Challenges in Producing an Australian Noise Exposure Forecast

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ABSTRACT

Commonwealth owned airports are required to produce an Australian Noise Exposure Forecast (ANEF) every 5 years under the Airports ACT 1996. An ANEF is developed using Australian Standard AS2021. In 1999 the Minister for Transport and Regional Services directed Airservices to endorse ANEFs for technical accuracy. This ministerial direction is still current. The interpretation of technical accuracy has changed over the years since 1999. In the past basing a new ANEF on the previous one was an acceptable practice however this is no longer valid. New technology is changing the way aircraft fly. The improved accuracy resulting from modern navigation instruments has allowed (suitably equipped) aircraft to fly with reduced clearances. New flight paths are today being designed to take advantage of these emerging technologies. Though the majority of the current aircraft may not use them, these new flight paths are within the scope of today's ANEFs. In many cases an ANEF will need to predict how ATC will manage operations at close to the airport's physical capacity. A further complication is the tendency of airports to use long range and ultimate capacity ANEFs that try to predict well beyond the normal 20 year ANEF horizon. This paper examines the common issues past and present that Airservices has had to deal with in carrying out its obligations for technical endorsement of ANEFs and ANEIs.

Keywords: Aircraft Noise

1. INTRODUCTION

There are two ways to evaluate the impact of aircraft noise in the vicinity of an airport; monitoring or modelling. As aircraft have the potential to affect a large area, monitoring aircraft noise with a degree of rigour requires a large array of microphones. Modelling aircraft noise is a more cost effective method for assessing the impact of aircraft on the community. Modelling aircraft noise can also predict future impacts whereas monitoring can only access the past. By modelling aircraft noise we can answer questions like which areas are more likely to experience an increase in noise. Modelling noise can provide a "What if" tool to determine the effectiveness of alternative strategies.

An ANEF consists of a set of noise contours on a base map of the surrounding regions at an airport. The ANEF system of noise contours was developed as a result of a major socio-acoustical survey carried out in the vicinity of major Australian airports during the early 1980s (Hede A J and Bullen R B, 1982). The ANEF contains a weighting factor of 4 for the night period, 7pm to 7am, as this best correlated with the community's reaction to aircraft noise dose. The metric used is based on summing the energy from individual aircraft effective perceived noise levels (EPNL). For an airport the noise contours should include 20 ANEF to 45 ANEF in 5 ANEF steps.

The ANEF system is a land use planning tool to help control encroachment on airports by noise sensitive buildings. It is based on the forecast growth of the airport for a point in time that is no less than 20 years into the future. By comparison an Australian Noise Exposure Index (ANEI) is the noise contours for historical noise exposure, typically for a calendar year. An example of an ANEF/I contour is shown in Figure 1. This figure is the contour for Sydney Airport for the 2013 calendar year. The Integrated Noise Model (INM) provided commercially by the Federal Aviation Administration (US) is used for calculating noise contours.

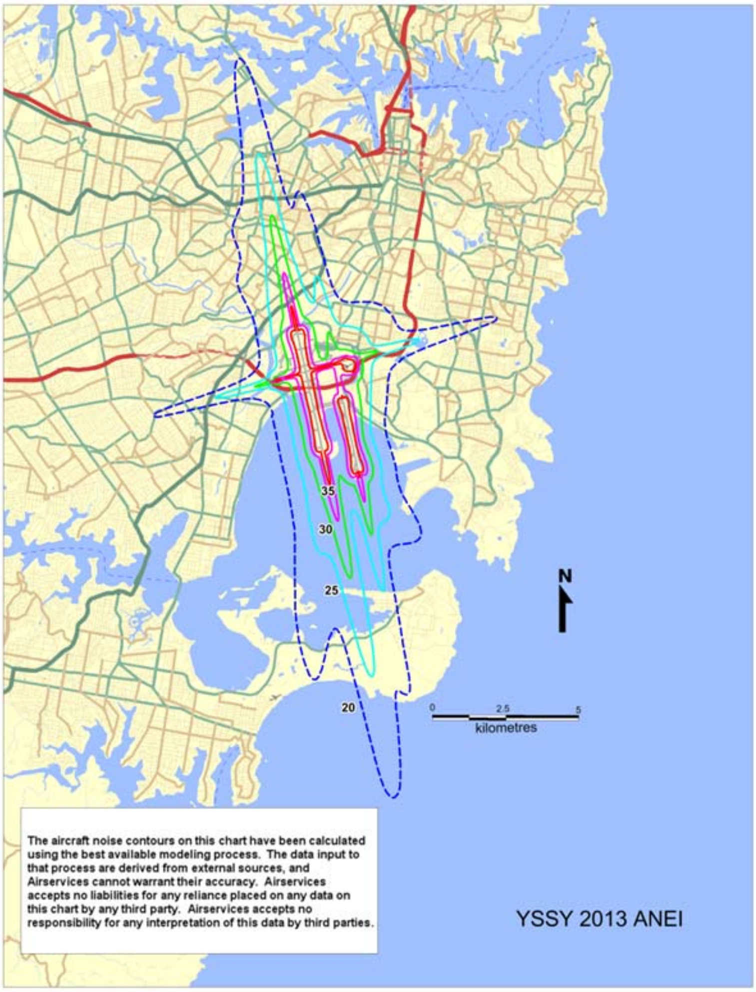

Figure 1 – ANEI contours for Sydney Airport for the calendar year 2013.

