NatCen
Social Research that works for society

Annex A Sample design: areas of low night noise exposure

Why we need a separate sampling approach in areas of lower night noise exposure

Available noise contours go down to different levels in each airport. The lowest continuous noise exposure contour value for each airport in the survey sample is presented in Table A1.

Table A1: Lowest continuous noise exposure contour value for each airport in the sampling dataset

Airport	Lowest continuous exposure contour value
Heathrow	41dB
Gatwick	46dB
Bristol	48dB
East Midlands	45dB
Manchester	45dB
Stansted	41dB
Luton	40dB
Glasgow	43dB

Noise Consultants Limited (NCL) have used overflight data to expand the target sample indicated by the noise contours to include addresses estimated to be exposed at around 35dB to the lowest continuous noise exposure contour value at each airport. It's a big methodological step forward to be able to include addresses exposed at lower levels in the target sample for this survey, and represents a big improvement on previous survey sampling strategies such as the Survey of Noise Attitudes (SoNA 2014) which sampled from 51dB $L_{Aeq,16h}$. Sampling lower levels makes it more likely that thresholds for where effects begin can be identified (e.g., Lowest Observed Adverse Effect Levels (LOAEL values). However, the approach used to estimate exposure at lower levels cannot assign a particular dB to addresses exposed at greater than 35dB and less than the lowest continuous noise exposure contour value. For instance, for addresses around East Midlands, we know that an address in the target population is exposed at a level somewhere between 35dB and 45dB, but are not able to estimate the exact exposure at this point in time.

Therefore, we will not be able to sample addresses at lower levels of exposure (<47.9dB) using the same approach as those with greater exposure (48+dB – the lowest common value available across all 8 airports). In particular we will not be able to sample in 2 or 3dB bands within the lower exposure areas. Lower exposure areas will require a separate sampling approach.

The proposed sampling approach

All airports have continuous noise exposure contours down to 48dB. We will be able to use the sampling approach previously outlined for addresses exposed at 48+dB L_{night}. However, because it is not possible to discriminate between noise exposure in the 35-47.9dB group, these will need to be treated as one large exposure contour and sampled separately.

Table A1 indicates that some airports do have data on more specific noise exposure between 41dB and 47.9dB. The following proposed approach is designed to make use of all the available information.

A simple approach is to sample the 35-47.9dB band in proportion to the population distribution by airport.

Step 1: Work out the number of addresses exposed to night-time noise around each airport in the 35-47.9dB band.

Step 2: Allocate the target sample so that each airport is represented in proportion to the distribution in the population.

Step 3: Calculate number of addresses needed to issue to achieve target sample.

Step 4: Sample separately by each airport to make use of all available data.

To illustrate this process, consider the distribution of addresses by airport in Table A2.

Table A2: Population distribution of addresses exposed at 35-47.9dB by airport

Airport	Proportion of addresses in the 35-47.9dB band around each airport
Bristol	1.5%
EMA	4.2%
Glasgow	2.0%
Heathrow	72.7%
LGW	2.3%
Manchester	7.5%
Stansted	3.3%
Luton	6.4%
Total	**100%**

Totals may differ due to rounding.

We suggest allocating 1456 target responses (36%) in the low exposure areas out of a total target of 4000 responses across the survey. This number was estimated based on allocating the sample size equally across noise bands.

Step 2 will allocate the target sample in the low exposure areas in each airport based on the population distribution in Table A2.

Table A3 illustrates the target responding sample per airport based on the proportion of addresses reported in Table A2.

Table A3: Target responding sample by airport in the low exposure areas

Airport	Proportion of addresses in the 35-47.9dB band around each airport	Target responding sample
Bristol	1.5%	22
EMA	4.2%	62
Glasgow	2.0%	30
Heathrow	72.7%	1059
LGW	2.3%	33
Manchester	7.5%	109
Stansted	3.3%	49
Luton	6.4%	93
Total	**100%**	**1457**

Totals may differ due to rounding.

Step 3: Apply completion rates to calculate the number of addresses needed to issue around each airport to achieve the target number of responses (this can differ by airport - i.e. apply a different rate to Glasgow addresses).

Step 4: Take a stratified sample of addresses around each airport using the same stratification scheme as the higher exposure area sample: L_{night}, area-level socio-economic status, ambient noise level, and area-level estimates of the proportion of the population who are ethnic minority.

This simple approach ensures that the selected sample will be representative of the 35-47.9dB addresses in the target population and uses the information on more specific noise contours where available to stratify the sample and ensure that addresses across the 35-47.9dB band are included around each airport.

A key disadvantage of this approach is that addresses will be selected in proportion to the distribution of noise exposure around each airport in the 35-47.9dB band. There are likely to be more addresses exposed at the lower end of the 35-47.9dB range compared to the upper end of that range.

For instance, 62% of addresses around Heathrow in the 35-47.9dB band are exposed somewhere between 35-40.9dB. If we select a sample implicitly stratified by dB around Heathrow in the 35-47.9dB areas, then we would expect 62% of the responding sample around Heathrow to come from the 35-40.9dB band. This could present some challenges when trying to produce the part of the dose-response curve in areas of low exposure. There may be smaller than desired sample sizes in the relatively higher exposure areas within the 35-47.9dB band.

Alternative approach

A potential solution to this is to be very specific about target sample sizes per airport within each band.

For instance, we could try to allocate ideal target sample sizes by sub-band within the 35-47.9dB range. Table A4 illustrates ideal target sample sizes based on a total target sample size of 1456 in the low exposure areas using 2dB sub-bands in areas where some airports have data (totals may be slightly off due to rounding).

Table A4: Ideal target sample sizes by sub-band in low exposure areas

Sub-band	Ideal proportion of sample in each sub-band	Ideal target sample size by sub-band
46-47.9dB	25%	364
44-45.9dB	25%	364
42-43.9dB	25%	364
35-41.9dB	25%	364
Total	**100%**	**1456**

Totals may differ due to rounding.

Because of limits to data availability, we will almost certainly not be able to achieve these target sample sizes by sub-band. However, we could consider applying ideal proportions of samples by sub-band in airports where the data exists in order to guarantee larger sample sizes in the relatively higher exposure bands withing the 35-47.9dB range.

Since data is available at many airports at 45+dB, we could design the sample to ensure adequate sample sizes in sub-bands where data is available. For instance, at Heathrow data is available at 41+dB. We could apply the proportions from Table A4 to the target responding sample of 1059 from Heathrow outlined in Table A3 to aim to achieve the target sample sizes in Table A5.

Table A5: Target sample sizes at Heathrow: alternative approach

Sub-band	Ideal proportion of sample in each sub band	Ideal target sample size by sub-band
46-47.9dB	25%	265
44-45.9dB	25%	265
42-43.9dB	25%	265
35-41.9dB	25%	266
Total	**100%**	**1061**

Totals may differ due to rounding.

Table A5 illustrates what this would look like for Heathrow, but we propose to do this for all airports where there is available data at <48dB. It won’t be possible to apply this approach in airports where data is not available at <48dB (e.g. Bristol). Airports without data available will be sampled according to the approach outlined in the previous section.

The key advantage of this approach is that it would help ensure larger sample sizes at the relatively higher levels of exposure in the 35-47.9dB band and the approach takes full advantage of all available data. This approach is attractive, given that Heathrow has available data at lower exposure levels, and makes up a very large proportion of the low exposure sample frame.

Table A6 illustrates the expected sample size by noise band in the low exposure areas using this approach. Columns distinguish between the expected sample size from airports that have data down to each noise band, and airports without data. Calculations assume that the distribution of addresses by noise band in airports without specific noise exposure data follow a similar pattern to airports with more exposure contours (i.e. Heathrow, Stansted and Luton where data goes down to 41dB). This assumption may not be true for all airports without data, and so the estimates of sample size for airports without data should be interpreted with caution.

Table A6: Expected sample size by noise band

	Airports with data		**Airports without data**		
Noise band	***Expected* number of participants**	**Airports**	***Estimated* number of participants**	**Airports**	**Total estimated sample**
46-47.9dB	360	EMA, LGW, MAN, GLA, LHR, STN, LTN	2	BRS	362
44-45.9dB	309	GLA, LHR, STN, LTN	20	BRS, EMA, LGW, MAN	329
42-43.9dB	301	LHR, STN, LTN	28	BRS, EMA, LGW, MAN, GLA	329
35-41.9dB	0		439	BRS, EMA, LGW, MAN, GLA, LHR, STN	439
Total	**970**		**489**		**1459**

Totals may differ due to rounding.

Comparing Table A6 with the ideal sample sizes from Table A4, suggests that the approach is likely to come close to meeting ideal sample sizes in the 46-47.9dB band. However, it is likely to underachieve the sample in the 44-45.9dB and 42-43.9dB band and overachieve the ideal sample in the 45-41dB band.

The main disadvantage of this approach is that we are treating airports differently and would be more likely to achieve a more representative sample according to noise exposure in the airports with better noise data. The more specific we are about target sample sizes, and the less efficient the sample will be (i.e. higher design effects). For this survey, however, it can be argued that efficiency is a secondary concern and that achieving bigger sample sizes in the 42-48dB sub-bands is a priority.

Efficiency of the low exposure sample

To investigate potential design effects of the different low exposure sampling strategies, we calculated the design effects of the household level selection weights based on 4 different approaches. Design effects are a measure of the statistical efficiency of a sample. Technically, it is the ratio of the actual variance to the variance expected if we used simple random sampling. The more variable the selection probabilities are in our sampling strategy, the higher the design effect is likely to be. Higher numbers indicate a less efficient sample.

The four approaches considered were:

<u>Simple approach</u>: allocate the target sample in the low exposure areas in each airport based on the population distribution in the whole 35-47.9dB band.

Alternative approach: allocate the target sample in the low exposure areas in each airport based on the population distribution and apply ideal target sample sizes by sub-band within the 35-47.9dB range where data is available. Apply the simple approach where more specific exposure data is not available.

Hybrid approach 1: Apply the alternative approach to sub-band 46-47.9dB (where six airports have data available), apply the simple approach to airports without data availability AND to all airports in the 35-45.9dB range.

Hybrid approach 2: Apply the alternative approach to sub-band 46-47.9dB (where six airports have data available) AND sub-band 44-45.9dB (3 airports), apply the simple approach to airports without data availability AND to all airports in the 35-43.9dB range.

Table A7 presents the design effects for the *household level selection weights* based on each approach for the low exposure sample only (35-47.9dB). It's important to note these don't take into account any non-response or calibration adjustments that would likely be applied when survey weights are calculated.

Table A7: Design effects: Low exposure sample

Approach	**Design Effect**
Simple Approach	1.0
Alternative Approach	1.8
Hybrid Approach #1	1.1
Hybrid Approach #2	1.2

Table A8 illustrates expected achieved sample sizes in each noise band under each approach. Similar to Table A6, these calculations assume that the distribution of addresses by noise bands in airports without specific noise exposure data follow a similar pattern to airports with more exposure contours. Numbers may not match due to rounding.

