing Community Expectations*. United States Transportation Research Board, Washington, D.C.

APPENDIX C LITERATURE REVIEW

C1 Australia

The following documents from Australia have been reviewed:

- Expanding Ways to Describe and Assess Aircraft Noise
- Guidance Material for Selecting and Providing Aircraft Noise Information
- Going Beyond Noise Contours – Local Approaches to Land Use Planning Around Smaller Australian Airports – Discussion Paper
- Civil Aviation Safety Authority guidelines for development of a Fly Neighbourly Advice
- Aircraft activity and sound levels relative to recreation opportunity spectrum settings in the Great Barrier Reef Marine Park: A case study from Whitehaven Beach, Whitsunday Island
- Seaplanes at Green Island: A study for the Great Barrier Reef Marine Park Authority

C1.1 Department of Infrastructure and Regional Development

The Australian Department of Infrastructure and Regional Development provides a number of publications to guide the communication of aircraft noise information. Key documents include:

- *Expanding Ways to Describe and Assess Aircraft Noise* (2000);
- *Guidance Material for Selecting and Providing Aircraft Noise Information* (2003); and
- *Going Beyond Noise Contours – Local Approaches to Land Use Planning Around Smaller Australian Airports – Discussion Paper* (2003).

These documents provide a comprehensive discussion of the importance of the provision of aircraft noise information to assist land use planning, management of aircraft operations and inform affected communities. However, they do only address impacts in urban areas, and there are no specific requirements or recommendations for addressing such impacts in wilderness areas.

A general point however, is that The Department of Infrastructure and Regional Development (2003) notes avoiding a comparison of aircraft noise levels with other noise sources such as road traffic, i.e.

While the sound pressure level of an aircraft overflight may be the same as a car passing down a road, using this as an argument for justifying aircraft noise is likely to generate a negative reaction; treat aircraft noise as a separate issue.

C1.2 Civil Aviation Safety Authority

The Civil Aviation Safety Authority (CASA) was established in 1995 as an independent statutory authority, separate from the Commonwealth. CASA's primary role is to conduct the safety regulation of civil air operations in Australia and the operation of Australian aircraft overseas.

CASA is also responsible for provision of advice on the form and content in the development of a Fly Neighbourly Advice (FNA). A FNA is a voluntary code of practice, typically established between aircraft operators and communities or authorities that have an interest in reducing impacts, including disturbance caused by aircraft over a particular area, such as environmentally sensitive areas within uncontrolled airspace.

The development of a FNA is based on consideration of the following (Civil Aviation Safety Authority 2017):

- *the extent and values of the designated area over which an FNA would cover;*
- *the nature and extent of the disturbance caused by aircraft and, where possible through measurement or other scientific analysis;*

- *all principal stakeholders in the potential FNA;*
- *the nature and purpose of aircraft operations that are affecting the designated area;*
- *mandatory procedures that apply to aircraft operating in the proposed area of the FNA;*
- *targets for reasonable reductions in the disturbance being caused by aircraft operations;*
- *opportunities for aircraft operators to vary their operations to reduce disturbance without being unreasonably penalised by doing so; and*
- *aviation safety requirements.*

A consultation and development process is then put in place to draft the FNA, before it is sent to the relevant authorities, including Airservices Australia for consideration in regards to any related aviation issues. Through the process, it is important to identify any natural environment areas or National Park areas which are considered particularly sensitive. Such sensitivities, may, for example, be due to concerns over disturbance of the environment because of vibration or noise.

