Proceedings of 20th International Congress on Acoustics, ICA 2010

23-27 August 2010, Sydney, Australia

Alternative Aircraft Metrics – Useful or like moving the deck chairs on the Titanic?

Steven E Cooper

The Acoustic Group, Sydney Australia

PACS: 43.50Rq

ABSTRACT

Widespread criticism of the ANEF system to predict aircraft noise impacts has lead to the use of supplementary tools (N70, $N_{XX,\ 10+}$,TA, daily ANEF). Do these tools work? Are they of benefit to the community or the aviation industry? Do they add confusion? Are they appropriate for military aircraft or general aviation?

Australian Standard AS2021 [1] considers in the first instance the suitability of a building site in terms of an ANEF value. By use of Table 2.1 (building side acceptability based on ANEF zones) the site can be classified as "acceptable", "conditionally acceptable", or "unacceptable" for the relevant building type.

If a proposed site is in an ANEF zone above "acceptable" the acoustical assessment of the proposed development (by the methodology in AS2021) disregards the ANEF value as the assessment is then conducted in terms of the maximum A-weighted level.

Appendix A of AS2021 provides information as to the basis of the ANEF system and refers to the NAL study [2]. The NAL report recommended a different weighting system to the (then) standard NEF assessment procedure used in the USA. The last two pages of the NAL report were clear as to the outcomes of the study as to describing excessive noise limits and community reaction by stating:

> to describe 20 NEF as an excessive amount of aircraft noise is to offer a reasonable interpretation of the scientifically determined dose/response relationship. Whether or not areas within this exposure are incompatible with residential zoning is another matter. As scientists, the authors are charged with describing community reaction to aircraft noise. The task of prescribing regulations and standards relating to land-use around airports properly belongs to legislative and planning authorities. They must translate the findings of the present investigation into practical guidelines. This translation will necessarily involve reaching a compromise between what is desirable in terms of the quality of life in a residential area, and what is practical given the demand for housing and many other facets of urban community management.

The dose-response curve set out in AS2021 is slightly different to the curve recommended in the NAL study.

The proposal for a third runway at Sydney airport generated debate on aircraft noise impact with general criticism of the use of the ANEF system for determining noise impacts. There was widespread criticism by the community in relation to the Third Runway draft Environmental Impact Statement [4] and the draft Noise Management Plan [3] as reported in the Senate Inquiry report into the Third Runway [5].

Chapter 8 of the Senate Inquiry, titled "An inaccurate prediction of noise impact", discussed the limitations of the ANEF system and noted various submissions repeated the position that the ANEF is only an average value and therefore does not provide a complete picture.

The ANEF is subject to variations in noise level as a result of changes in aircraft composition, weather, and wind conditions prevailing at a time. If there are large periods of time during the day when there are relatively few aircraft then at other times (so as to obtain the required average over the whole day as part of the ANEF system) there will be either a much larger number of aircraft movements or a grouping of aircraft that give rise to significantly greater noise levels. Accordingly an ANEF value does not indicate variations of noise exposure that residents may receive from one day to the next and throughout any day.

Criticisms were made in the Senate Inquiry as to the relevance of the NAL report in that the period in time where aircraft noise intrusion for the NAL study was no longer valid, vis: 1979 – 1980 using aircraft types in of B707, B727, B747, DC8, DC9, DC10, F27, F28 and (for Richmond Air Base) C130, CC08, C141, having a different mix to aircraft operations in 1994. The most common types of aircraft in service at the time of the NAL study were Boeing 727s and Fokker F27s.