Table A8: Estimated number of participants by noise band in the low exposure sample

Noise band	**Simple approach**	**Alternative approach**	**Hybrid approach 1**	**Hybrid approach 2**
46-47.9dB	130	360	360	360
44-45.9dB	153	326	126	326
42-43.9dB	191	326	158	126
35-41.9dB	982	445	812	645
Total	**1456**	**1457**	**1456**	**1457**

Totals may differ due to rounding.

The simple approach has the lowest design effect but cannot guarantee adequate sample sizes in sub bands within the 35-47.9dB range to contribute to the estimation of a dose-response curve. The alternative approach uses all available data on noise exposure to strive for ideal sample sizes by sub-band but sacrifices some statistical efficiency. The hybrid approaches represent more of a balance between achieving ideal sample sizes and statistical efficiency. We suggest Hybrid Approach 2 as the best compromise between ensuring adequate sample sizes to estimate a dose-response curve and statistical efficiency.

NatCen
Social Research that works for society

Annex B Sample design

Address-level sampling stratification scheme

The sampling strategy for the survey of night-time aviation noise will be a stratified systematic sample.

A stratification scheme has two main purposes:

1. Ensure a representative sample according to the stratifying variables
2. Improve the precision of survey data

The sample will be drawn from the postcode address file (PAF), which is a list of all known delivery points and postcodes in the UK. The target sample is all addresses around the selected airports exposed to greater than an estimated 35dB L_{night}. This sample frame does not have individual level information on the people living in each address, but using the location of the address, addresses can be linked to area level information from different sources such as noise exposure maps and the Census.

The choice of stratification variables is usually based on theoretical and empirical associations between the stratifying variables and survey outcomes of interest. A stratification scheme will aim to ensure that the sample is representative according to the chosen variables. If the chosen stratifiers are correlated with the outcome of interest, they will also improve the precision of the survey data. NatCen's experience of working on many large surveys suggests that most surveys use 3 or 4 variables to stratify PAF samples. The order of the stratification variables is important. The sample will be most representative of the first variable in the stratification order, followed by the others (in order). More than 3 or 4 variables can be chosen, however, NatCen's experience of sampling indicates that it is difficult to achieve representativeness according to the 4th, 5th or 6th stratifier in a sample of this size. Therefore, stratifiers will need to be prioritized in order of importance.

After discussions with stakeholders and the steering group, we decided that the most important stratifiers (in order) for this survey are:

1. Noise exposure
2. Airport
3. Area-level socio-economic status
4. Ambient noise level
5. Area-level estimates of the proportion of the population who are ethnic minority

In practice this means that the sample frame will be sorted according to these variables before a systematic selection (i.e. every kth address) will be selected. This means instead of choosing addresses at random within each stratum, it is selected at fixed intervals to cover the entire range of the stratum. This avoids clustering which could occur if selection were completely randomised.

Noise exposure

The noise exposure metric chosen for this study is a measure of L_{night} which has been adjusted by the CAA to better reflect 2022 exposure. Typically, this measure is modelled/estimated down to 42-45dB depending on airport. Noise Consultants Ltd have been able to obtain flight track data from airports to estimate exposure at lower levels (down to an estimated 35dB). All addresses in the sample frame will be categorised in 2dB or 3dB bands according to their estimated measure of L_{night}, which will form the key strata for the sampling strategy. These strata will be sampled separately to ensure adequate sample sizes in each noise band (see the following section on 'Distribution of sample by noise exposure band'). Within each strata, addresses will be implicitly stratified by measure of L_{night} to ensure that addresses are representative of noise exposure within the noise strata. For instance, in the 48-49.9dB L_{night} noise strata, addresses will be sorted by L_{night} before a systematic stratified sample is taken. This will ensure that addresses at the lower, middle and upper parts of the 48-49.9dB range are selected to participate in the study.

Airport

The second stratifier will be airport to ensure good representation of participants from all the airports in the study. Using airport as the second stratifier will ensure that the proportion of addresses around each airport in the target population will be reflected in the selected sample of addresses.

Area-level socio-economic status

The third stratifier uses the proportion of households in the 2011 Census with a Household Reference Person (HRP) who works in a non-manual occupation (Socio-Economic Groups 1-6, 13[1]) at the lower super output area (LSOA) level as an indicator of area-level socio-economic status. We examined a number of potential indicators of area-level socioeconomic status in a stratification review using SoNa 2014 data. The proportion of households with an HRP who works in a non-manual occupation emerged as the indicator which offered the greatest gain in precision and is consistently available across both England and Scotland. We discussed using the Index of Multiple Deprivation (IMD), which is a more recent indicator (2019) and offered the second highest gain in precision in the stratification review. Ultimately however, IMD is calculated differently across England and Scotland, and we chose a measure that is consistently collected across both countries and commonly used in other UK surveys.

Ambient noise level

The fourth stratifier will be Ambient noise level (High, Medium, Low), specifically indicative night-time noise levels (L_{night}) on roads and rail. This measure was developed using Defra strategic noise mapping data from 2016, produced under the Environmental Noise Directive.

Ambient noise data in Scotland was not available at the time of sampling. Without an ambient noise level stratifier, the sample design cannot ensure that the selected sample of

[1] These include: Higher managerial, administrative and professional occupations, Lower managerial, administrative and professional occupations, Intermediate occupations, Small employers and own account workers, Lower supervisory and technical occupations, and Semi-routine occupations. Occupations excluded from this measure are routine occupations and never worked and long term unemployed.

addresses to issue around Glasgow airport within each noise band will be representative in terms of ambient noise exposure.

Area-level estimates of the proportion of the population who are ethnic minority

Finally, to ensure that addresses in areas with different concentrations of ethnic minority residents are included in the sample, the final stratifier will be the proportion of residents from ethnic minority backgrounds. A key challenge in many social surveys is ensuring participants from different backgrounds participate and it theoretically will be important to represent residents from ethnic minority backgrounds in this survey. Unfortunately address-level information about which addresses have ethnic minority residents is not available on the PAF sample frame. We do know, however, that there are some areas around the selected airports that have a high concentration of ethnic minority residents. Including the proportion of ethnic minority residents as a stratifying variable will ensure that addresses will be selected from areas across the range of ethnic minority concentrations. However, this approach cannot guarantee good representation of ethnic minority participants in the responding sample. Ethnic minority residents tend to have lower response rates to household surveys, and there is no direct cost-effective way of oversampling ethnic minority residents in surveys using a PAF sample. This approach, however, does ensure that areas including a range of different ethnic population distributions are invited to participate in the survey.

As proportion of ethnic minority residents is the final stratifier, it will be used as a continuous variable (the measure can theoretically range from 0-100%). The data will be sorted according to noise exposure band, airport, proportion of households in the 2011 Census with a Household Reference Person (HRP) who works in a non-manual occupation, ambient noise level and finally proportion of ethnic minority residents in the LSOA of the postcode before a systematic sample is chosen. After selecting the sample, we will investigate how representative addresses are according to population tertiles of ethnic minority residents at the LSOA level.

Distribution of sample by noise exposure band

The main analysis priority of this survey is to provide information for constructing a national exposure-response curve quantifying the relationship between aviation noise exposure and being highly annoyed and highly sleep disturbed. Power calculations using regression estimates from prior studies indicate the greatest uncertainty around annoyance and sleep disturbance estimates is located in the middle of the range of noise exposures in the target population for this survey. This would suggest that it would be useful to concentrate more sample in these middle range noise exposure bands to improve the precision of estimates of annoyance and sleep disturbance.

However, policy decisions are often made around the extremes (both high and low) of the noise exposure bands included in the target population. This suggests that more sample should be concentrated at the extremes in order to improve the precision around those estimates of annoyance and sleep disturbance, and to be able to assess where onset thresholds for effects are, which was an issue with the Survey of Noise Attitudes (SoNA 2014).

Therefore, in order to balance these competing priorities, we propose to distribute the sample evenly across noise bands in our target population. This means we will aim to achieve an equal number of participants per noise band. Noise bands with fewer overall addresses in the target population will therefore be oversampled (e.g. areas with very high exposure) and each address in these areas will have a higher probability of selection, and noise bands with more addresses in the target population will be undersampled (e.g. areas with very low exposure) and each address in these areas will have a lower probability of selection. This approach ensures the sample is representative of the target population within each noise band according to the stratifying variables.

Minimum sample sizes per airport

A final issue to resolve regarding the sample is whether to include minimum sample sizes by airport. Unlike previous surveys, the sampling strategy for this survey does not currently specify sample sizes per airport. Rather its focus is on obtaining a representative sample of the population exposed at different levels of night-time noise exposure. Airports will therefore be represented in proportion to the target population in each noise band. For instance, if 35% of addresses exposed to night-time noise in the 54-57dB L_{night} band in the target population are around Manchester airport then we would expect a similar proportion of sampled addresses in the 54-57dB L_{night} band to be located around Manchester airport.

We may, however, want to consider imposing a minimum sample size per airport for a few reasons:

- We are relying on airports to 'donate' flight track data so that Noise Consultants can produce estimates of exposure at lower levels. We may want to ensure that their efforts are 'rewarded' with a minimum sample size per airport.
- This survey will also be analysed using public funds. We want to seek to ensure a minimum sample from each airport to maximise the use of the data that is provided / ensure we have some level of representation at all 8 airports.
- A key critique of SoNA 2014 from those that analysed the data was the tiny sample sizes at some airports. A minimum sample size per airport would ensure that this survey is not critiqued in the same way.
- While possible, it is typically inadvisable to analyse cell sizes of less than 30 in formal statistical tests. This rule of thumb is often used because of the Central Limit Theorem (CLT) which states that sample means from samples of at least 30 approach a normal distribution, making statistical inference more reliable (such as hypothesis testing or confidence intervals). It is important to note that even if a minimum sample size per airport is introduced there may still be extremely small sample sizes by airport within noise band strata.

From a statistical standpoint, there are some concerns that can't be resolved simply by ensuring a minimum sample size of 30 per airport, such as:

- Oversampling of some airports leading to more variability in the probabilities of selection, and a less efficient sample (i.e. a higher design effect).
- The sample in each noise band being less representative relative to the other stratifiers.
- The survey still not being large enough to detect airport level differences in annoyance or sleep disturbance for every airport. We have clarified with stakeholders that this is not a key aim of this particular survey.

On balance, we therefore propose to impose a minimum sample size of 30 responding addresses per airport. Although this reduces the efficiency of the sample as stated above, adjustment techniques, like weighting and variance estimation methods can be used to correct for some of these effects and ensure valid conclusions.

NatCen
Social Research that works for society

Annex C Sample design: target sample sizes and completion rates

Target sample sizes

The main analysis priority of this survey is to provide information for constructing a national exposure-response curve quantifying the relationship between aviation noise exposure and being highly annoyed and highly sleep disturbed. Power calculations using regression estimates from prior studies indicate the greatest uncertainty around annoyance and sleep disturbance estimates is located in the middle of the range of noise exposures in the target population for this survey. This would suggest that it would be useful to concentrate more sample in these middle range noise exposure bands to improve the precision of estimates of annoyance and sleep disturbance.

However, policy decisions are often made around the extremes (both high and low) of the noise exposure bands included in the target population. This suggests that more sample should be concentrated at the extremes in order to improve the precision around those estimates of annoyance and sleep disturbance, and to be able to assess where onset thresholds for effects are, which was an issue with the Survey of Noise Attitudes (SoNA 2014).