The content of a FNA, including opportunities for an aircraft operator to reduce impacts will be limited by the nature of the operation. However, CASA (2017) note the following potential options to be considered:

- *the number of operations;*
- *the heights of operations;*
- *flight tracks used, including the avoidance of sensitive areas and the repetitive use of particular tracks;*
- *the origins and destinations of operations;*
- *times of operations;*
- *operating procedures available to the type of aircraft in use; and*
- *changing the type of aircraft used.*

Example piloting techniques are also described as follows:

- *avoiding noise-sensitive areas:*
 - *follow high ambient noise routes (highways, etc); and*
 - *follow unpopulated routes (waterways, etc).*
- *when operating near noise-sensitive areas:*
 - *maintain an appropriate fly-over altitude (most National Parks have suggested 1,500 to 2,000 feet above ground level);*
 - *maintain an appropriate hover/circling altitude;*
 - *speed reduction;*
 - *low noise speed/descent settings;*
 - *route variation;*
 - *use high take-off/descent profiles.*

C1.3 Great Barrier Reef Marine Park Authority

Aircraft activity and sound levels relative to recreation opportunity spectrum settings in the Great Barrier Reef Marine Park: A case study from Whitehaven Beach, Whitsunday Island

Aircraft overflight and associated noise in National Parks was identified as an environmental management issue which, as growth in the tourism industry occurs, is becoming increasingly important. The protection of natural quiet is considered arguably as important as the protection of wildlife and clean water. In 1999, the Great Barrier Reef Marine Park Authority commissioned a social survey of visitors to Whitehaven Beach in the Whitsunday Islands that aimed to assess visitor use and experience of the area, while evaluating the influence of aircraft and watercraft noise on peoples use and amenity.

Hamilton's study (2003), aimed to complement the survey by providing quantitative information including aircraft activity and noise levels along Whitehaven Beach and in particular, four (4) nominated recreational areas. The majority of aircraft events recorded were above background noise levels, with maximum levels for aircraft events ranging between 54 dB L_{Amax} and 98 dB L_{Amax} , across all sites. Typical maximum noise levels were in the range 60 dB L_{Amax} and 64 dB L_{Amax} . Seaplane take offs were the loudest recorded event type followed by helicopter flyovers associated with a landing or take off. In terms of aircraft event duration, the average time noise levels were above background was 57 seconds, while the longest recorded event was 420 seconds. A statistical analysis on the measurement data was undertaken to determine average noise levels, number of events and number of visitors at the recreational areas. However, the noise impacts on the visitors were not quantified. In such cases, it would have been necessary to have undertaken concurrent measurements (noise level, time above background) and a human response.

Seaplanes at Green Island: A study for the Great Barrier Reef Marine Park Authority

In another study (Brown 1986), the aim was to determine how seaplanes affect people's experience on Green Island, Great Barrier Reef. During the study, spot noise level measurements were taken to determine background and seaplane noise levels. He used the metrics ' L_{max} ' (maximum noise level) and 'duration above background' as means of assessing the intrusiveness of seaplane noise. For background sound levels as a result of waves, wind and people, peak noise (maximum) ranged between 40 dBA and 54 dBA. Seaplanes take offs were the loudest 'event,' in the range of 58 dBA and 76 dBA, generally 10 - 20 dBA above background noise for a duration of 25 seconds. Brown (1986) found that for 95 % of visitors, seaplanes were an acceptable part of their experience. For the other 5 %, the main reasons identified were noise and beach conflicts that decreased their enjoyment. The proportion of people who found that seaplanes decreased their enjoyment increased with an increase in the frequency of seaplane operations.

C2 United States

The following documents from the United States (US) have been reviewed:

- Airport Cooperative Research Program (ACRP) Synthesis 9: Effects of Aircraft Noise: Research Update on Select Topics
- Airport Cooperative Research Program (ACRP) report 15: Aircraft Noise: A Toolkit for Managing Community Expectations
- Study of Visitor Response to Air Tour and Other Aircraft Noise in National Parks
- Protecting National Park Soundscapes.

C2.1 US Transport Research Board

***Airport Cooperative Research Program (ACRP) Synthesis 9: Effects of Aircraft Noise:
Research Update on Select Topics***

This document (Mestre 2008) reviews the literature available at the time of current knowledge and studies on effects of select aircraft effects. Chapter 7 reviews the effects of aviation noise on parks, open space and wilderness areas in relation to both animals and humans, from a United States perspective.