In critising the NAL study the issue of the accuracy of the predicted noise contours (from predictions in late 1970s) versus actual field measurements has never been addressed. If the predicted contours were wrong, then the basis of the

dose-response curves must be wrong. Cooper considered that issue [6] and concluded:

> "The INM program that was available at the time of the NAL study was significantly less sophisticated than the model that is available to date. The source material in terms of flight tracks, aircraft numbers, movements and types were not appended to the NAL report that could permit one to take the original data and model it with the knowledge gained from experience in operating an INM (and more recent versions of that model that are purported to be accurate).
>
> The NAL report indicates an assessment of the population based on noise contours that had been determined where the population had been placed in the various noise NEF zones. As the NEF zones determined in the NAL report were NEF_3 and not the $NEF_{3,6}$ that NAL recommended, then the contours used do not directly relate to the percentage population affected that appears in the Australian Standard.
>
> The NAL report is silent upon the matter of noise monitoring that was utilised for verifying the noise exposure zones so depicted in the report with respect to the aircraft movements used for the purpose of assessment.
>
> Furthermore, the NAL report is silent on the distribution of the population surveyed with respect to the NEF contours.
>
> Is the NAL report dose-response wrong? I say the report could overestimate the noise impacts. However, the dose-response curve set out in the Standard is not the same curve as recommended by the NAL report and is a dose-response curve that is lower than that proposed by NAL. Accordingly, it would be correct to attribute questions of the accuracy of the dose-response curve to the Department of Aviation, who modified the NAL dose-response curve to provide the curve set out in AS2021."

Chapter 8 of the Senate Inquiry report recommended the ANEF system be re-evaluated and NAL explore the development of indices or other information for predicting the noise impact. But NAL is no longer the eminent research group that existed in the late 1970s and such studies cost a lot of money.

Cooper [7] proposed a mini-NAL study but was denied completing such work by academic issues.

As a result of criticism of the ANEF system that was brought before a Senate Inquiry into Sydney Airport, additional acoustic descriptors/metrics have been suggested to supplement the ANEF contours so as to better describe aircraft noise impacts [8].

But those descriptors whilst primarily applied to domestic airports are not based on socio-acoustic studies and in some circles are considered to be politically motivated to say there is no aircraft noise impact.

Because military jet operations result in a different aircraft noise exposure to that typically encountered at domestic or international civil airports, the noise exposure zones are subject to intermittent high levels of noise throughout the day and night. And as such represent a different relationship of maximum level versus exposure levels to that obtained for domestic/international jet operations.

As a consequence of military operations, residential development in unacceptable areas (with respect to aircraft noise) and proposed residential release areas in proximity to a military aerodrome, there is some confusion as to the use or the validity of these additional noise metrics that have been proposed to assist an understanding of the ANEF.

In seeking to provide residential development in areas that by reference to Australian Standard AS2021 should not be used for residential purpose the cost ramifications in terms of implementing noise control measures to achieve a satisfactory internal environment are considered by some to be excessive, with a suggestion that such noise controls are not required, or such controls may be reduced with respect to the required degree of attenuation.

AS2021 and the ANEF System

Australian Standard AS2021 "Acoustics – Aircraft Noise – Building Siting and Construction" was originally prepared based upon the American noise exposure system identified as NEF (Noise Exposure Forecast). That system considered the cumulative impact of aircraft operations for an entire year averaged over a day using various acoustic parameters and reliance upon a computer program. The system indicated various noise exposure levels related to the acceptability of such noise and the use of the site, which in general is for consideration of residential premises.

With the introduction of jet aircraft to Australia the early form of jet aircraft had a significant difference in the noise signature when compared to propeller aircraft that operated at that time. Accordingly the community response to the introduction of these new aircraft was somewhat vocal and ultimately following various Inquiries a socio-acoustic study was undertaken by the National Acoustics Laboratory to consider the noise impact at various airports around Australia [1]. That study involved a social survey of sample populations around airports and analysis of the community's response with respect to predicted noise contours around airports based upon a computer model of the aircraft noise exposure levels.

The social survey covered the major capital city airports in Australia and included one military base at Richmond which was predominantly (and still is) an aerodrome operating propeller aircraft. There were some Boeing 707 refueller aircraft operating from Richmond at the time.

The results of the social survey were assessed against various acoustic descriptors utilising the data averaged across Australia to recommend the use of an energy averaged assessment base (similar to the NEF system) but utilising different weighting factors for night time operations to account for Australian conditions.

The NAL assessment curve provided the dose-response for persons affected by aircraft noise which is slightly different to that contained in the Australian Standard AS2021.