Therefore, in order to balance these competing priorities, we propose to distribute the sample evenly across noise bands in our target population. This means we will aim to achieve an equal number of participants per noise band. Noise bands with fewer overall addresses in the target population will therefore be oversampled (e.g. areas with very high exposure) and each address in these areas will have a higher probability of selection, and noise bands with more addresses in the target population will be undersampled (e.g. areas with very low exposure) and each address in these areas will have a lower probability of selection. This approach ensures the sample is representative of the target population within each noise band according to the stratifying variables.

Size of sampling band

Previous surveys such as SoNA 2014 have typically used 3dB bands in sampling. We propose to use 2dB bands in the survey of night-time aviation noise in order to generate a responding sample that will be more appropriate for estimating a dose-response curve. The 2dB banding also better accounts for uncertainty that exists in the noise estimation, where uncertainty can be + or – 1dB on any estimate, which means that a 3dB band covers a range of exposures. Using 2dB bands offers greater precision as this uncertainty is reduced in terms of using specific threshold levels to set policy. We examined the impact on statistical efficiency of using 2dB bands instead of 3dB bands and found there was no impact on the design effects of the survey.

Table C1 indicates the proposed target sample sizes per 2dB band. These calculations assume we will achieve 1.4 responses per responding household. The table also assumes that 5% of the returned sample will be excluded through NatCen's quality control process.

Table C1: Ideal target sample sizes by noise band

Exposure area	dB Band	Target number of participants	Target number of responding addresses	Target number of responding addresses accounting for 5% falsifications
Higher exposure areas >48dB (data available for all airports)	60+dB	364	260	274
	58-59.9dB	364	260	274
	56-57.9dB	364	260	274
	54-55.9dB	364	260	274
	52-53.9dB	364	260	274
	50-51.9dB	364	260	274
	48-49.9dB	364	260	274
Lower exposure areas <48dB (data goes down to different noise contours in different airports)	46-47.9dB	364	260	274
	44-45.9dB	364	260	274
	42-43.9dB	364	260	274
	35-41.9dB	364	260	274
Total	Total	4004	2860	3014

Totals may vary due to rounding.

The allocation to the lower exposure areas is based on **ideal** targets of 364 participants each in sub-bands of 35-41.9dB, 42-43.9dB, 44-45.9dB, and 46-47.9dB. Because exposure data is not available at such low levels at all airports, the sampling strategy cannot guarantee these targets will be met. The 'Annex A Sample design: areas of low night noise exposure' note[2] outlines some of the potential approaches to meet these ideal targets.

Minimum sample sizes by airport

Based on the allocation of the target sample in Table C1 and the population distribution of residential addresses in the sample frame, Table C2 outlines the expected number of responses per airport.

[2] Annex A Sample Design - Areas of low night noise exposure

Table C2: Expected number of participants by airport

L_{night} dB band	BRS	EMA	GLA	LHR	LGW	MAN	STD	LTN	Total
60+dB	3	17	0	236	6	99	4	0	365
58-59.9dB	6	2	0	235	4	114	3	0	364
56-57.9dB	3	5	15	172	6	157	5	1	364
54-55.9dB	4	6	20	219	6	96	8	7	366
52-53.9dB	2	4	33	216	10	90	7	2	364
50-51.9dB	4	14	37	176	9	113	6	5	364
48-49.9dB	4	8	31	235	7	69	7	4	365
35-47.9dB	22	62	30	1060	33	109	49	93	1458
Total	**48**	**118**	**166**	**2549**	**81**	**847**	**89**	**112**	**4010**
Proportion of sample	**1%**	**3%**	**4%**	**64%**	**2%**	**21%**	**2%**	**3%**	**100%**

We expect the fewest responses around Bristol airport, where we still expect to achieve around 48 participants. Therefore, it does not appear that we will need to alter the sampling strategy to ensure a minimum sample size by airport. Even with a large margin of error, we still expect to achieve at least 30 responses in each airport.

Completion rates

In order to decide how many addresses to sample in each area to achieve the target number of responses, we need to decide on an expected completion rate. The completion rate is the proportion of the sampled addresses that complete the survey.

Completion rates are made up of two components:

Ineligibility rate: the proportion of sampled addresses that are ineligible to complete the survey (because they do not contain an occupied private household).

Response rate: the proportion of eligible addresses that complete the survey.

When estimating the proportion of ineligible addresses on a push-to-web survey, it is best practice to assume the same ineligibility rate as a recent face-to-face survey which uses the same sample frame and sampling approach, and for which detailed outcomes are known for the entire issued sample. Ineligibility rates in postcode address file (PAF) face-to-face surveys tend to fall between 8% and 10% and 9% is the rate recorded in the most recent face-to-face British Social Attitudes Survey (2019) and has been used as an appropriate default for this survey.

SoNA 2014 reported 5% of addresses were known to be ineligible. SoNA interviewers were unable to make contact with a further 12% of addresses, some of which were likely also ineligible. Ineligibility rates varied slightly by airport but were all within the 2%-7% range. Rates of non-contact varied more widely by airport ranging from 3%-34%. SoNA 2014 had very small issued sample sizes around some airports so these results should be interpreted with caution.

Response rates on push-to-web surveys can vary considerably based on the topic of the survey. Based on NatCen's experience of running push-to-web survey's our initial estimate of the response rate for the ANNE study was 22%.

An ineligibility rate of 9% and a response rate of 22% gives an overall completion rate of 20%, that is we expect 20% of issued addresses to complete the survey.

We ran a pilot survey to test these assumptions (see Aviation Night Noise Effects Pilot Study report for details). The pilot survey issued 2,200 addresses across different levels of night-time aviation noise exposure at 4 different airports: Heathrow, Manchester, Glasgow and East Midlands. Areas of high noise exposure (>54 dB L_{night}) were oversampled around Heathrow and Manchester.

Overall, 445 addresses responded to the survey for an overall completion rate of 445/2200=20%, suggesting that our assumptions on ineligibility and response are reasonable. However, results from the pilot indicated differences in completion rates by airport and noise level.

Table C3 illustrates the achieved completion rates by L_{night} noise band from the pilot survey.

Table C3: Pilot completion rates

	45 – 47.9dB	**48 – 50.9dB**	**51 – 53.9dB**	**54 – 56.9dB**	**57 +dB**	**Total**
East Midlands	25%	32%	17%	*29%*	*21%*	26%
Glasgow	14%	18%	8%	-	-	15%
Heathrow	17%	17%	24%	22%	9%	18%
Manchester	16%	23%	30%	29%	33%	22%
Total	17%	23%	21%	26%	19%	20%

Note: *Percentages in italics are based on very small sample sizes (denominators <30) and should be interpreted with care.*

Table C3 indicates that the pilot achieved lower completion rates across the Glasgow addresses compared to the other airports. Completion rates also appear lower in the areas of very high noise exposure around Heathrow airport, and in the areas of relatively low night-time noise exposure around all airports (45-47.9dB).

These results fit with NatCen's experience of sampling on many national surveys in the UK. There are often regional differences in completion and response rates. London typically has the lowest completion rates in England, while Glasgow typically has the lowest completion rates in Scotland[3].

The relatively low completion rates in the highest noise areas may be the result of a higher ineligibility rate in those areas, as residential properties experiencing high levels of noise

[3] For instance, in the 2020 technical report of the British Social Attitudes survey (which was conducted as a push-to-web survey), London had low completion rates compared to the rest of the UK. bsa37_technical-details.pdf (natcen.ac.uk)
The 2019 Scottish Health Survey found that household response rates in Glasgow were the lowest among all local authorities in Scotland. 6 Survey Response - Scottish Household Survey 2019: methodology and fieldwork outcomes - gov.scot (www.gov.scot)

exposure may be more likely to be vacant. Residents in lower noise areas may be less engaged with the survey topic and therefore less likely to respond to the survey.

Regardless of the reasons behind differences in completion rates, given the priorities of this survey, we suggest using different completion rates to calculate the number of addresses to issue to achieve the target number of responses by airport and noise band.

We suggest using lower estimates of completion rates for Glasgow. Glasgow is the only Scottish airport represented in the survey, and it is important to ensure that Scotland is represented adequately in the survey.

We also suggest using lower completion rates in areas experiencing high levels of night-time noise exposure (>57dB Lnight). These areas may have higher levels of ineligibility.

Finally, we suggest using a slightly lower completion rate for areas exposed to a low level of night-time aviation noise based on results of the Pilot Study.

We do not suggest using different completion rates for London airports compared to the rest of England. Rather, we propose to use a slightly lower completion rate for all (non-Glasgow) airports. This will allow us to ensure that target numbers are achieved.

Four airports were not represented in the Pilot Study: Stansted, Luton, Gatwick and Bristol. It is reasonable to assume that completion rates in Stansted, Luton, and Gatwick will be similar to pilot results from Heathrow. While not a perfect comparison because of the different mode of administration (face-to-face versus push-to-web), SoNA 2014 achieved very similar completion rates for Heathrow (55%), Gatwick (55%), Luton (54%) and Stansted (50%)

There is a chance that completion rates may be different in Bristol, compared to the other airports sampled in the pilot. Given that completion rates on most surveys tend to be lower in London compared to the rest of England, we would expect the completion rate in Bristol to be higher than the completion rates achieved in the pilot at Heathrow.

Using the same completion rates in all the non-Glasgow airports may lead to a slight overachievement of the samples in Bristol, Manchester and East Midlands compared to the London airports. A key criticism of SoNA 2014, was the focus of the sample in London. Aiming to slightly overachieve the samples in the non-London airports is a way to guard against this survey facing a similar criticism.

Table C4 illustrates some proposed completion rates to use in calculating the numbers of addresses we need to issue to achieve the target number of responses.

Table C4: Proposed completion rates

Exposure area	dB Band	Completion rate (LHR, LGW, STN, LTN, MAN, EMA, BRS)	Completion rate (GLA)
Higher exposure areas >48dB (data available for all airports)	60+dB	15%[4]	-
	58-59.9dB	15%[2]	-
	56-57.9dB	19%[5]	14.5%[6]
	54-55.9dB	23.3%[7]	16.1%[6]
	52-53.9dB	23.3%[5]	16.1%[6]
	50-51.9dB	23.3%[5]	16.1%[6]
	48-49.9dB	23.3%[5]	16.1%[8]
Lower exposure areas <48dB (data goes down to different noise contours in different airports)	35-47.9dB	19%[9]	14.0%[10]

Number of addresses to issue

In order to accommodate a sample design which aims to achieve a certain number of responses by noise band in the high exposure areas, different data availability in the low exposure areas, and the flexibility to assign different completion rates by airport and noise band, the sample frame of addresses will be divided into sampling strata based on noise band and airport. Each strata will be sampled separately. Addresses in each sampling strata will be sorted by the stratification variables (described in the 'Annex B Sample design: stratification scheme, distribution and minimum sample sizes' note[11]) and selected systematically.

Table C5 calculates the total number of addresses to issue in each sampling strata based on the target number of responding addresses accounting for falsifications and completion rates.