Mestre (2008) discusses the legislative measures, the passing of the *National Parks Overflight Act of 1987*, that have been implemented in the US to instigate measures for the preservation of quiet and natural soundscapes in national parks and Native American tribal lands. In 2000, the *National Parks Air Tour Management Act* was introduced that required commercial tour operators to develop air tour management plans (ATMP) and to also obtain Federal Aviation Authority (FAA) approval to conduct operations over parks or tribal lands. These plans may include provisions for banning commercial air tour operations in certain areas, as well as also establishing conditions on operations, including restrictions on noise, visual, or other impacts. Importantly however, the Act does not define specific noise limits to be adhered to by aircraft operations.

In addition, the 2000–2004 National Park Service (NPS) “Soundscape Preservation and Noise Management” Director’s Order #47 articulated a suite of policies that:

...require the preservation, protection, maintenance, or restoration of the natural soundscape resource in a condition unimpaired by inappropriate or excessive noise sources...

While the Order provides a broad structure for consideration of soundscape preservation as part of the planning process, again, it does not address or provide specific noise levels to be adhered to.

A number of wide scale surveys have also been carried out in US national parks, with the aim to assess the impact of aircraft noise on the user’s experience of the natural environment. These surveys confirmed noise as a key impact to consider for such settings. The findings also indicate there are limitations to assessing aircraft noise intrusion in natural settings on the basis of noise level information alone. Instead, in low noise level environments predominantly characterised by natural sound sources, the regular intrusion by man-made sound sources, the duration of periods by external noise unexpected in the area, and the duration of periods in which the natural soundscape can be experienced without such intrusion, may be more relevant in assessing these impacts. In addition, the studies confirm that due to the low ambient noise levels in park settings, noise associated with high-altitude flyovers or lower-altitude tour operations are readily audible and are considered intrusiveness.

Reviewed by Mestre (2008) is as well the NPS report (1994), which focused on an extensive review of aircraft overflights of national parks and covered effects of overflights on natural quiet, wildlife, visitors, culture and historical resources, and safety. Such impacts include interference with enjoyment, annoyance, and interference with appreciation of natural quiet, depending on the level of overflight noise the visitors may have experienced. With regards to noise, a dose-response curve was derived for visitor annoyance in terms of time that aircraft are audible and hourly equivalent noise level (L_{eq}).

The report finds that aircraft overflights can and do impact on both visitor and park resources, however, the impacts vary and may be considerably greater at some locations than at others. For example, a survey of visitors to the Grand Canyon found there to be greater sensitivity in areas away from existing external noise sources or which are not accessible by vehicle as opposed to visitors frequenting easily accessible overlooks.

Airport Cooperative Research Program (ACRP) report 15: Aircraft Noise: A Toolkit for Managing Community Expectations

This report (Woodward, 2009) states its purpose as a guidebook designed for airport managers and sponsors to help them improve their communications with the public about issues related to aircraft noise, and for example, document techniques identified as the best practices in airport communication. The guidebook has been based on a combination of literature reviews and surveys conducted by relevant parties.

Of interest in the document is the reference to suitable metrics for the assessment and evaluation of aircraft noise impacts. Aircraft noise policy and public perception are often different in the view of what conditions or level of aircraft noise constitutes an adverse noise impact. For example, in the U.S., the Day Night Level (DNL) is used as the main descriptor of aircraft noise. Several studies of public reaction to noise have found the DNL to best correlate to the number of persons highly annoyed by transportation noise, including aircraft. The DNL is similar to the Australian Noise Exposure Forecast (ANEF) used in Australia, in that it is a cumulative noise metric that takes into account every aircraft noise event and weights them according to the time of day. However, the DNL or ANEF is expressed as an overall exposure or average noise level, over a defined period (typically an average over 1 year of aircraft operations). A number of airport surveys and studies have found that individuals respond more positively or better understand aircraft noise levels related to individual events that they directly experience.