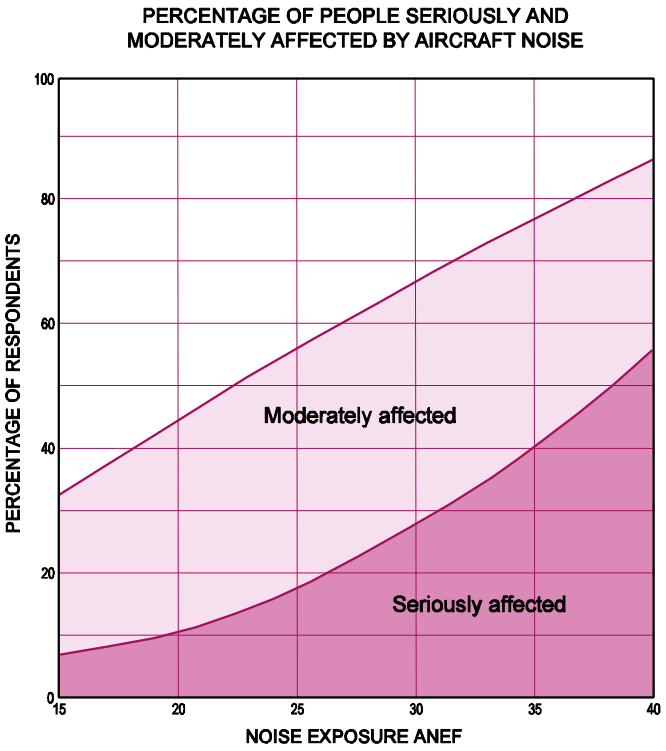

Figure 1: Dose/Response Relationship Diagram

(AS2021)

As a result of the NAL study the Australian Standard adopted the concept that for an ANEF level of less than 20 a building site was considered acceptable for residential purposes, for the area between 20 and 25 the site was considered conditionally acceptable for residential use whilst for a level greater than ANEF 25 the site was considered unacceptable for residential use.

For other forms of use such as commercial and industrial the classifications of unacceptable, conditionally acceptable and acceptable fall under different noise zones to that for residential purposes.

There have been a number of editions of the Standard which have benefited from a practical application of the Standard, particularly with respect to experience following the opening of a third runway at Sydney Airport. As a result of a requirement for noise controls to premises affected by aircraft noise from Sydney Airport sections of previous versions of the Standard were eliminated or significantly modified in light of such experience.

As a consequence of there being residential developments already existing or planned to occur in noise affected zones that in terms of the Standard are considered unacceptable for such use, the recognition of those situations is identified in the notes to Table 2.2 of the Standard. If such development is to occur in the interest of the community then the development may occur provided the buildings are acoustically treated to achieve the internal noise levels set out in Table 3.3 of the Standard. Those noise levels are average maximum A-weighted internal levels and to achieve such noise levels if it is necessary for doors and windows of the building to be closed then mechanical ventilation is required for the occupied areas so as to satisfy Australian Standard AS1668.

All of the above recommendations as to acceptability relate to persons pre-exposed to aircraft noise. For persons that move into an area or the introduction of a new flight path to areas that were not previously exposed to aircraft noise there will be a different community response to such noise.

The dose/response relationship diagram shows that the noise impact does not stop at the 20 ANEF contour. Extrapolation of the graph suggests a flattening of the seriously affected curve that at one point may tend to join an extension of the moderately affected curve.

If one extrapolates the curves in Figure 1, to obtain Figure 2, it can be seen that the seriously affected curve tends to flatten out to reveal that whilst aircraft noise is present there can still be a small percentage of the population who are affected by aircraft noise. Even at 5 ANEF some 5% of the population could be seriously affected. Alternatively does the extrapolation indicate the ANEF system may not have an appropriate database to consider aircraft noise that on a cumulative basis do not generate a significant noise? As the NAL study did not incorporate sufficient survey results in lower ANEF zones there may be limits on relying upon the ANEF system for determining the response/reaction of people in low exposure zones.

However the NAL study incorporated a control point at which the impact should be 0 but the nature of the extent of such areas and what still constitutes no aircraft noise impact has a very small dataset.