Notes: This particular table is based on hybrid approach 2 of the low exposure sampling strategy (see the 'Annex A Sample design: areas of low night noise exposure' note[12]). The target number of responding addresses is based on an assumption of 1.4 participants per responding address. The target number of total responding addresses in Table C5 (3015) is slightly different to Table C1 (3014) due to rounding.

---

[4] This completion rate is slightly lower than the non-GLA average in the pilot in high exposure areas to account for the lower completion rates around London airports.
[5] This is the average completion rate from the pilot for non-GLA airports 57dB+
[6] This completion rate is slightly lower than the GLA average in the pilot to account for more ineligible properties in high exposure areas
[7] This is the lowest completion rate from the pilot across all non-GLA areas in the 48-56.9dB areas
[8] From the pilot GLA 48dB+ average completion rate
[9] From the pilot average across all non-GLA airports
[10] This is the GLA estimate from the pilot
[11] Annex B Sample Design - Stratification scheme, distribution and minimum sample sizes
[12] Annex A Sample Design - Areas of low night noise exposure

Table C5: Example numbers of addresses to issue in each sampling strata

Strata	Airport	Noise band	Target number of responding addresses	Completion rate	Number of addresses to select
1	Bristol, East Midlands, Heathrow, Gatwick, Stansted, Manchester, Luton	60+dB	274	15.1%	1814
2	Bristol, East Midlands, Heathrow, Gatwick, Stansted, Manchester, Luton	58-59.9dB	274	15.1%	1814
3	Bristol, East Midlands, Heathrow, Gatwick, Stansted, Manchester, Luton	56-57.9dB	263	19.0%	1386
4	Bristol, East Midlands, Heathrow, Gatwick, Stansted, Manchester, Luton	54-55.9dB	259	23.3%	1112
5	Bristol, East Midlands, Heathrow, Gatwick, Stansted, Manchester, Luton	52-53.9dB	249	23.3%	1069
6	Bristol, East Midlands, Heathrow, Gatwick, Stansted, Manchester, Luton	50-51.9dB	246	23.3%	1056
7	Bristol, East Midlands, Heathrow, Gatwick, Stansted, Manchester, Luton	48-49.9dB	251	23.3%	1077
8	Glasgow	60+dB	0	n/a	0
9	Glasgow	58-59.9dB	0	n/a	0
10	Glasgow	56-57.9dB	11	14.5%	76
11	Glasgow	54-55.9dB	15	16.1%	93
12	Glasgow	52-53.9dB	25	16.1%	155
13	Glasgow	50-51.9dB	28	16.1%	174
14	Glasgow	48-49.9dB	23	16.1%	143
15	Bristol	35-47.9dB	17	19.0%	89
16	East Midlands	46-47.9dB	12	19.0%	63
17	East Midlands	35-45.9dB	34	19.0%	179

18	Glasgow	46-47.9dB	6	14.0%	43
19	Glasgow	44-45.9dB	6	14.0%	43
20	Glasgow	35-43.9dB	10	14.0%	72
21	Heathrow	46-47.9dB	199	19.0%	1046
22	Heathrow	44-45.9dB	199	19.0%	1046
23	Heathrow	35-43.9dB	399	19.0%	2098
24	Gatwick	46-47.9dB	6	19.0%	32
25	Gatwick	35-45.9dB	19	19.0%	100
26	Manchester	46-47.9dB	20	19.0%	105
27	Manchester	35-45.9dB	62	19.0%	326
28	Stansted	46-47.9dB	9	19.0%	47
29	Stansted	44-45.9dB	9	19.0%	47
30	Stansted	35-43.9dB	19	19.0%	100
31	Luton	46-47.9dB	18	19.0%	95
32	Luton	44-45.9dB	18	19.0%	95
33	Luton	35-43.9dB	34	19.0%	179
	Total		**3014**		**15774**

Totals may vary due to rounding.

Annex D - Noise Data for the ANNE Subjective Study

1.1 Introduction

This annex describes the use of and generation of noise metrics as part of the subjective study.

The noise data used in this study has been split into two parts:

1. Data used to support sampling; and
2. Data generated to support the subjective study.

This differentiation reflects information available at different points in the study.

Noise Data during Sampling

As described in Section 2.1 of the Report, a two-stage approach to the sampling framework has been adopted for the subjective Study.

Stage 1 of the sampling framework involved the purposive sampling of the airports, with Stage 2 involving the identification of populations and addresses around the sampled airports to invite into the subjective study.

Stage 1 of the sampling was carried out in the first quarter of 2022. To support the purposive sampling a review was carried out to help characterise the noise situation at the UK's airports. This is set out in **Annex A**.

The selected airports for the study were determined as:

- Bristol Airport (BRS)
- East Midlands Airport (EMA)
- Glasgow Airport (GLA)
- London Gatwick Airport* (LGW)
- London Heathrow Airport* (LHR)
- London Stansted Airport* (STN)
- London Luton Airport (LTN)
- Manchester Airport (MAN)

* Noise designated airports[13]

[13] An airport 'designated' for noise regulation by the government. A designated airport has government restrictions which run alongside those governed by local planning authorities through the planning process. London Heathrow, London Gatwick, and London Stansted are designated airports.

With the airports selected, **Stage 2** commenced by gathering datasets to support the identification of populations and addresses exposed to various levels of night-time aircraft noise exposure. This information was needed to assist in enrolling participants to the subjective study.

Stage 2 was carried out in summer 2022. At this time, UK airports had begun to recover from disruption resulting from the COVID-19 pandemic. At this time there was no noise exposure data available for 2022 for each of the selected airports.

At the start of Stage 2, data sharing agreements were entered into with each of the selected airports. The data sharing agreements requested information that would allow the location and type of aircraft operations from 21.00 to 08.00 within the first 6 months of 2022 to be identified. This was received in the form of radar datasets. This is discussed further in Section 2 with respect to the generation of noise exposure data for the subjective study.

Based on the review, the only consistent source of noise exposure data available across all selected airports was information produced for the 'third round' noise maps and noise action plans under the Environmental Noise Regulations[14] (as they apply to England, Scotland, Wales and Northern Ireland). This data is representative of the noise situation at each airport in 2016 with night-time noise exposure described using the L_{night} metric.

Through the data sharing agreements and through engagement with the Department for Environment, Food and Rural Affairs (Defra), and the environmental division of the Scottish Government, noise result grid datasets for the 2016 L_{night} metric for each sampled airport were obtained. These datasets provided noise exposure levels for the annual average 2016 L_{night} metric on 10 metre postings around each airport.

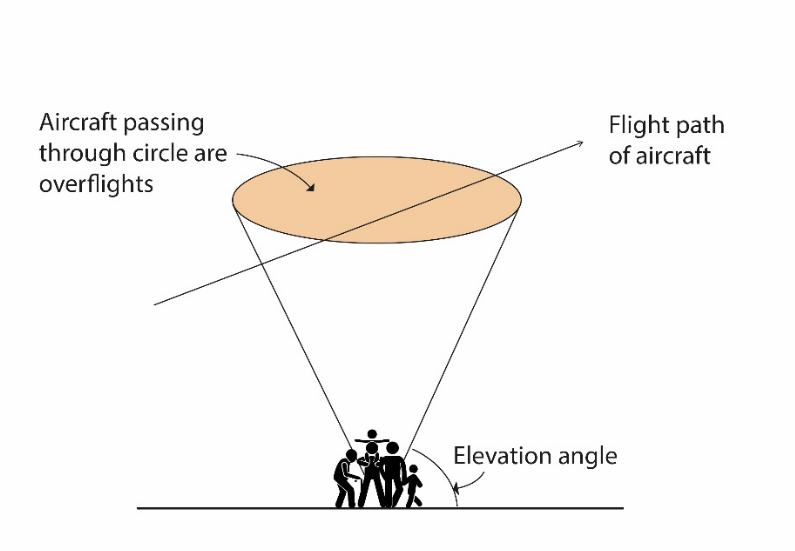
Working with the Environmental Research and Consultancy Department (ERCD) of the Civil Aviation Authority (CAA) and the Department for Transport, estimated summer 2022 night-time noise exposure datasets in terms of the $L_{Aeq,8h}$ metric were produced from this data. This process was carried out by ERCD by applying logarithmic corrections taking into account the annual average number of night-time aircraft movements at each airport in 2016 and the expected number of night-time movements at each airport in the summer 2022 season.

Based on these adjustments, the lowest noise exposure values available consistently across all sampled airports was found to be 48dB $L_{Aeq,8h}$. As the subjective study requires consideration of airport noise exposure from 35dB $L_{Aeq,8h}$ and above, the indicative 2022 $L_{Aeq,8h}$ data was then supplemented by overflight data which was used to help estimate the location of possible 'low noise' areas - i.e., areas potentially above 35dB $L_{Aeq,8h}$ but below 48dB $L_{Aeq,8h}$.

To estimate the 'low noise' areas, overflight contours were produced for all nights of the first 6 months of 2022 to identify where on average at least 1 overflight of an aircraft occurred at or below 7,000 feet above ground level. Figure D1 presents an illustration of the overflight metric. For the purposes of sampling and the estimation of 'low noise' areas, an elevation angle of 48.5 degrees has been used. Further information regarding the overflight metric can be found in Section 2.1.8 of this Annex.

[14] As transposed from European Commission Directive 2002/49/EC

Figure D1: Overflight Definition



With the areas of overflight identified, to further estimate the 'low noise' areas above 35 dB $L_{Aeq,8hr}$ the number of aircraft events at different Sound Exposure Levels (SEL)[15] were then considered to help further refine the 'low noise' areas based on the average number of night-time overflights between 23.00 and 07.00 local time in the first 6 months of 2022. This is illustrated in Table D1.

Table D2: Illustrative Night-time Noise Exposure Levels ($L_{Aeq,8hr}$) based on average aircraft Sound Exposure Levels (SEL) and average number of movements.