AS2021 (Australia, Council of Standards, 2000) details the calculation of an ANEF and the classification of regions according to the range in ANEF value. The classification used is based of the suitability of land use. The categories are; residential, motel, hospitals, libraries, schools and industry.

The critical contour is the 20 ANEF as this corresponds to the minimum level for acceptability for residential buildings. The value 20 ANEF corresponds to 10% of the population being seriously affected according to the 1980 NAL study. The region corresponding to the range of 20-25 ANEF is classed as conditionally acceptable for residential building. This means noise attenuation is required to meet the target levels of Table 3.1 in AS2021.

Ministerial Direction M37/99 (May 1999) prescribes that Airservices Australia is responsible for the endorsement of ANEFs for all Australian airports. Following changes to the Act in 2007, it is a requirement that ANEFs for leased federal airports are endorsed in a ‘manner’ approved by the Minister.

Airservices is responsible for Technical endorsement of ANEFs for all Australian airports that are required to produce an ANEF. Initially ANEFs were required for Federally owned airports under the Master Plan section in the Airports Act (Australia, 1996). However, various state legislations have also identified other non-Federally owned airports as requiring to produce an ANEF.

2. Process for Developing ANEF Contours

The key aspects of an ANEF that are considered as part of the endorsement process are shown in Figure 1 as black boxes. The corresponding endorsement criteria that Airservices uses for each aspect are shown as red and blue boxes. Each of these is describe in more detail in the following sections. Note the blue boxes were added to the endorsement criteria followed changes to the Airports Act in 2007.

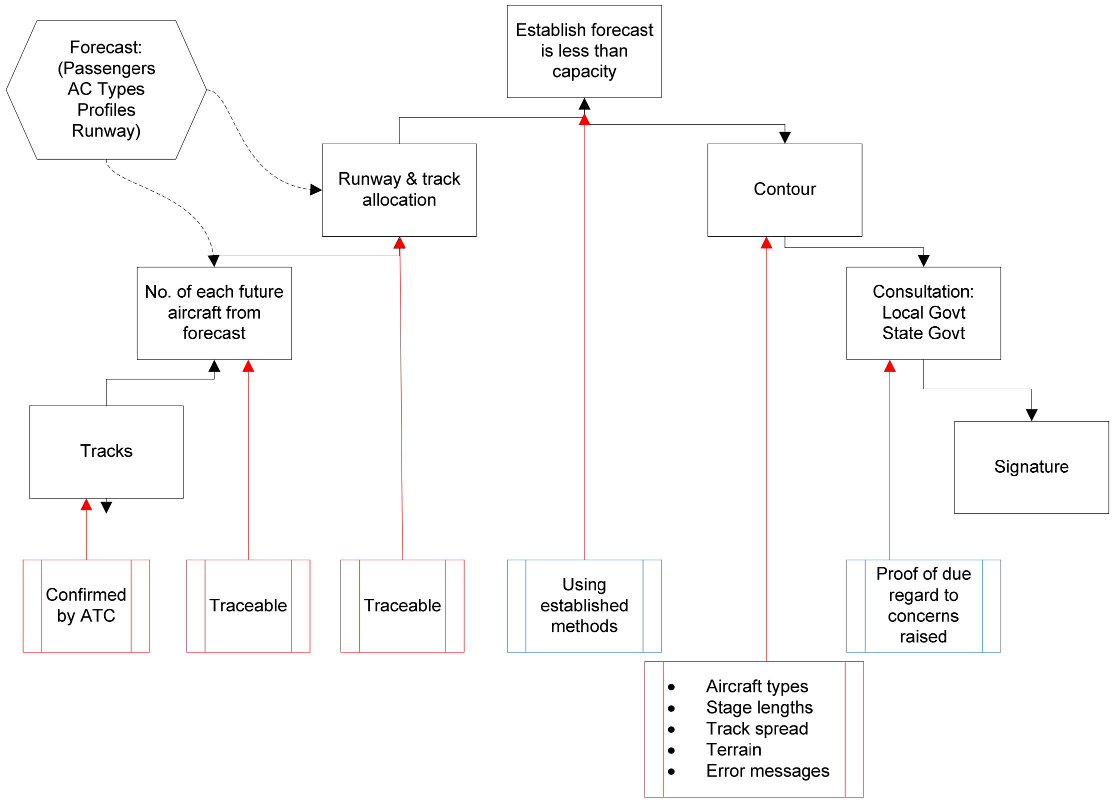

Figure 2 – Key aspects considered when endorsing an ANEF.

In general terms the endorsement criteria used by Airservices are not concerned with justifying the assumptions used by the airport, as most of these relate to the business plan for the airport, but are focused on determining the assumptions are traceable to a credible source or basis. There are three threshold issues in the endorsement process;

- The track and their spread are operationally suitable.
- The forecast for the number of aircraft is less than the capacity of the airport.
- Demonstration that the concerns raised by state and local governments have been addressed by the airport.

2.1 Tracks

Establishing the suitable model tracks, including their spread, should be based on the existing tracks with some changes due to expected take-up of new/future technology such as Required Navigational Performance (RNP) procedures. RNP use the in-aircraft flight management system and GIS technology to define the procedure pat. The result is a path which is flown more precisely than for other traditional navigation aids (these are a combination ILS, VOR, DME and outer marker beacons). This results in a flight path with a small variation (less than 0.3 nm). In Australia RNP operations have been progressively implemented at the major airports. To date the focus for RNP has been with arrival procedures but the technology can be used for departures. The current complication in using RNP is that when there is a mixture of RNP and non-RNP equipped aircraft using the same air space at the same time air traffic control (ATC) often revert to the lowest common denominator, which is the non-RNP procedure. This limits the number of operations utilising RNP during busy periods, however for future operations in the 20 year horizon of an ANEF, most aircraft, if not all, will be RNP equipped.