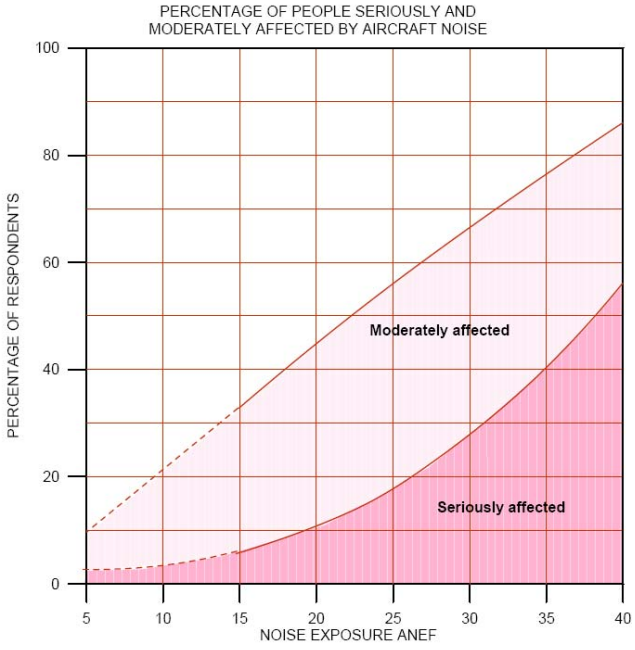

Figure 2: Dose/Response Relationship Diagram

(Cooper modification of AS2021)

In the *Draft environmental impact statement: Second Sydney Airport proposal* [9, 10, 11 & 12] an adjustment of 7 ANEF units was applied to the ANEF system for an adjustment for persons newly exposed to aircraft noise (citing papers produced by the principal author of the NAL study Dr. A. Hede). This adjustment appears to provide correlation to the reaction of Sydney residents when originally exposed to the

operations for the Third Runway and the Long Term Operating Plan for Kingsford Smith Airport. This adjustment contradicted the *Draft Environmental Impact Statement for the Third Runway* [3] position of accepting the AS2021 dose/response curve. This position was subsequently altered by the *EIS Supplement for the Third Runway* that accepted the view that, in the short term, there would be a penalty in the response of populations that are newly affected by an increase of approximately 5 dB in aircraft noise exposure [13].

Accordingly for persons that move into an area affected by aircraft noise there is an expectation of a heightened sensitivity to aircraft noise than indicated in AS2021, thereby questioning the decision to permit new development in an unacceptable zone.

The Standard **does not** utilise any alternative noise metrics for determining the acceptability of a building site or noise control measures. The Standard only utilises the ANEF zoning maps and the maximum noise level that is used as the external noise level design criterion. Therefore, the use of supplementary indices is not recognised in planning documents.

Supplementary Acoustic Concepts

The ANEF zone represents an average daily operation of an airport being made up of the total number of flight movements in a year, and then averaged out over the number of operating days.

For a military only base not all 365 days a year are used for flying purposes which therefore may lead to some confusion if persons take the total number of flights and divide by the number of days in a year to obtain a different average count to that nominated for the subject base. This becomes of significance with respect to the use of a weapons range which is of limited capacity in terms of use but when in use is subject to a significant number of movements.

As the operational mode (direction) of an airport is subject to variations in the wind not all aircraft are concentrated over a particular point all the time and there can be variations from day to day and also from season to season. Some persons therefore suggested that there should be an ANEF representing worst case scenario of an operational day, which by definition cannot be an ANEF and must be an ANEC. An ANEC cannot be used for planning purposes but could identify seasonal weather conditions that dictate different runway use.

Others have suggested the concept of N70 contours where the 70 indicates an external maximum noise level of 70 dB(A). The N70 level is suggested not as a planning tool but as a guide to indicate the degree of disturbance that may occur as a result of the aircraft overflights. The Standard does not consider noise disturbance to external spaces of residential premises but is to an internal noise target, whilst the N7 is an external noise level.