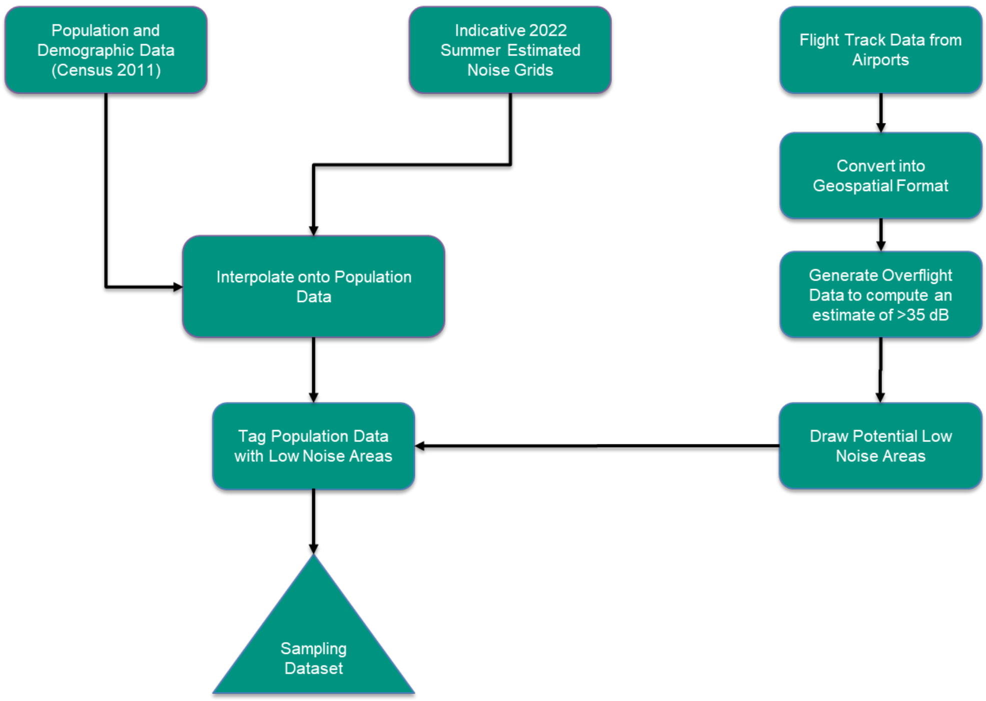
Average Number of Night-time Movements	Average Aircraft SEL						
	60 dB	65 dB	70 dB	75 dB	80 dB	85 dB	90 dB
1	15.4	20.4	25.4	30.4	35.4	40.4	45.4
2	18.4	23.4	28.4	33.4	38.4	43.4	48.4
3	20.2	25.2	30.2	35.2	40.2	45.2	50.2
4	21.4	26.4	31.4	36.4	41.4	46.4	51.4
5	22.4	27.4	32.4	37.4	42.4	47.4	52.4
6	23.2	28.2	33.2	38.2	43.2	48.2	53.2
7	23.9	28.9	33.9	38.9	43.9	48.9	53.9
8	24.4	29.4	34.4	39.4	44.4	49.4	54.4

[15] Sound Exposure Level (SEL) is the total sound energy above an established threshold for a single event considering both intensity and length of the event all compressed into 1 second. The SEL of any noise event is the entire event's total energy expressed in a reference period time as though it had occurred within one second.

Taking into account the illustrations in Table D1, and that in general aircraft departure events result in higher levels of aircraft noise than arrivals at similar altitudes, the ‘low noise’ areas were estimated based on locations of at least four arrival overflights on average per night, and at least 1 departure overflight on average per night.

Using a full postcode[16] level demographic dataset prepared using data from the 2011 Census, indicative 2022 summer $L_{Aeq,8h}$ exposure values were assigned to each postcode point and/or whether the postcode fell within the ‘low noise’ area. This process is summarised in Figure D2.

Figure D2: Process of creating the dataset for sampling



The areas used for sampling for the subjective study based on the process and datasets described above are presented in the following noise contour figures for each airport in the study.

- **Figure D3:** Bristol Airport (BRS)
- **Figure D4:** East Midlands Airport (EMA)
- **Figure D5:** Glasgow Airport (GLA)
- **Figure D6:** London Gatwick Airport (LGW)
- **Figure D7:** London Heathrow Airport (LHR)
- **Figure D8:** London Stansted Airport (STN)
- **Figure D9:** London Luton Airport (LTN)
- **Figure D10:** Manchester Airport (MAN)

[16] A full postcode (also known as a ‘postcode unit’) centroid provides a geographic reference point for an address or group of addresses e.g. (SE11 5SS).

Legend

Figure D3: Bristol Airport (BRS)

Indicative Low Noise Area

2022 BRS Estimated 92 Day Summer Night Average Noise Contour

48 dB | 51 dB | 54 dB | 57 dB | 60 dB | 63 dB | 66 dB | 69 dB

1 2 3 4 5 km

$L_{Aeq,8hr}$ Air Noise Contours

Drawn Date 2024-06-27

Project Ref: 13212A

Legend

Figure D4: East Midlands Airport (EMA)

Indicative Low Noise Area

2022 EMA Estimated 92 Day Summer Night Average Noise Contour

48 dB | 51 dB | 54 dB | 57 dB | 60 dB | 63 dB | 66 dB | 69 dB

0 1 2 3 4 5 km

$L_{Aeq,8hr}$ Air Noise Contours

Drawn Date

2024-06-27

Project Ref: 13212A

Noise CONSULTANTS

St George's University of London

Department for Transport

Legend

Figure D5: Glasgow Airport (GLA)

Indicative Low Noise Area

2022 GLA Estimated 92 Day Summer Night Average Noise Contour

48 dB | 51 dB | 54 dB | 57 dB | 60 dB | 63 dB | 66 dB | 69 dB

0 1 2 3 4 5 km

$L_{Aeq,8hr}$ Air Noise Contours

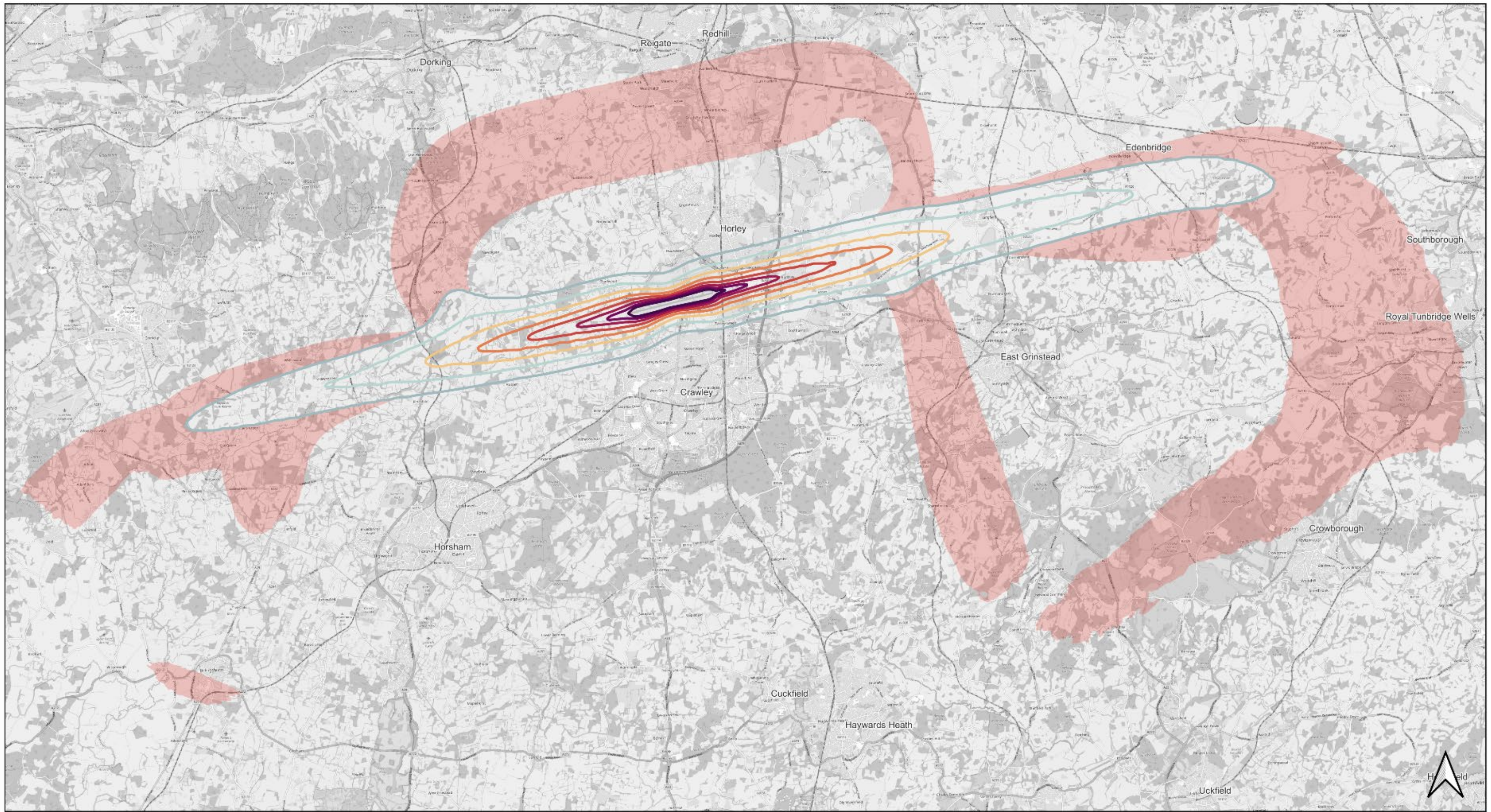
Drawn Date

2024-06-27

Project Ref: 13212A

St George's University of London

Department for Transport



Legend

Figure D6: London Gatwick Airport* (LGW)

Indicative Low Noise Area

2022 LGW Estimated 92 Day Summer Night Average Noise Contour

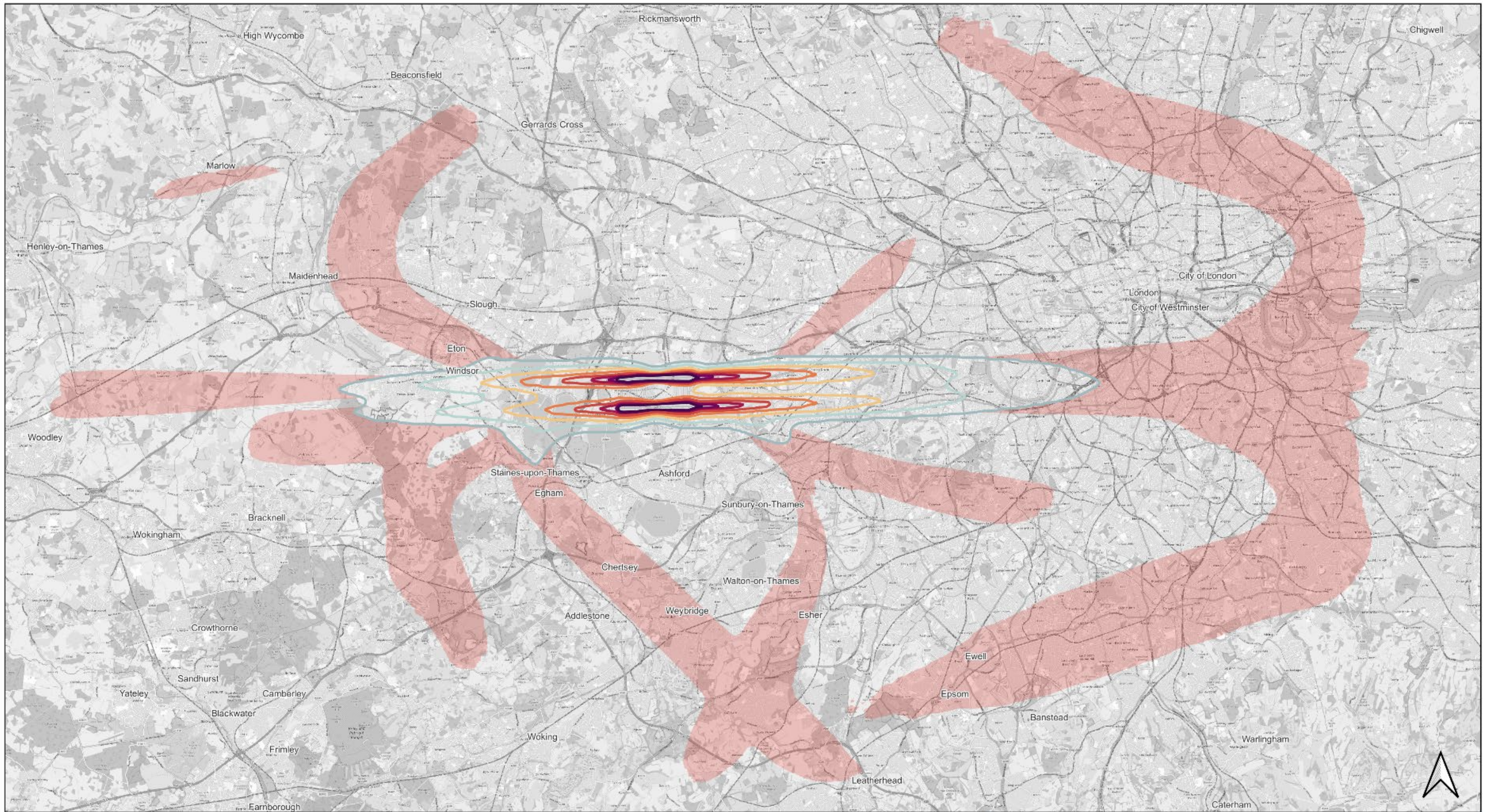
48 dB | 51 dB | 54 dB | 57 dB | 60 dB | 63 dB | 66 dB | 69 dB