Usually the modelled tracks and their spread will need to be confirmed by letter from Air Traffic Control. Advice can be obtained from Airservices for which airports this is required.

2.2 Forecast

The forecast is a determination of the aircraft types that will be used at the airport, the destination and origin of these aircraft, what runways will be used and the day or night period for these operations for a point in time 20 years or more into the future. This starts with the base line for the current operations.

How does the airport obtain the base data necessary to build the forecast of operations?

A data suite of the current operations and sample of current tracks can be obtained from Airservices Noise and Flight Path Monitoring System (NFPMS) provided the movements at the airport concerned are captured by this system. Currently 8 major airports and 8 regional airports are covered by the NFPMS. For other airports billing data collected either by the Airport can provide the base data for aircraft types and the day night time for the operation. This leaves the runway and destination/origin data, which may be sourced from the operators at the airport.

Once the baseline of current operations has been established the forecast is built from identifying the existing market segments and applying the appropriate growth for each segment. For a major airport the market segments could be:

- International – Europe (heavy wide body jet aircraft)
- International – US (heavy wide bodied jet aircraft)
- International – Pacific (a mixture of narrow and wide bodied jet aircraft)
- Domestic – major cities (narrow bodied jet aircraft)
- Domestic – regional (turbo prop) aircraft)

For a regional airport the market segments could be:

- Pilot training (single engine fixed wing)
- Agricultural
- Charter (twin engine fixed wing and larger helicopters)
- Search and rescue (large helicopters)
- Police (large helicopters)
- Pilot training – helicopters (small single engine helicopters)

There are some good sources for medium and long-term trends for the growth in certain markets. For instance the Boeing website (www.boeing.com/boeing/commercial/cmo/index.page) predicts a relatively high growth in Asian and Pacific region, as well as a growth in the use of narrow and medium wide bodied jets.

It would be expected that during the ANEF time frame aircraft like the Boeing 737 to be replaced by Boeing 737-NG, Boeing 767-300 to be replaced by either Boeing 787 or Airbus A350's.

2.3 Runway and Track Allocation

The endorsement process does not validate the runway and track allocation but Airservices does expect the prevailing wind conditions, physical limitations, current track and current runway usage to be factored into the results.

2.4 Forecast Less Than Capacity

An important part of the endorsement process since 2007/8 has been establishing the forecast number of operations is less than the capacity of the airport. The particular requirement is specifically identified in the " manner approved by the Minster" and requires the estimate for the capacity to be done using an acceptable and creditable method. Some examples of these are:

- Based around the FAA document AC 150/5060-5 (Federal Aviation Administration, 1983)
- Using fast-time air traffic control simulation tools such as Total Airspace and Airport Modeler (TAAM)

- In the case where there is no change to the physical layout of the airport, to base the estimate on the historical busiest hour at the airport

2.5 Contour

In terms of the endorsement process this section is fairly straight forward it is making sure that all of the assumptions are included in the setup file for INM. Having said that there have been occasions where the supporting documentation and the INM model had different movement numbers or that the incorrect INM aircraft types had been selected.

The atmospheric pressure and temperature affect the atmospheric absorption of sound which can change the ANEF contours. INM allows the user to set the temperature and pressure within the study file. The forecaster has to determine the correct logic in setting these.

Terrain data is relatively easy to obtain and there are very few airports where the contours are not affected by the local terrain. Therefore terrain is expected to be included.

As part of the endorsement process Airservices will import the terrain and run the study to examine the error/warning file that the INM file generates.

2.6 State and Local Government Consultation

A requirement since 2007/8 is that endorsement must require the airport to demonstrate that it has paid due regard to the concerns that state and local governments have with the ANEF contours. This requires the airport to consult with both state and local governments when a new draft ANEF has been established and to respond directly with them on the concerns raised. Some typical concerns that Airservices has seen during the endorsement of many ANEFs are; to seek further clarification of key assumptions made during the modelling phase, to determine the impact of the ANEF or to simply make a comment. To gain endorsement the airport must provide evidence that consultation and what concerns were raised and record how these have been responded to.

2.7 Signature

There final stage is for the airport to provide three copies of a map containing the contour including required disclaimers ready for signature by the delegate.

2.8 Supporting Documentation

The airport needs to produce supporting documentation detailing the processes and the assumptions that went into generating the ANEF. This needs to be submitted with the three copies of the ANEF map and the INM model file. In a lot of cases a draft ANEF map or sample is provided. The final being produced once the technical aspects of the process have been completed.

Typically the endorsement process takes about 8 weeks plus additional time taken in corresponding with the airport seeking clarification of the assumptions and to re-run the model when required by the endorser.

3. Issues to Consider in Developing an ANEF

Depending on the nature of the assumptions used in the ANEF study it may be possible to end up with unreasonably large contours. If these overlap or are close to existing residential area this would result in large pieces of land being quarantined from residential development by local or state government. For this reason the inputs into the model need to be scrutinized. During the endorsement process the question of why an assumption or approach has been used can be asked. In many cases this is not done as a criticism but in an effort for the endorser to understand the basis for the noise model. In the next section we discuss some examples.