In terms of the evaluation of national parks and other similar areas of national interest (e.g. monuments, wilderness areas, etc.), the Time Above Ambient (TAA) noise level metric is often used, where natural quiet is an essential component of the environment. To derive this metric requires knowledge of ambient noise levels at specific locations or an understanding of the distribution of non-aircraft ambient noise across the area of interest, and indicates the amount of time noise exceeds a user-defined threshold (e.g. the ambient level in the absence of aircraft operations).

However, it is difficult to calculate precisely, for example, the computed TAA levels tend to overestimate in situations where simultaneous events at low noise levels occur and which will be added independently, rather than considered together.

Audibility is a metric developed for the National Park Service that is applied in national parks and other park areas where natural quiet is an important part of the visitor experience. The metric is similar to TAA in that it considers the amount of time each aircraft event is audible, but it also considers exceedances across the frequency spectrum associated with aircraft noise. The calculation however is also subject to overestimation through the addition of simultaneous occurring events.

Study of Visitor Response to Air Tour and Other Aircraft Noise in National Parks, 2005

This report (Rapoza et al 2005), conducted by the Acoustics Facility at the United States Department of Transportation's John A. Volpe National Transportation Systems Center (U.S. DOT/Volpe Center), presents the findings of a study which analysed all known aircraft noise dose and visitor response data previously collected in National Parks throughout the US. The data consisted of nearly 2500 visitor interviews and simultaneous noise measurements collected at four different National Parks between 1992 and 1999. The data and information obtained was then used as part of this study to develop relationships that relate the noise (dose level) data to visitor response (annoyance) for assessing aircraft noise in the National Parks.

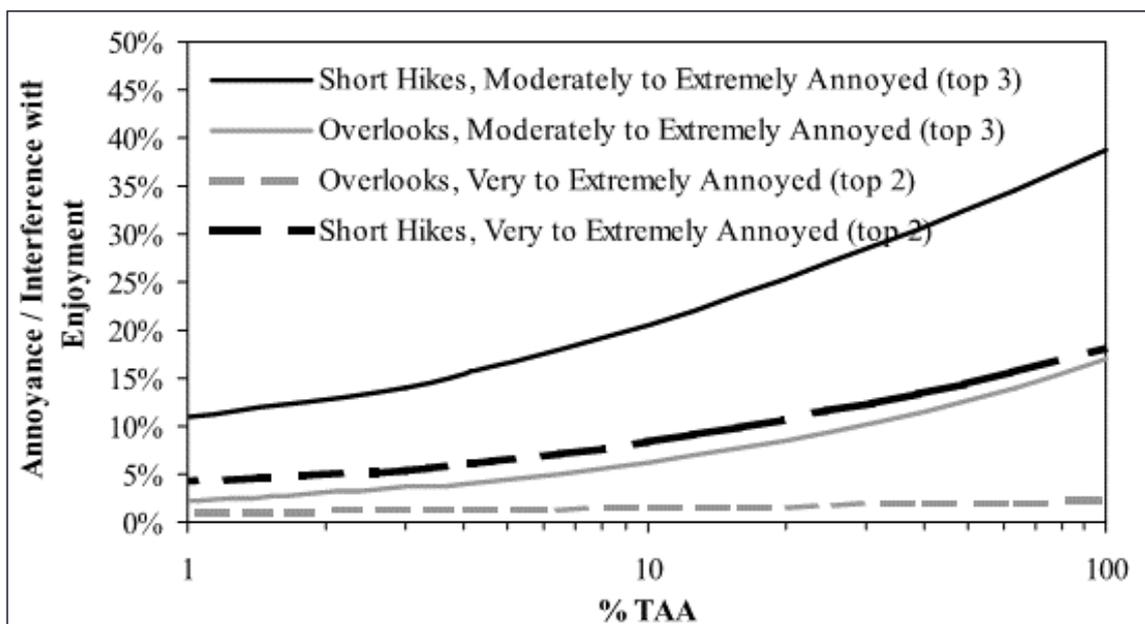
Key findings of the study are summarised as follows:

- The vast majority of visitors (more than 90 %) rate annoyance equal to or higher than interference with enjoyment;
- Visitors appear to be less sensitive to high-altitude jet overflight noise as compared with noise from tour aircraft, though the data do not show this with statistical certainty;

- Visitor response to tour overflight noise differs between overlooks and short hikes;
- A respondent's familiarity with the site can influence visitor response to aircraft noise, for example repeat visitors are generally more annoyed by aircraft noise intrusion;
- Noise metrics that showed best correlation between noise level and annoyance were A-weighted %TAA and aircraft equivalent sound levels, $L_{Aeq,1h}$.

An example output from the study for assessing aircraft noise in the National Park, that relates the noise (dose level) data to the visitor response (annoyance) is shown in Figure 2. In this example, it shows the level of annoyance or interference with enjoyment of the park as a percentage, based on the amount of time aircraft noise is audible above the ambient level. It is clear that the level of annoyance increases as the amount of time aircraft noise is audible above the ambient level also increases.

Figure 2: Example dose response relationship



It should be noted that the study (Rapoza et al 2005) and analysis considers all aircraft noise (high altitude jets as well as low altitude air tour operations), although air tour operations was the main contributor to the overall aircraft noise level for the data. The study also found interference with the appreciation of natural quiet and the sounds of nature was a more frequently reported response to aircraft noise than either annoyance or interference with enjoyment of the site; however, these were not analysed nor included in the development of the dose response data.

Also of interest is the work by Horonjeff (2005) who aimed to define methods to quantify the natural soundscape of the wilderness park environment. Horonjeff defines the soundscape in terms of duration of quiet time and time a visitor has to wait until they experience a quiet time of certain duration. This "wait time" provides a means for evaluating the impact of external man made noise on areas where the ambient environment is largely absent of man made noise sources. Furthermore, it is noted these external noise sources although relatively low in level, compared to within an urban environment, are distinctly audible in low-ambient noise environments, with their presence readily obvious at large distances. For example, during periods of low wind conditions, and ambient noise level near or below the human threshold of hearing, external noise sources (tour and jet aircraft) can be audible for long periods of time and heard at distances beyond 10 km.

C2.2 National Academy of Sciences

This summary document (Fleming 2013) reflects on a workshop hosted by the National Park Service (NPS) in 2012. The NPS has a mandate to protect the soundscape in its 400-plus properties and actively manages noise in its properties and has taken actions, both administrative and legal, to protect soundscapes. The US understands that national parks provide significant experiences to visitors every year, not only from what they see, landscapes, wildlife, cultural activities but also what they hear, adding a dimension that sight alone cannot provide. The NPS understands that natural sounds can dramatically enhance visitors' experience of many aspects of park environments.

Discussed in the document are a number of studies that have looked at the effects of noise on the people who visit national parks. Surveys of visitors show that soundscapes are important to them, and that the scenery is more meaningful to people when there is less artificial noise. From the research, it suggests lower noise levels assist visitors to hear natural wildlife, e.g. wolves, which are more likely to be heard than seen.

A number of studies found that interference with natural quiet was a more commonly expressed reaction to noticeable aircraft noise than annoyance, although the two measures tended to correlate with one another.

Results from the survey data also indicate that visitors are willing to help keep park areas quiet. As an example, Muir Woods National Monument, visitors observe "quiet zones" and "quiet days" when requested by posted signs. There was however greater support for the quiet zone concept. The research suggests on posted quiet days, visitors were significantly quieter than on other. In addition, since many people had little understanding what a decibel [unit of measurement of noise] means, the use of a "lost listening area" concept was an effective way to talk about noise without mentioning decibels.

The metrics used to measure and characterise the noise are typically different to those used by other agencies given the specific need to preserve natural and cultural resources and the fact that other agencies are for example, aimed at protecting human health.