0 1 2 3 4 5 km

$L_{Aeq,8hr}$ Air Noise Contours

Drawn Date 2024-06-27

Project Ref: 13212A



Legend

Figure D7: London Heathrow Airport* (LHR)

Indicative Low Noise Area

2022 LHR Estimated 92 Day Summer Night Average Noise Contour

48 dB | 51 dB | 54 dB | 57 dB | 60 dB | 63 dB | 66 dB | 69 dB

0 1 2 3 4 5 km

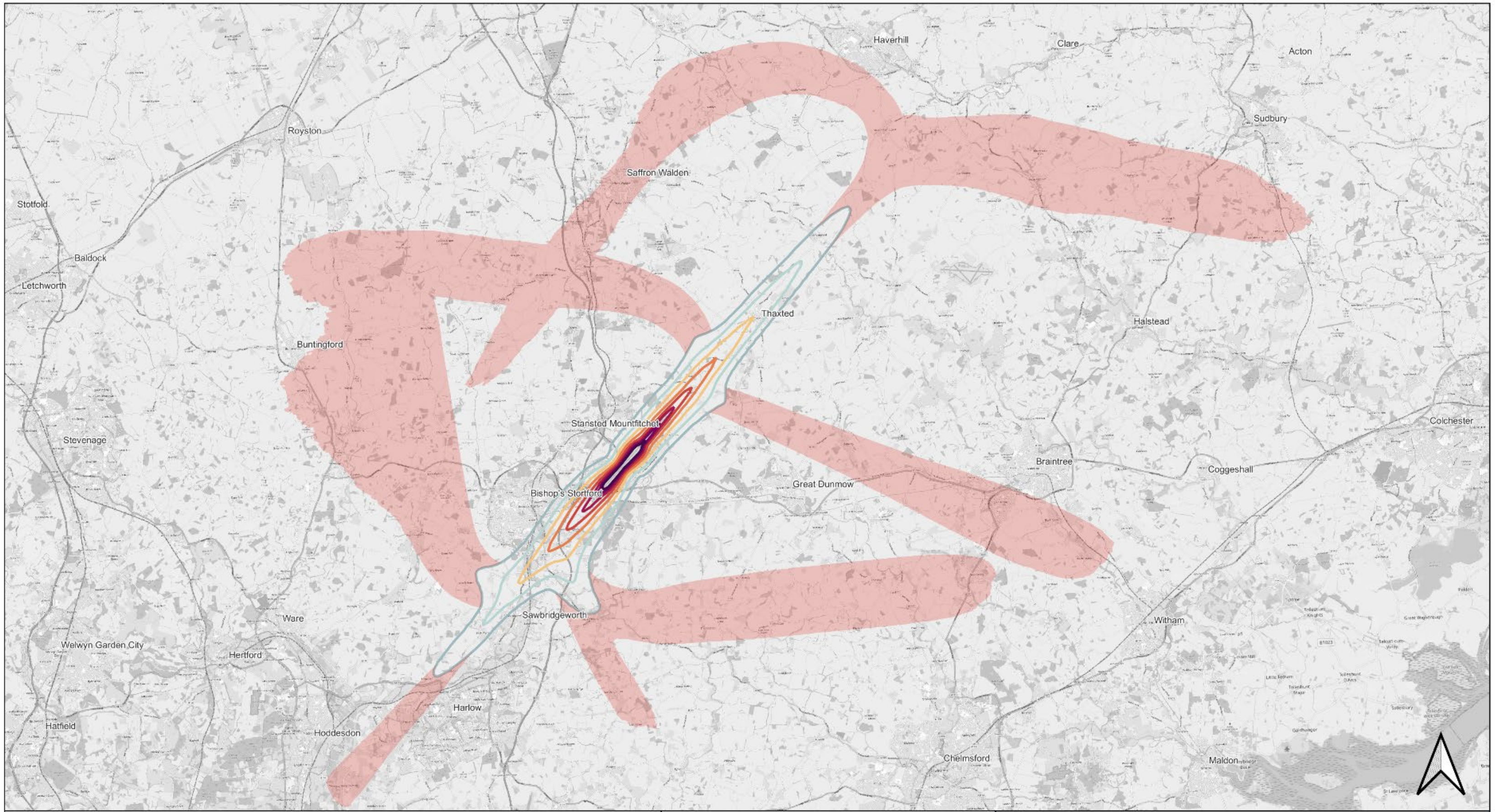
$L_{Aeq,8hr}$ Air Noise Contours

Drawn Date
2024-06-27
Project Ref: 13212A

Noise CONSULTANTS

St George's University of London

Department for Transport



Legend

Figure D8: London Stansted Airport* (STN)

Indicative Low Noise Area

2022 STN Estimated 92 Day Summer Night Average Noise Contour

48 dB 51 dB 54 dB 57 dB 60 dB 63 dB 66 dB 69 dB

0 1 2 3 4 5 km

$L_{Aeq,8hr}$ Air Noise Contours

Drawn Date
2024-07-02
Project Ref: 13212A

St George's University of London

Department for Transport

Legend

Figure D9: London Luton Airport (LTN)

Indicative Low Noise Area

2022 LTN Estimated 92 Day Summer Night Average Noise Contour

48 dB | 51 dB | 54 dB | 57 dB | 60 dB | 63 dB | 66 dB | 69 dB

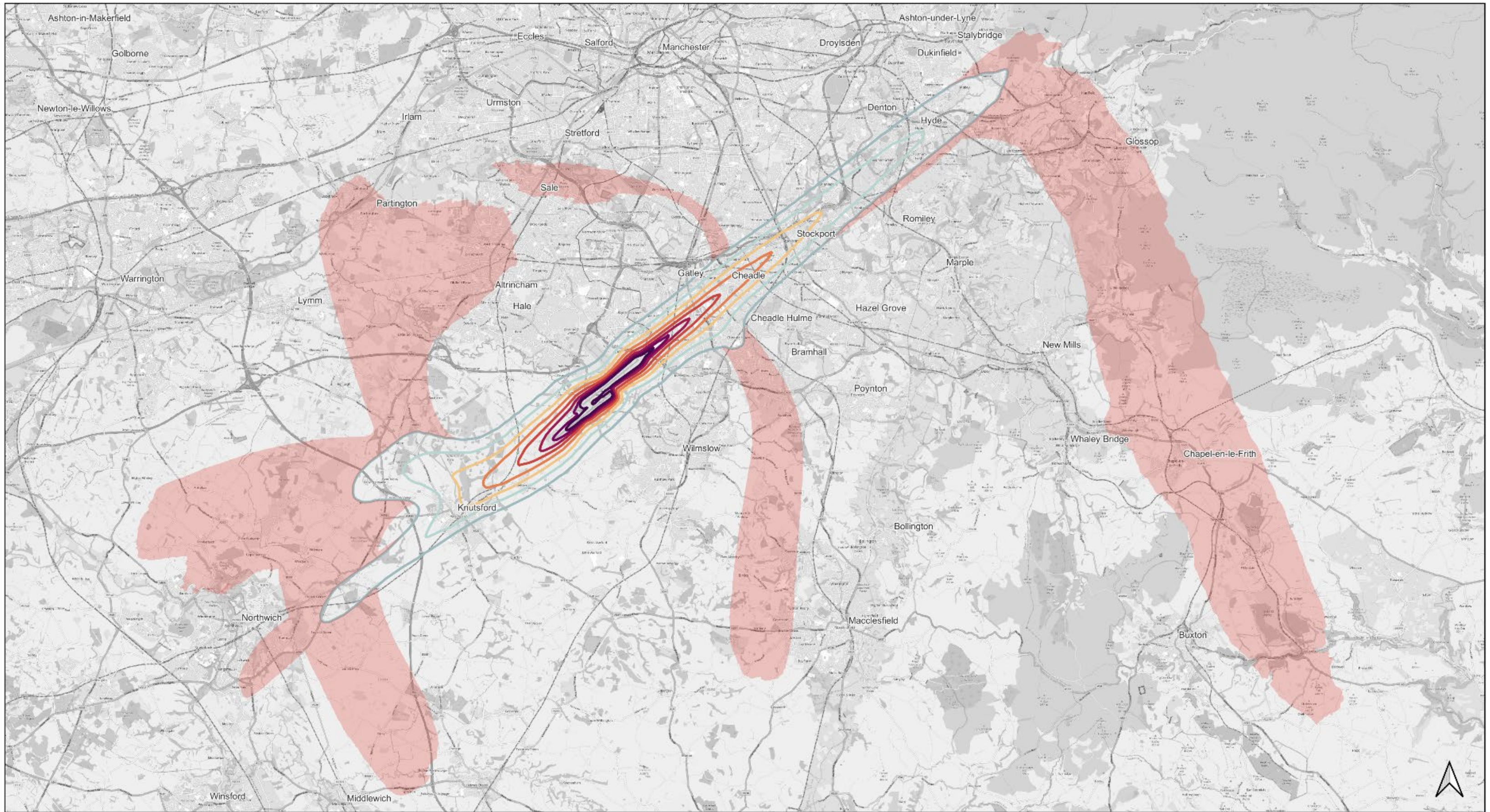
0 1 2 3 4 5 km

$L_{Aeq,8hr}$ Air Noise Contours

Drawn Date

2024-07-02

Project Ref: 13212A



Legend

Figure D10: Manchester Airport (MAN)

Indicative Low Noise Area

2022 MAN Estimated 92 Day Summer Night Average Noise Contour

48 dB | 51 dB | 54 dB | 57 dB | 60 dB | 63 dB | 66 dB | 69 dB

0 1 2 3 4 5 km

$L_{Aeq,8hr}$ Air Noise Contours

Drawn Date

2024-06-27

Project Ref: 13212A

2 Generation of Noise Exposure Datasets for the Subjective Study

2.1.1 Metrics and Modelling

The subjective study has considered the following noise metrics as set out in Table D2.