3.1 The Physical Layout of the Airport

The orientation of the runway is the major determinate of the shape of the contours. Often airports will forecast changes to the runway configuration, for example:

- New runway introduced
- Runway closures
- Runway extensions

How the runways will be used by ATC following any of these changes needs to be taken into account. For example when a third runway is forecast parallel to an existing one the airport has a view that the new runway would be used for international operations, because of its proximity to the international terminal, and the other for domestic. ATC would have a view on the feasibility of this. In some cases it may be appropriate to have separate forecasts for the current configuration and another including the runway changes. This makes sense if it is the forecast is a long range forecast (or an ultimate capacity forecast) and the current configuration will remain for a significant proportion of the forecast period.

3.2 Spread of Tracks for Future Flight Paths

The contours tend to be an oval shape with the main axis inline with the runway. For those airports which have multiple runways departure tracks may deviate from the straight lines and the contours become less aligned with the runways. Much effort needs to be devoted to get the right shape for these tracks.

INM uses backbone tracks with adjustable/configurable sideline tracks to which aircraft are assigned to, to represent the flight paths used by aircraft. The challenge in setting up an ANEF is to decide how many backbone tracks are required and how many sideline tracks are needed (for each backbone track) to adequately describe the operations using each flight path. One approach is to use fewer backbone tracks with a larger number of sideline tracks. This approach places a greater emphasis in getting the correct percentage use across the sideline tracks. If a larger number of backbone tracks are used then the impact of the spread on the final contour is lessened.

Aspects to consider when deciding on the position of a sideline tracks are; what aircraft are currently doing today, what is the expected performance for future aircraft types and what navigation tools will these future aircraft use. An example of this issue is the current situation for departures off 16L passing through the heads of Botany Bay at Sydney Airport. In Figure 3 the spread of tracks for two different operators using similar aircraft are shown as different colours (red and yellow). The difference is the yellow colored tracks (first operator) cover a wider area though the heads than the red tracks (second operator). The issue here for the ANEF is what will be the spread for future aircraft using this flight path and does it make any difference to the contours? This question is very relevant for ANEF’s being modelled from now on as these need to consider the probable use of RNP departures for future tracks.

To quantify the impact contained within this question, 100 Boeing B737-800 (using stage length 2) are modelled using two the different scenarios for the spread of tracks (yellow versus red). The scenario with the wider spread (yellow contours in Figure 3) results in contours enclosing more of the residential area of La Perouse. The 100 737-800s could be considered realistic given that 400 aircraft depart from Sydney per day and some of these would be heavier, and therefore provide a larger foot noise print. So in this case it may be advisable to include the narrow spread for this departure track.

Note, if these movements were part of an ANEI the appropriate spread to use is not open to interpretation and the combination of the yellow and red tracks should be used.