The NAL report identified that whilst the NEF provided a significantly stronger relationship with reaction to aircraft noise and other types of index tested, including “peak-level” indices, the index referred to as N70 (the number of aircraft per day whose level exceeds 70 dB(A)) can provide information on reaction in addition to that given by NEF. The NAL report identified that the increase in ones ability to predict reaction by way of the peak-level index was not that large but if desired, values of N70 could be given for a noise-effected area in addition to the NEF. In this regard, DoTRS [8] have sought to explain aircraft noise impact in terms of an N70 concept where the use of coloured planning maps provides a coloured thermometer type approach to the number of noise events. In some areas of aircraft noise debate, various community representatives have sought to discount the N70 concept when such a procedure is presented on its own as a means of suggesting the aircraft noise impact has been ameliorated by use of a new mapping graph, where there is no change in the noise exposure.

The provision of an N70 contour for describing aircraft noise in the absence of an ANEF contour map therefore appears to be contrary to the position expounded in the NAL report and is an approach that should not be taken in isolation.

The 70 dB(A) limit has been identified as an external noise such that when assessed inside a residential development (via an open window) to be a level that would interfere with communication or watching television. This as such could be taken as an internal level in the order of 60 dB(A), which is higher than the maximum level nominated in AS2021 for a dedicated living area.

Similarly an N85 concept intends to portray a noise level above 85 dB(A). The relevance of such a level is not identified in any quantitative manner for aircraft noise other than it is significantly louder than 70 dB(A). On a subjective basis one cannot compare a maximum noise level of 85 dB(A) versus a number of events of a lower level, i.e. 12 events at 70 dB(A).

However, to assist in the comparison of different flight paths or determining impacts of noise, N70 contours have typically been provided with respect to 5 events a day, 10 events a day, and 15 events a day.

There has been no suggestion or recommendations provided by aviation authorities to identify what is an acceptable number of N70 events per day but simply to use the N70 as a comparison tool. Therefore one is left in a quandary as what use is a number of N70 events is an acceptable aircraft noise limit.

There have also been maps utilising a time above concept to indicate the number of minutes per day that aircraft noise would be above a certain level so to then indicate the degree of disturbance or if one utilised the 70 dB(A) concept the time period in which interference with communication would occur.

Again there is no set target for an acceptable/unacceptable time above limit and therefore the value of such material is of limited assistance and certainly has no relevance in terms of a planning concept.

Another target or supplementary metric that has been nominated is to consider an $N_{XX,10+}$ to represent an A-weighted maximum noise level of XX dB value that experiences 10 or more events a day. However the relevance and the method of utilising an $N_{XX,10+}$ is not subject to any qualification. For example one could quote a noise level that relates to a position that experiences more than 10 aircraft events at or above that level. However that position could also in the same concept be a position that experiences 20 or 25 events a day yet the descriptor is not qualified.

If the qualification of the descriptor was 10 to 11 events a day then that may in some concept give the indication of that level of disturbance but again it is not a planning tool. Furthermore neither the N70 nor the $N_{xx,10+}$ take account of the difference between day and night operations.

The NAL study did consider the survey results with respect to such concepts but found such results had a significantly lower correlation coefficient than that used for the equal energy concept that ultimately became the ANEF system.

Figures 6.3a, j and m in the NAL report show the community response components for the different acoustic metrics to reveal that the N70, the $N_{XX,\ 10+}$ and the $NEF_{3,6}$ have a nonlinear result. These three graphs are attached and include my quadratic line of best fit (to be consistent with the $NEF_{3,6}$ method.

It is noted that graphing the NAL data and seeking a quadratic line of best fit does not provide the same line of fit as per the NAL report or the Australian Standard.