Table D3: Noise Metrics Required for the Subjective Study

Metric	Description of Metric	Time Period	Unit
L_{night}	L_{night} represents the noise exposure index over the night-time period, 23.00-07.00 local time. The L_{night} metric is required under the Environmental Noise Regulations (as they apply to England, Scotland, Wales and Northern Ireland) as transposed from European Directive 2002/49/EC. The metric is required for the preparation of strategic noise maps and airport noise action plans under these Regulations. The metric is measured over a calendar year from 1 January to 31 December (inclusively).	Annual (12-month calendar year)	dB(A)
$L_{Aeq,8h}$	Average summer night over the period from 16 June to 15 September inclusively for the 8 hours of the night, between 23.00 and 07.00 local time. This metric is currently cited in government policies relating to aircraft noise management and assessment.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
$L_{Aeq,1h}$ (2100—2200)	Average hourly noise exposure over the period from 16 June to 15 September, between 21.00 and 22.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
$L_{Aeq,1h}$ (2200 – 2300)	Average hourly noise exposure over the period from 16 June to 15 September, between 22.00 and 23.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
L_{Aeq1h} (2300 – 0000)	Average hourly noise exposure over the period from 16 June to 15 September, between 23.00 and 00.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
L_{Aeq1h} (0000 – 0100)	Average hourly noise exposure over the period from 16 June to 15 September, between 00.00 and 01.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
L_{Aeq1h} (0100 – 0200)	Average hourly noise exposure over the period from 16 June to 15 September, between 01.00 and 02.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)

L_{Aeq1h} (0200 – 0300)	Average hourly noise exposure over the period from 16 June to 15 September, between 02.00 and 03.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
L_{Aeq1h} (0300 – 0400)	Average hourly noise exposure over the period from 16 June to 15 September, between 03.00 and 04.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
L_{Aeq1h} (0400 – 0500)	Average hourly noise exposure over the period from 16 June to 15 September, between 04.00 and 05.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
L_{Aeq1h} (0500 – 0600)	Average hourly noise exposure over the period from 16 June to 15 September, between 05.00 and 06.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
L_{Aeq1h} (0600 – 0700)	Average hourly noise exposure over the period from 16 June to 15 September, between 06.00 and 07.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
L_{Aeq1h} (0700 – 0800)	Average hourly noise exposure over the period from 16 June to 15 September, between 07.00 and 08.00 local time.	92-day Summer Period (16 June to 15 September inclusively)	dB(A)
Overflight 0 – 7000ft, AGL (2300-0700, Annual)	Location overflown where aircraft are at or below 7,000ft Above Ground Level (AGL) between the hours of 23.00-07.00 over the calendar year, 1 January to 31 December (inclusively). Locations overflown have been determined using the methodology described in CAA publication CAP1498[17] utilising a 48.5 and a 60 degree elevation, respectively.	Annual (12-month calendar year)	Number of overflights (count)
Overflight 0 – 7000ft AGL (92-day)	Location overflown where aircraft are at or below 7,000ft Above Ground Level (AGL) between the hours of 23.00-07.00 over 92-day summer period, 16 June to 15 September (inclusively). Locations overflown have been determined using the methodology described in CAA publication CAP1498 utilising a 48.5 and a 60 degree elevation, respectively.	92-day Summer Period (16 June to 15 September inclusively)	Number of overflights (count)
Overflight 0 – 4000ft AGL (Annual)	Location overflown where aircraft are at or below 4,000ft Above Ground Level (AGL) between the hours of 23.00-07.00 over the calendar year, 1 January to 31 December (inclusively). Locations overflown have been determined using the methodology described in CAA publication CAP1498 utilising a 48.5 and a 60 degree elevation, respectively.	Annual (12-month calendar year)	Number of overflights (count)

[17] CAA CAP1498 Definition of Overflight (2017)

Overflight 0 – 4000ft AGL (92-day)	Location overflown where aircraft are at or below 4,000ft Above Ground Level (AGL) between the hours of 23.00-07.00 over 92-day summer period, 16 June to 15 September (inclusively). Locations overflown have been determined using the methodology described in CAA publication CAP1498 utilising a 48.5 and a 60 degree elevation, respectively.	92-day Summer Period (16 June to 15 September inclusively)	Number of overflights (count)
N60	Number of average summer night aircraft events equal to or above 60dB L_{ASmax} over the period from 16 June to 15 September inclusively for the 8 hours of the night, between 23.00 and 07.00 local time. This metric is currently cited in government policies relating to aircraft noise management and assessment.	92-day Summer Period (16 June to 15 September inclusively)	Number of aircraft events above 60dB L_{ASmax} (count)

The above metrics have been generated specifically for this study using a process of analysis and aircraft noise modelling.

The following sections set out the calculation methodology and software selection, along with the processes and information obtained from the selected airports to support this exercise.

2.1.2 Calculation Methodology and Software Selection

The L_{Aeq} and N60 metrics set out in Table D2 have been calculated in accordance with European Civil Aviation Conference (ECAC) CEAC Doc 29 Volume 2 4th Edition[18] as implemented in the Federal Aviation Administration (FAA) Aviation Environmental Design Tool (AEDT) version 3.0e software.

ECAC Doc 29 provides guidance and a methodology for calculating aircraft noise in the vicinity of airports.

Volume 1 of the ECAC Doc 29[19] series describes the factors that are of importance for the calculation of aircraft noise and encourages those carrying out the calculations to ensure that the datasets being used to support the calculations reflect local circumstances.

Volume 2 provides the methodology and equations for calculating aircraft noise in line with internationally agreed methods using an International Civil Aviation Organisation (ICAO) sponsored ANP (Aircraft Noise and Performance) database.

The ICAO ANP database provides manufacturer supplied aircraft performance and noise information which is essential to the calculation of aircraft noise using the methodology set out in ECAC Doc 29 Volume 2. The ANP also provides information on aircraft aerodynamic characteristics, engine thrust and noise characteristics along with

[18] Available at: https://www.ecac-ceac.org/images/documents/ECAC-Doc_29_4th_edition_Dec_2016_Volume_2.pdf

[19] Available at: https://www.ecac-ceac.org/images/documents/ECAC-Doc_29_4th_edition_Dec_2016_Volume_3_Part_1.pdf

information that describes flight procedures. The latter are typically referred to as 'flight profiles'.

Volume 3 of ECAC Doc 29 provides a set of reference calculations based on the methodologies and equations provided in Volume 2. This can be used by software developers when confirming the validity of their ECAC Doc 29 implementations.

2.1.3 Relevant Modelling Guidance

Volume 1 of the ECAC Doc 29 provides guidance to noise modellers on the factors which are of importance when preparing noise models and carrying out calculations.

All environmental noise modelling is based on datasets. In the case of aircraft noise modelling, these datasets need to describe how much noise is being produced by an aircraft at various stages of a departure and arrival, along with its location and altitude (to establish the height of the aircraft above ground level).

The CAA publication CAP2091[20] sets out the minimum acceptable level of sophistication for airport noise modelling that can be used to provide the CAA with outputs as part of discharging its duties. It is also used in general by aircraft noise practitioners when preparing aircraft noise models and assessments that are not regulated by the CAA. It can therefore be considered as providing best practice.

CAP2091 sets out the considerations that should be made when modelling aircraft noise, and the level of sophistication that is required in the noise models. This is achieved through the concept of 'noise modelling categories' which are determined by the population that is forecast or is already exposed to aircraft noise above day and night-time Lowest Observed Adverse Effect Levels (LOAELs). LOAELs are set out in current government policy[21]. For night-time noise, the current government policy LOAEL is 45dB $L_{Aeq,8h}$.

CAP2091 describes minimum noise model sophistication by setting out minimum requirements for the aircraft noise datasets and aircraft track datasets to be used to inform the model with respect to each airport's noise modelling category.

The noise modelling categories range from Category A (the most sophisticated) to Category E (the least sophisticated).

CAP2091 also sets out exceptions where the noise modelling categories for airports are effectively mandated due to other provisions, such as noise designation[22].

CAP2091 describes requirements against aircraft noise datasets relating to 'noise data' and 'flight profiles'.

Noise Data

The least sophisticated 'noise data' is what is available within the Aircraft Noise and Performance (ANP) database[23]. The 'noise data' is often referred to as 'Noise-Power-

[20] CAA CAP2091 CAA Policy on Minimum Standards for Noise Modelling (2021)
[21] Department for Transport Air Navigation Guidance (2017)
[22] Heathrow, Gatwick and Stansted as these airports are designated for the purposes of noise regulation under the Civil Aviation Act 1982. For these airports, CAP2091 requires aircraft noise models to conform to noise modelling Category A.
[23] Further information can be found here: https://www.easa.europa.eu/en/domains/environment/policy-support-and-research/aircraft-noise-and-performance-anp-data (accessed 18 June 2024)

Distance' (NPD) information. This data provides a look-up for the level of noise that can be expected at a given power setting and distance from the aircraft. NPD information can differ depending upon the metric which is being calculated for an aircraft. In the case of the L_{Aeq}-based and the N60 metrics required for this study, NPD information reflecting the SEL and L_{ASmax} is required.

CAP2091 Category A requires modellers to modify the ICAO ANP NPD datasets to reflect measurements taken at local noise monitors for all aircraft types. CAP2091 Category B requires that ICAO ANP NPD datasets are modified for the 'major' or 'main' aircraft types[24]. All other CAP2091 noise modelling categories can rely on unadjusted ICAO ANP NPD datasets.

Flight Profiles

'Flight profiles' effectively represent the vertical performance of an aircraft, and the aircraft configuration used to achieve this performance i.e., engine power settings, speeds, climb rates, etc. The standardised information on flight profiles held within the ICAO ANP do not usually reflect operations at major airports. For this reason, Category A and B of CAP2091 recommends using local track-keeping data from the airport radar to update flight profiles to better reflect vertical performance. For Category C, CAP2091 recommends that local track-keeping data is used for the major aircraft types.

CAP2091 recognises that the process of adapting flight profiles can be a labour-intensive process and as such this can be managed by limiting the number of aircraft types for which this process is carried out.

A similar approach is taken in CAP2091 for the development and use of aircraft track datasets. These describe the location of aircraft arrivals and departures in terms of the main centreline of the routes to and from the airport along with the dispersion around the routes and how the air traffic is allocated to the routes.

For airports of noise modelling Category A – C, CAP2091 recommends that local track keeping data is used to determine the mean centreline and dispersion of aircraft ground tracks.

2.1.4 Methodological Considerations

This study has required L_{eq}-based noise exposure metrics and N60 metrics be generated from 35dB and 1 N60 event respectively. This level of noise exposure is 10dB lower than the night-time LOAEL set out in policy, and which has been used to inform the CAA's CAP2091 guidance. In the case of N60, CAA guidance[25] for Airspace Change Proposals' requires these metrics to be reported from 5 events and above.