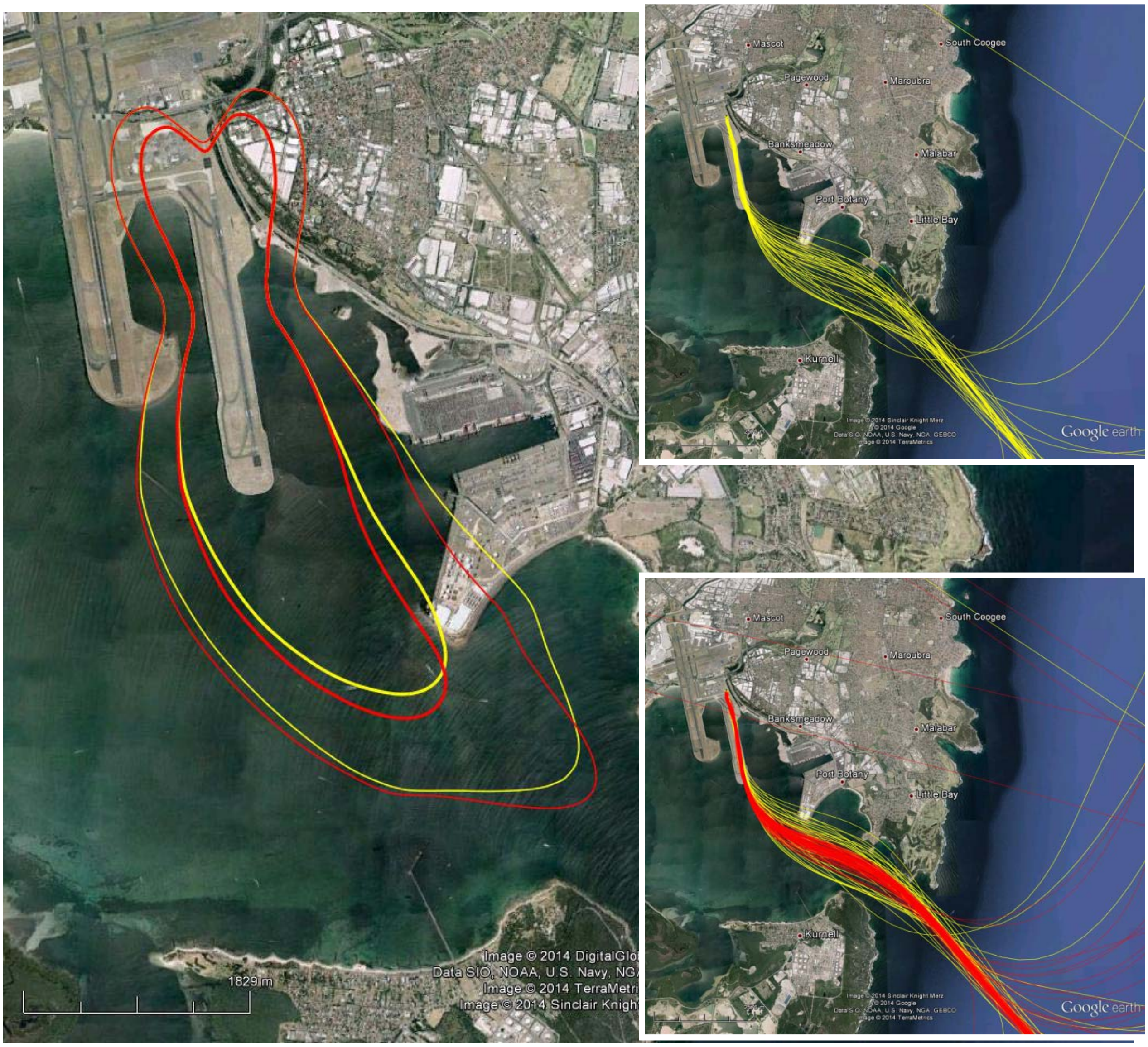

Figure 3 – Tracks for two different operators, using similar aircraft, departing off runway 16L passing through the heads of Botany Bay and the comparison of the contours (using the same aircraft). The wider track spread produces contours that pass over a greater portion of La Perouse.

3.3 Fleet Mix

The impact of using the wrong fleet mix can be significant. In Figure 4 the contours are shown for the 6300 passengers using 17 Boeing 747-400 (wide bodied) aircraft (red lines), overlaid on these are the contours for the same number of passengers but using Boeing 737-800 (narrow bodied) aircraft (yellow lines). In this example the destination for both scenarios is the same (stage length 2). Approximately 37 Boeing 737-800s are required to fly the same number of passengers, 6300. The contours for using the Boeing 747-400 are almost twice as long as those using the 737-800. Potentially there can be large errors in the ANEF contours if care is not taken in selecting the correct the fleet mix.

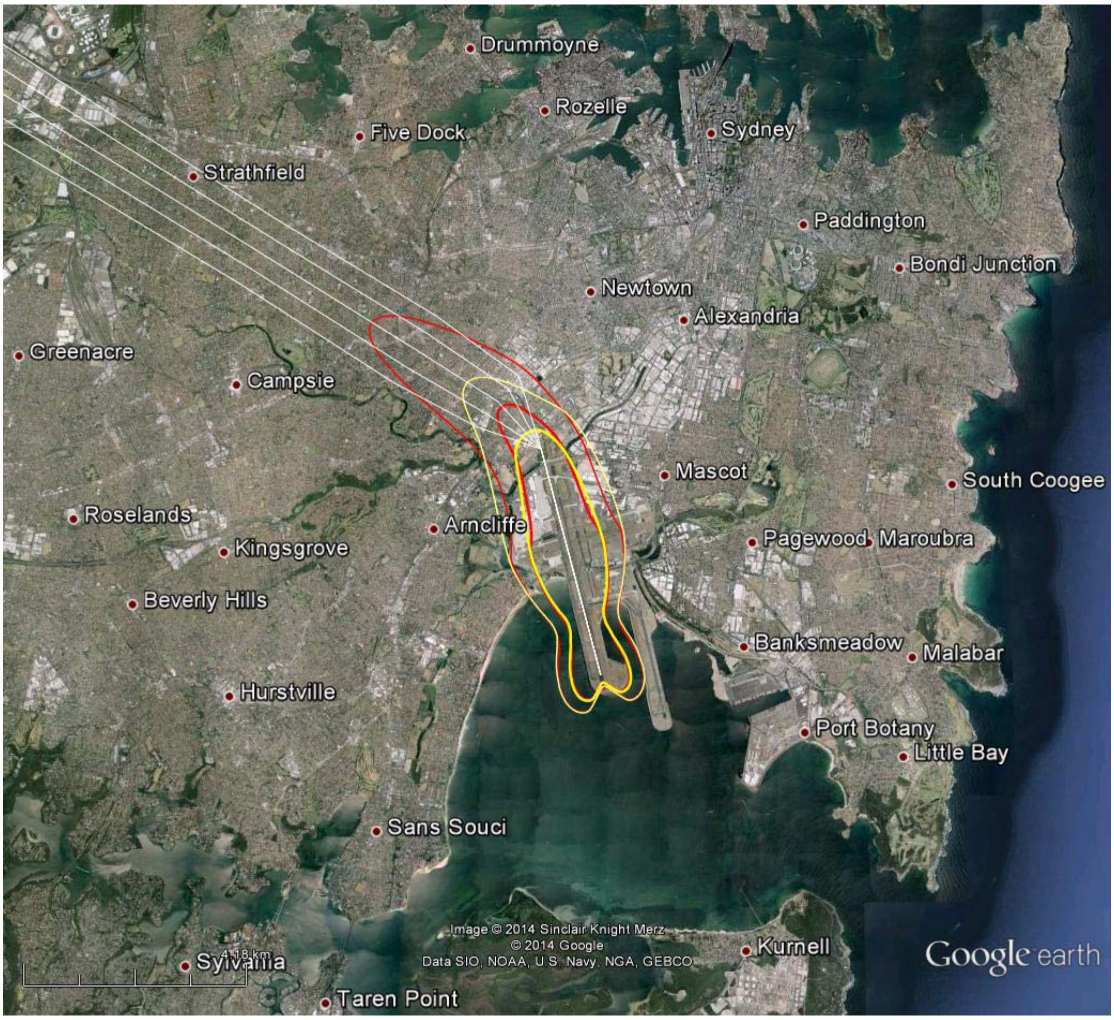

Figure 4 – The contours for 17 Boeing 747-400 (red) and 37 Boeing 737-800 (yellow) flying the same number of passengers to the same destination.