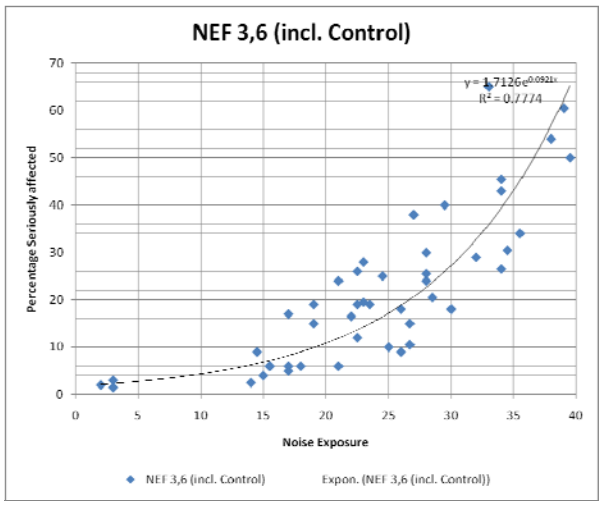

Figure 3: NAL $NEF_{3,6}$ (NAL Report)

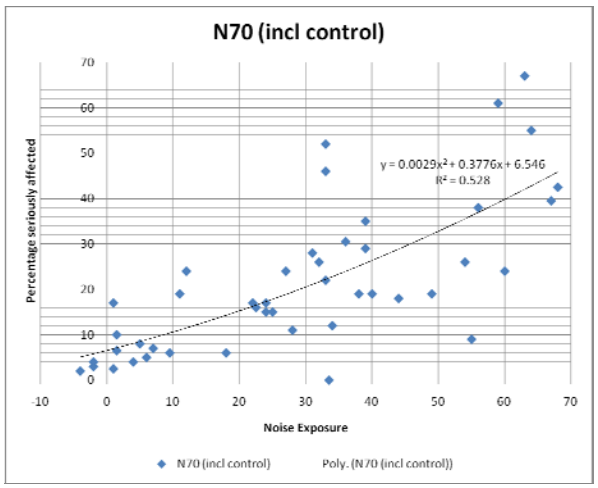

Figure 4: NAL N70 (NAL Report)

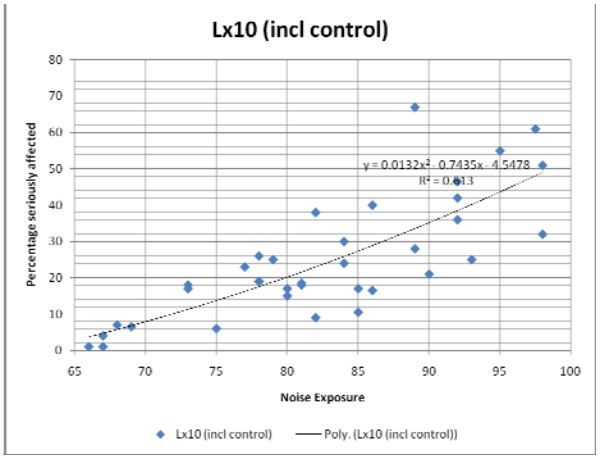

Figure 5: NAL Lx10 (NAL Report)

If one was to consider the concept of persons seriously affected from the NAL report with respect to N70 and $N_{XX,10+}$ then, from the acceptable and unacceptable ANEF thresholds (12% and 17% of people seriously affected), the following number of events per day (averaged across Australia in the 1979/1980 survey) are as follows:

Index	ANEF 20	ANEF 25
Seriously Affected	12%	17%
N70 events	11	22
$N_{XX,\ 10+}$	73	78

TABLE 1: Extrapolation from NAL report

It can be seen that if one utilises the N70 concept the unacceptable level for aircraft is 22 movements a day. Similarly if there were less than 11 movements per day then in terms of the ANEF Dose Response that would identify an acceptable limit.

But what happens when there are aircraft events significantly greater than 70 dB(A), yet the N70 value is the same as another site with all events just above 70 dB(A)? How does that change the impact?

Technically one could have 9 events a day at 100 dB(A) and then next maximum level down being one event a day at 70 dB(A) and still by way of Table 1 to have less than 11 events per day at or greater than 70 dB(A).

To place that variation in context one needs similar data for N80, N90 and N100 curves.

But the NAL report does provide that information.

On the basis of the $N_{xx,10+}$ concept the unacceptable level becomes 10 events at or above 78 dB(A). But this index could have a scenario of 8 events at 101 dB(A) and 10 at 73 dB(A) to obtain a $N_{73,\ 10+}$ value.