Researchers sometimes measure the average noise level generated by a given source, but it is difficult to relate this measure to everyday experiences for the public. Knowing how often a noise is present and how loud it is helps with public education. A perceived loudness standard also may be preferable for higher noise levels and what is unacceptable in one park may be acceptable in a different park where levels of background noise are higher.

The document also raises debate on whether less noise for a longer period is preferable to more noise over a shorter period. Researchers note that in addition to the 'amount,' the timing and duration are also important. From the survey data, a participant observed that what people perceive can differ greatly from what they actually hear.

C3 New Zealand

The impact of noise on recreationists and wildlife in New Zealand's natural areas: a literature review

The New Zealand Department of Conservation (2011) prepared a report on the available literature regarding noise effects on recreationists and wildlife in New Zealand's natural areas. Part of the report focused on International literature on the general nature of noise impacts, factors that influence them, response to noise impacts and how to monitor these, as well focus on a number of key theoretical concepts.

A review on methods in which to measure and quantify the impact of noise on recreationists and in the natural areas is provided. Five broad categories of the methods are identified as follows:

- Sound measures with no response measures - using instrumentation or trained observers to measure the physical properties of particular sounds. For example, this may include counting the number of discrete noise events such as aircraft overflights or vehicle movements or measuring the maximum or average sound levels, its duration or the percentage of time that a sound source is audible.
- Dose-response studies - combining a quantitative measure of the amount of activity or noise levels (the dose) with a response variable such as the level of annoyance reported by recreational users.
 - o Such studies are used for the prediction of the likely responses from future users over a range of given noise levels. This is useful in determining thresholds of acceptable activity and for predicting the likely effects of future scenarios or management actions. However, such studies and the results are site specific; hence a study may not be representative of a particular scenario in a different setting.
 - o The use of a questionnaire helps to identify those areas where aircraft noise may be an issue or concern to the quality of visitor experiences. The questionnaire typically comprised two parts; open-ended questions asking respondents what they liked and disliked generally and secondly, more direct, closed-ended questions on specific issues, e.g. score annoyance levels with selected social impact issues, including aircraft noise.
- Simulation experiments – involves examination of responses to controlled dose/level of sound while controlling other variables that could otherwise affect the response.
 - o In terms of a recreational setting, the studies tend to have not focused so much on measuring impacts, but, instead, assist with the park to understand the relationship between sound levels and the visitor experience.
- Noise modelling – involves the use of software to predict noise levels at a given location and over wide areas around airports. The software is almost exclusively used in the management and land use planning around airports
- Response measures with no sound measures – a broad category with typical study approaches including surveys that enquire about respondents' sensitivity to noise, general likes and dislikes, or the effect of particular noise-generating activities on their experience. Such studies including the use of diaries and interviews, has increased the understanding on the complexity of impacts of noise on park users.

From the report, it was found that monitoring of the impact of noise on recreationists has generally focused on relatively simple methodologies that are affordable and can be easily carried out by non-specialist staff. The development of a Standard Aircraft Monitor (SAM) technique in 1997 and the application of this at multiple sites has enabled areas where a recorded annoyance level was greater

than a defined threshold to trigger a management response; e.g. prompt consultation between park managers and the noise source generators to consider and discuss options to address noise impacts.

However, it is acknowledged there is a need to develop better understanding of people's values, expectations and preferences associated with the natural areas. These understandings and any site-specific findings would add to the value and relevance of any noise impact monitoring tools.

C4 Europe

The Environmental Noise Directive (END) aims to define a common approach intended to avoid, prevent or reduce health effects from exposure to high environmental noise. As well as reducing human exposure to this noise, the END highlights the need to preserve environmental noise quality in quiet areas. These quiet areas have been the focus of The European Environment Agency (EEA) good practice guide (2004).

The EEA defines quiet areas not only by the average noise level, but an area where 'calm' can be found, noting most people feel the need to compensate their busy, noisy city life with an occasional or more regular calm and relaxing day. Such areas are where noise is absent or at least not a dominant feature, for example, within natural parks or protected areas, also unused land or areas outside the city.