3.4 Modelling Future Aircraft that are Not Included in INM: Surrogate Aircraft Types

There have been some cases where it is necessary to accurately model future aircraft when these are not yet available in the INM. This was the case when the Airbus A380 was first introduced at major airports. The noise data or profile data in INM did not exist for this aircraft. As a result the Boeing 747-400 was used for the A380 even though the industry was aware it was quieter than the 747-400. This practice quickly leads to significantly larger contours that did not accurately represent the future impact. The UK CAA addressed this problem by introducing the method of using surrogate aircraft.

For each aircraft type in INM there are noise data and performance data for thrust, height and speed. In determining the noise dose for each aircraft calculations combining the aircraft specific noise and performance data sets are made.

As part of the delivery process for a new aircraft the certificated noise levels are provided. The INM noise data for aircraft is more than just the noise certification values. What the UK CAA did to improve their modelling for the A380 was to create their own user defined aircraft type within INM which the noise data is to simply apply a correction to the Boeing 747-400 noise data (in INM) equal to the difference between the certificated noise level(s) of the Airbus A380 and the Boeing 747-400. The performance data for thrust, height and speed were the adopted from the B747-400. Several years after UK CAA implemented this approach a latter version of INM, which did include the A380, was released by FAA. The subsequent remodeling for A380 operations proved the surrogate method worked, it better estimated the noise while at the same time not under-stating the noise impact. Since then the surrogate methodology has been used for modelling future aircraft such as the Boeing 737-Max, Airbus A350 and new versions of the Boeing 787. In these cases the aircraft have not been introduced and the certificated noise levels are not available, so the forecasted or target certification values for these aircraft were used when setting up the user defined aircraft type.

3.5 Using Sensitivity Test to Resolve Uncertainty in Selecting Aircraft Profiles (Stage Lengths)

As mentioned above INM also has individual performance profiles for each aircraft types. There is usually a single arrival profile, and multiple departure profiles. The departure profiles (referred to stage lengths) will depend how far the aircraft is forecasted to fly. For departing aircraft with a range of less than 500nm there is only a single departure profile. For aircraft types capable of long distances may have as many as 9 departure stage lengths to choose from.

The challenge of selecting which stage profile to use can be more complicated than knowing the distance to the next airport. Consider for example Boeing 737-800 departures off runway 34L at Sydney airport flying to Adelaide. According to how far these aircraft fly the stage length should be 2. Figure 5 shows the height versus distance (from start of roll) figure for these aircraft captured by Airservices Noise and Flight Path System (NFPMS). Also contained in this graph are INM profiles for stage lengths 2 and 6. From the flight path data these tracks better match the INM profile stage length 6 rather than 2. One could be tempted to use stage length 6 for these departures in an attempt to better match the height-distance data in the NFPMS.

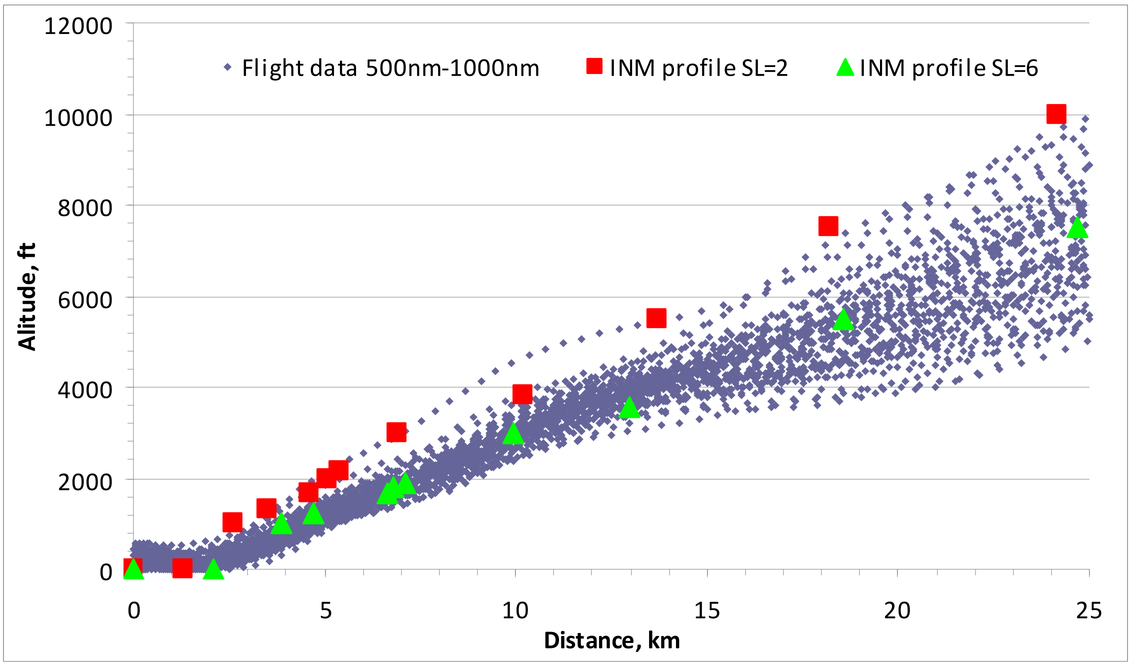

Figure 5 – Altitude profile for Boeing 737-800 departing off runway 34L (grey) are noticeably less than the expected profile (stage length 2). These match stage length 6 (green) profile.