CONCLUSION

In Australia the official aircraft noise descriptor for planning purposes is the ANEF. This cumulative energy index is similar in concept to the Ldn.

However, on the basis of such levels being an average over a typical day based on the total number of flights in a year such an index does not identify the impact of individual aircraft or the range of variation in exposure levels that occur from day to day, or week to week, or season to season.

From an energy concept one could derive an SEL value for the corresponding number of daily aircraft movements that constitute an ANEF/Ldn. Acousticians can understand the mathematical concept but how does one then address/explain the nature of a large number of flights at SEL X and a small number of flights at SEL Y?

Using general noise exposure concepts for domestic operations is an entirely different situation for military operation that could be described as the SEL X and SEL Y scenarios respectively.

Even if one then described the different SEL the concept of relating those results to maximum levels is even a greater challenge.

The use of N70 to describe the noise impact must by definition apply to areas that should be acceptable in terms of the exposure level. Experience has shown that for areas inside the aircraft noise affected zone (greater than ANEF20) the N70 is of no assistance.

From a planning perspective consideration of a residential dwelling in proximity to a flight path is first considered in terms of the ANEF and then in terms of the average maximum level that determines if is it practical to construct a dwelling and achieve the internal design levels. Where difficulty is encountered in terms of noise control measures the maximum level is well above 70 dB(A) and therefore makes an N70 of no value at such locations.

I do not support the use of the N70 as a supplementary index unless there is a limit as per Table 1.

From a community that is annoyed or disturbed by aircraft noise the use of N70, $N_{70,10+}$ or TA is of no real assistance (to the community). What the community needs to know is the average maximum level of the typical aircraft using the nominated flight paths and how often and when they will be impacted.

On an ANEF basis the daily average can have fractions of aircraft movements much less than 1 that still add to the ANEF. In deriving maximum levels for military aerodromes the author has used an averaging method by way of the INM outputs, to ignore movements less than 1 when rounded up and then derive a maximum from the flights that are left.

Whilst the ANEF provides weighting factors for night flights should one provide such a weighting factor to the maximum level? Or should to the maximum level one add a correction factor for the initial onset from high speed jet operations?

1 Australian Standard AS2021-2000, “Acoustics – Aircraft noise intrusion – Building siting and construction”, (Standards Australia International Ltd, Sydney 2000)

2 National Acoustic Laboratories, “Aircraft Noise in Australia: The Survey of Community Reaction”, Report No. 88 February 1982

3 Kinhill Engineers, “Proposed third runway Sydney (Kingsford Smith) Airport: draft environmental impact statement”, 1990

4 Mitchell McCotter, “Sydney (Kingsford Smith) Airport; draft noise management plan”, 1994

5 Report of The Senate Select Committee on Aircraft Noise in Sydney, “Falling on Deaf Ears”, Department of The Senate, Canberra, 1995

6 S. E. Cooper, “Problems with the INM: Part 4 – INM Inaccuracies”, Noise of Progress Acoustics Conference 2006, New Zealand

7 S. E. Cooper “Community Response to Aircraft & Helicopter Noise – Proposed PhD Research”, Technical Meeting of the Australian Acoustical Society, NSW Division being a Review of Acoustics Research at Sydney University, May, 1991

8 Department of Transport and Regional Services, “Expanding Ways to Describe and Assess Aircraft Noise”, DOTRS, Canberra 2000

9 PPK Environment and Infrastructure, “Summary of Draft Environmental Impact Statement, Second Sydney Airport Proposal (Badgerys Creek)”, December 1997.

10 PPK Environment and Infrastructure, “Draft Environmental Impact Statement, Second Sydney Airport Proposal”, Volume 1 Main Report,

11 PPK Environment and Infrastructure, “Draft Environmental Impact Statement, Second Sydney Airport Proposal”, Volume 2 Main Report

12 Wilkinson Murray & ERM Mitchell McCotter, “Noise Volume 1: Main Report, Proposal for a Second Sydney Airport at Badgerys Creek or Holsworthy Military Area”, December 1997

13 Federal Airports Corporation, “Proposed third runway, Sydney (Kingsford Smith) Airport; supplement to Draft Environment Impact Statement, 1991