The EEA state the purpose of preserving quiet areas is to protect human health. It is acknowledged by the EEA however, there is only marginal evidence that calm really does compensate negative effects from excessive noise, such as annoyance and sleep disturbance. However, the evidence does suggest that staying in a calm environment is good for health.

These quiet areas should therefore be identified, designated and protected. This is not necessarily a legislative action or a limited task for the authorities to implement, however they should be responsible to keep the noise from major sources, i.e. roads, railway lines, industry etc., away from the calm areas. The EEA then suggest the rest can be achieved by people, i.e. once people are made aware of the significance of calm, they are able to identify calm areas and will be more than happy to engage in an 'official' designation of these spots as calm areas, intended for relaxation, but if required, with some restrictions in place.

A number of European countries have made a determined effort to promote or protect quiet areas. The Netherlands, Belgium, Sweden and the United Kingdom acknowledge that acoustic quality of a quiet area is not only a function of the average noise level, but also relates to how an area is perceived by people. For example, this means understanding the balance between wanted and unwanted sound and the area's recreational value, or how appropriate the sounds present are to the area and its use. However, with that, requires new methods for the identification of quiet areas and in turn, the measurement of the perceived acoustic quality.

Four methods used for identifying quiet areas are as follows:

- Noise mapping, using specialist software to calculate environmental noise levels and identify areas that are not exposed to levels above a given threshold value. However, these are based on models of environmental noise emission and propagation, under given meteorological conditions and therefore may not correspond to actual noise levels in practise.
- Noise measurements of actual levels in situ, typically used to complement or to validate the noise maps. The measurements provide the actual level at a given place and time and therefore a more accurate representation than a calculated level. However, the process can be costly or time consuming, particularly for large areas.
- Evaluation of user/visitor experiences, that provide an insight into how people perceive a quiet area. Such studies may include understanding the perception and how dominant different sound sources are, the perceived acoustic quality or appreciation, tranquillity, annoyance or what sounds are appropriate to the place, and also the recreational value and actual use of the area.

However, these studies are time consuming and require expertise in behavioural science in order to develop appropriate questionnaires and obtain quality data.

- Expert assessments, including additional criteria to noise level information to identify quiet areas. These criteria may include land use plans, cultural heritage, ecological values, social and recreational values and accessibility, all which require a significant level of expertise.

C5 World Health Organization

World Health Organization Guidelines for Community Noise

The World Health Organization Guidelines for Community Noise (Berglund et al 1999) establishes the relationship between the definition of health and the effects of community noise exposure by noting that:

This broad definition of health embraces the concept of well-being, and thereby, renders noise impacts such as population annoyance, interference with communication, and impaired task performance as 'health' issues.

It also recognises 'disruption of tranquillity' or 'onset of disruption' as a potential health effect.

The effects of excess environmental noise are varied and complicated, and may be perceived in ways including sensations of loudness, interference with speech communication, interference with working concentration, studying, disruption of resting/leisure periods, and disturbance of sleep. Such effects can give rise to behavioural changes, e.g. avoiding the use of exposed external spaces or timing restful activities to avoid the most intense periods of disruption. Prolonged annoyance or interference with normal patterns can lead to possible effects on mental and physical health. In this respect, the World Health Organization (Preamble to the Constitution of the World Health Organization 1946) defines health in the following broad terms:

A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity

In terms of assessing the level of noise intrusion, the WHO guidelines note that measures based solely on equivalent sound level (L_{Aeq}) values do not adequately characterise most noise environments, nor do they adequately assess the health impacts of noise on human well-being. It recognises that the maximum noise level and the number of noise events is important when deriving guideline values.

Notwithstanding this, there are no guideline noise values in the WHO document for the *onset of disruption*. Instead for Parkland and conservation areas, WHO recommends such existing large quiet outdoor areas be preserved, and the 'ratio' of external noise to existing natural background noise be kept low.