In Figure 6 it becomes apparent what is really happening. These departures are being held down until they are clear of the arrivals on to the same runway (34L) from the north. The destination distance (and therefore the weight) for these aircraft matches a stage length 2 procedure however the thrust used is less than that normally used for a stage length 2 take off, resulting in the lower height and keeping well below the arrival aircraft. However this lower thrust does not correspond to stage length 6 even though the profile may look like it. Stage length 6 corresponds to the aircraft's overall weight being greater consequently using greater thrust and resulting in an overestimate of the noise energy for these aircraft. In short the departure procedure used for these departures cannot be modeled accurately in INM. If one was interested in a study for just these aircraft alone then a new profile and thrust data would need to be setup. However is this required for a full ANEF, which includes aircraft arriving and departing off all six runways? To answer that question a sensitivity test for these aircraft within the full ANEF model could be done. Two scenarios are compared; one using stage length 2 for narrow bodied jets flying to Adelaide and the second using stage length 6 for these aircraft. If the results of comparing these two scenarios show negligible difference then the default stage length of 2 (based on distance travelled) could be used.

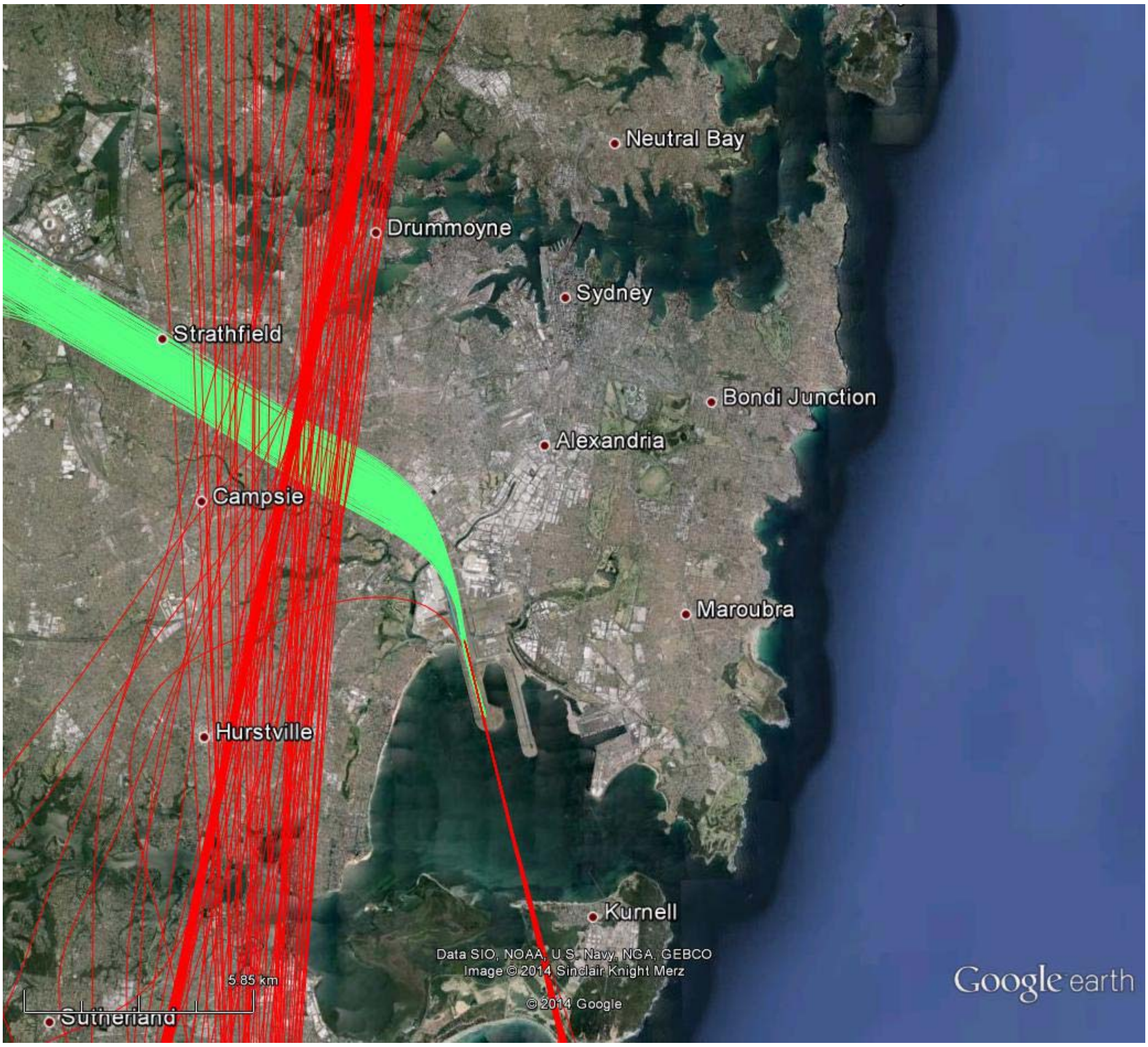

Figure 6 – The arrivals onto runway 34L overfly the departures off the same runway at Sydney Airport.

Another example where a sensitivity test could be used concerns modelling large helicopters. In the latter versions INM the modelling of helicopter operations was improved however there are only a small number of helicopter types in the software base data. The sensitivity exercise has been used in several ANEFs to test if the standard helicopter types can be used or if more accurate user-defined profiles need to be setup within the INM model. The contour calculation was repeated for a second scenario with twice or three times the number of helicopter than forecasted. There have been cases where this made no difference to the contours and so the generic INM helicopter types were used, and cases where this test revealed the ANEF was sensitive to the helicopter operations and more accurate base data to represent the helicopters forecasted was needed.

4. Composite ANEF

A composite ANEF is where there are two or more different scenarios for the ANEF are calculated, one set of contours is over laid on top of the other (or others) and the final composite ANEF is “drawn” around both (or all). A composite ANEF will cover more area than a single scenario ANEF. Some reasons why a composite ANEF may be required are:

- When a airport operates consistently and differently during winter/autumn as it does during summer/spring.
- Where it is expected that the configuration of the airport changes significantly midway through the forecast.
- Uncertainty in the preferred operational mode for an airport
- To include the overlap for two airports in close proximity or at airports where defence and civilian operations occur such as at Darwin.

5. Extensions on the ANEF

As part of the airport Masterplan the INM model used to develop its ANEF is often used to generate other metrics. For instance it has almost become standard for the Masterplan to include a N70[1] contour (for a regional airport the N65 is often included as well). There is no endorsement required for the N70 map. These contours will often include regions, which extend far beyond the 20 ANEF. An example of the N70 map is shown in Figure 7 below; the Sydney Airport N70 map for the 2013 calendar year.

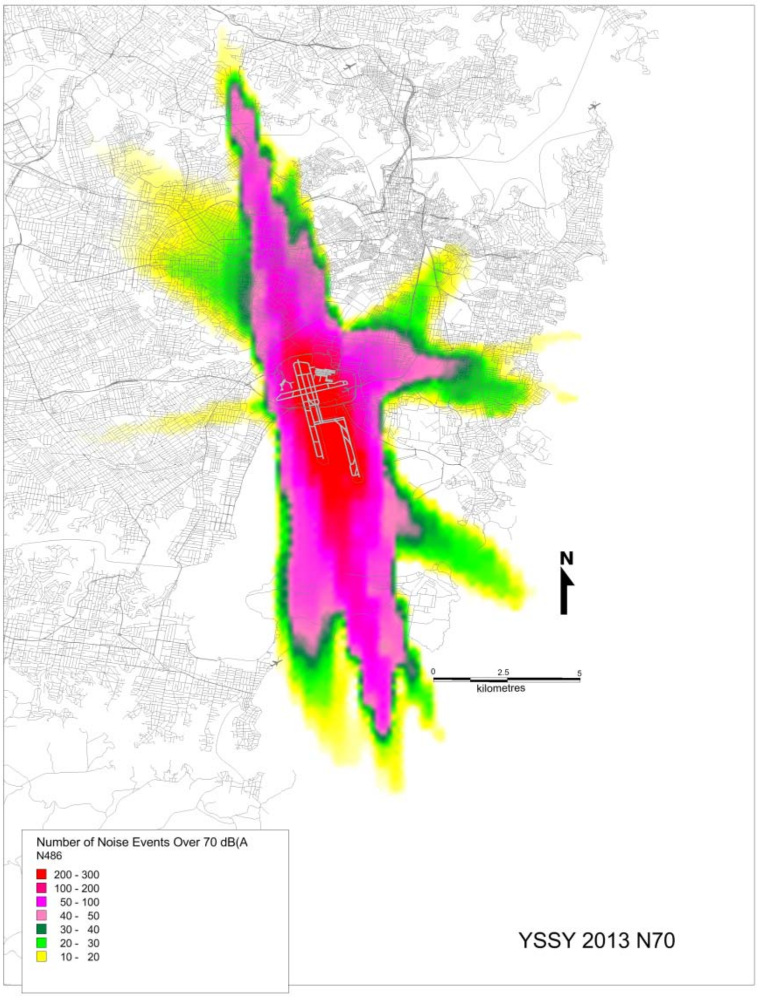

Figure 7 – The N70 map produced from the same INM model that was used to produce the ANEI in Figure 1.

[1] The N7- is the average number of aircraft noise events above 70 dB LAmax per day.

Anyone using a N70 maps needs to realize the INM software used to produce the ANEF map was not designed to be produce N70 values. In fact the N70 contour cannot be calculated within INM. The INM output for the detailed grid calculation has to be manipulated outside the INM software and displayed using GIS software. This paper is not suggesting there is little value in the N70 maps, these maps are be valuable for comparing one area to another. The N70 map may not be suitable for comparing to measured noise data.

6. Conclusion

Airservices has been endorsing ANEFs for 15 years and it has been producing ANEFs and ANEIs for longer. During this time there have been improvements to the modelling software. Fifteen years ago the ANEF calculations required a server, ran over several days and could not account for the local terrain. Now the software runs on a home PC, runs the software within an hour and even the added complication of including terrain causes little concern. The rate of change in the fleet and the way aircraft are managed is greater than it has ever been. The challenge for setting up an ANEF is about adopting the model to these changes, being able to justify the assumptions and being aware of the impacts for the assumptions made. The end result is that today's ANEFs have a higher degree of rigor about them than previously. But equally true is that the there are more people living closer to airports now and the expectations of the community is greater than previously so the consequences from an error in an ANEF are also higher than ever before.

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