There are number of uncertainties which are introduced when modelling aircraft noise exposure and noise events below the current policy LOAEL of 45dB $L_{Aeq,8h}$ and 5 N60. These are summarised below:

1. At these levels of exposure, aircraft may be subject to vectoring i.e., where air traffic controllers direct aircraft rather than where aircraft continue to follow a

[24] CAP2091 defined the 'major' or 'main' aircraft types as those which are responsible for more than 75 percent of the total noise energy produced by aircraft at that airport in terms of the L_{Aeq} metrics.
[25] CAA CAP1616i: Environmental Assessment Requirements and Guidance for Airspace Change Proposals (2023)

published route. This means that aircraft positions can be the subject of variations, which means that modelled noise exposure at such locations is the subject of greater uncertainty and variation than at locations closer to the airport. This requires additional attention to both modelled flight profiles and local track-keeping data.

2. At lower levels of noise exposure, aircraft noise events generally occur at lower event levels too i.e., SEL and L_{ASmax}. Noise monitoring terminals at airports are not normally sited in areas where low aircraft noise event levels occur. Where they are, it can be difficult to obtain clear and correlated aircraft event measurements as such events can be susceptible to extraneous noise sources.

3. When modifying NPD datasets to address low levels of aircraft noise events, extrapolation of this data may be required without reference measurements to support this exercise.

At levels of 45dB $L_{Aeq,8h}$ and above, such exposure is likely to occur in locations where aircraft ground tracks are more consistent e.g. final approaches and within noise preferential routes, and where noise monitoring terminals are likely to provide data to support adjustments to NPD datasets.

2.1.5 Adopted Modelling Methodology for L_{Aeq} and N60 Metrics

Taking these uncertainties into account, and to ensure consistency in both the approach and quality of the noise models informing the subjective study, a common approach has been taken to the preparation of the L_{Aeq}-based and N60 noise metrics set out in Table D2. This is to ensure as best as possible that all airports are modelled to CAA's CAP2091 Category A guidance and that the sources of uncertainty outlined above can be reduced or controlled as far as is practical.

Another aim of the noise modelling methodology adopted for this study has been to reduce the risk of uncertainties being introduced by the noise modellers themselves. A systematic approach to the noise modelling has therefore been adopted.

The noise modelling process for the subjective study commenced in Q2 2022.

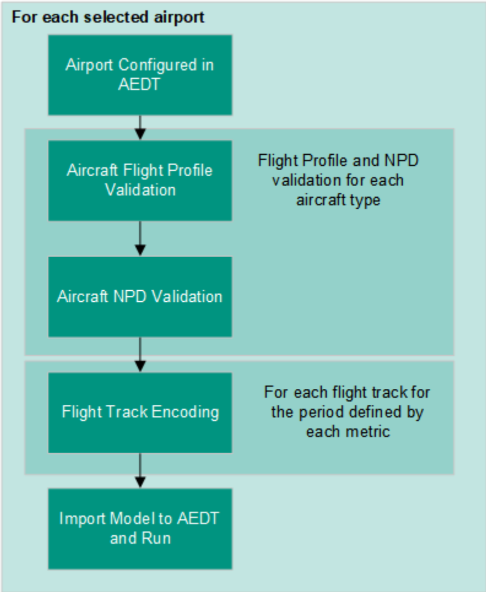
To facilitate this the following information was requested from selected airports:

- Local flight tracks for all aircraft operating between 1 January to 30 June 2022;
- Corresponding meteorological data for this period;
- The location of all fixed local noise monitoring terminals; and
- Correlated aircraft noise event measurements for the period.

This information was used to commence the modelling and the preparation of flight profiles and NPD datasets. A further request made in January 2023 allowed a complete year of data to be made available in support of the modelling exercise. With the full year of 2022 data, all flight profiles and NPD datasets were completed and referenced to both the 92-day and annual average metrics set out in Table D2.

Using the data provided by the airports the following noise modelling process was carried out as summarised in Figure D11. Much of this process was automated using software tools.

Figure D11: Process for Validation

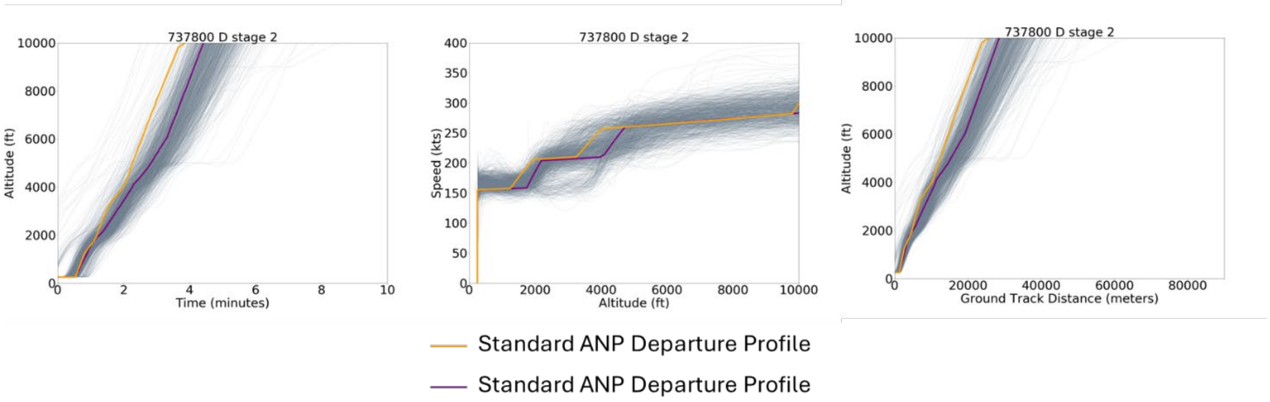


Each sampled airport was configured in AEDT to reflect their respective runway ends, thresholds, widths and altitudes. For each aircraft type, with the exception of any general aviation, a process of flight profile and NPD validation was then performed. The validation process was carried out for each airport, all flight paths to and from each runway end, and each aircraft type. For departure flight profiles, where clear differences were identified in the use of noise abatement departure procedures (NADP) between airlines and ascent rates, separate profiles were generated and assigned to specific operations. The validation process has considered all flight tracks received from the airports in support of the flight profile validation, and all correlated noise events in support of the NPD validation, subject to meteorological filtering.

Figure D12 presents an example of a profile validation with respect to aircraft altitudes and speeds. This illustrates the identification of steps in the flight profiles and the alignment of the profile with cross-sections of the underlying radar data. These present radar cross sections alongside a standard ANP flight profile and a validated profile. This process considers ascent rates through the 'stage length'[26] of aircraft departures, taking into consideration the take-off weights. The profiles were also extrapolated to 20,000ft for both arrivals and departures and for use within AEDT.

[26] Stage length provides a proxy for aircraft take-off weights taking into account the distance between the departure airport and destination.

Figure D12: Example of validated and unvalidated flight profiles



Using the validated flight profiles, a process of NPD adjustment has been carried out to better reflect measured SEL and L_{ASmax} noise levels from aircraft event at the noise monitoring terminals at each airport. This process has involved the following for each airport:

1. Each flight track from airport's radar has been assigned an AEDT aircraft type and the corresponding validated flight profile. The operation number or identifier along with the time of the aircraft movement is retained;

2. An AEDT model is then built for all tracks for the selected AEDT aircraft type operating at the airport using the radar data. The operation number or identifier is used within the model along with the actual flight tracks. Only minor adjustments are made to the tracks to ensure that geometries are aligned to the runways;

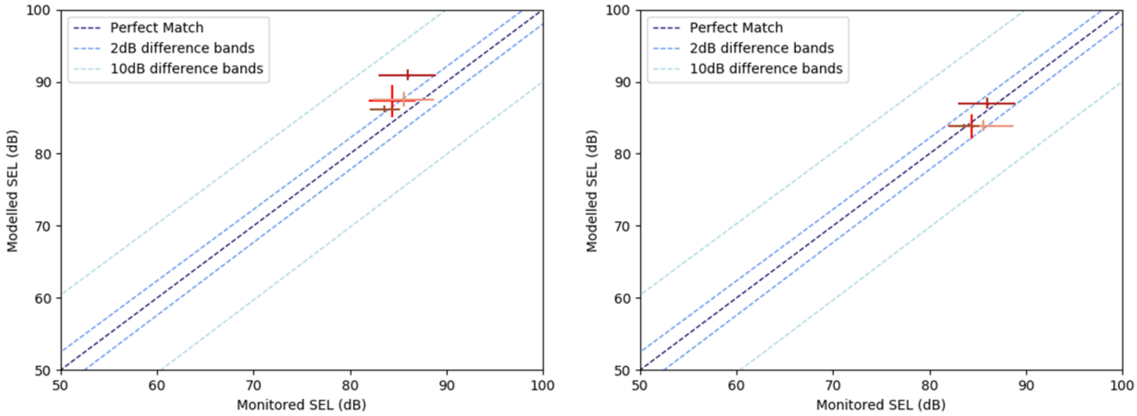
3. The AEDT model is run to report L_{ASmax} and SEL values for each aircraft event by their operation number and/or identifier and for its associated track;

4. The calculated L_{ASmax} and SEL values from the model are exported from AEDT and then compared directly to the correlated measured aircraft noise event values from the airport's noise monitoring terminals. This process utilises the retained operation number and/or identifier;

5. Modifications to the ICAO ANP NPD for the aircraft type are determined based on the differences observed between the correlated noise measurements and output of the noise model; and

6. The aircraft NPDs are modified and the process repeated to ensure that the modelled event levels align with measured values. An example of this is presented in Figure D13, which shows pre and post SEL validation results.

Figure D13: Example of validated noise model output against measured events



Pre-validation

Post Validation

2.1.6 Terrain Datasets

For each selected airport, terrain has been incorporated using the Ordnance Survey 50m Digital Terrain Model (DTM). This dataset has also been used to support the computation of overflight data. The terrain datasets have been used in all modelling including the process of noise model adaption as described in Section 2.1.5.

2.1.7 L_{Aeq} and N60 Noise Metric Generation for the Subjective Study

Following the noise model adaptions as discussed and described in Section 2.1.5, noise models for each airport were developed. The process of noise model assembly for each airport is summarised in Figure D14.

For each airport, a configuration describing the runway end, threshold[27] positions etc. was loaded into proprietary software along with the radar tracks. The radar tracks were then cleaned and filtered to represent either the 92-day or annual periods required by the metrics set out in Table D2. Based on the radar data, the aircraft type code, its destination and flight performance, an AEDT flight profile and associated NPD dataset was assigned to each radar track. The radar tracks are then converted into AEDT flight tracks having regard for the airport configuration and time stamped. The process of time stamping has involved using the time radar data indicates the aircraft was on an airport's runway for departure or arrival. As such, all times within the noise models are based on runway times. This process does introduce some uncertainties, particularly for the $L_{Aeq,1h}$ metrics described in Table D2. This is because aircraft noise events may occur at locations several minutes before or after the aircraft is on the runway. However, the only alternative would be to produce separate models based on the times at which aircraft present over certain locations. Such an approach is considered disproportionate. It should be noted that for this study the time of each aircraft operation is based on the runway times revealed by the radar data.

[27] The 'thresholds' of a runway describe the area of the runway that is usable for aircraft to land or depart on.

Once the AEDT flight tracks are time stamped, the models were written out in AEDT's Standard Input File (ASIF) format.

Figure D14: Model Processing for Subjective Study

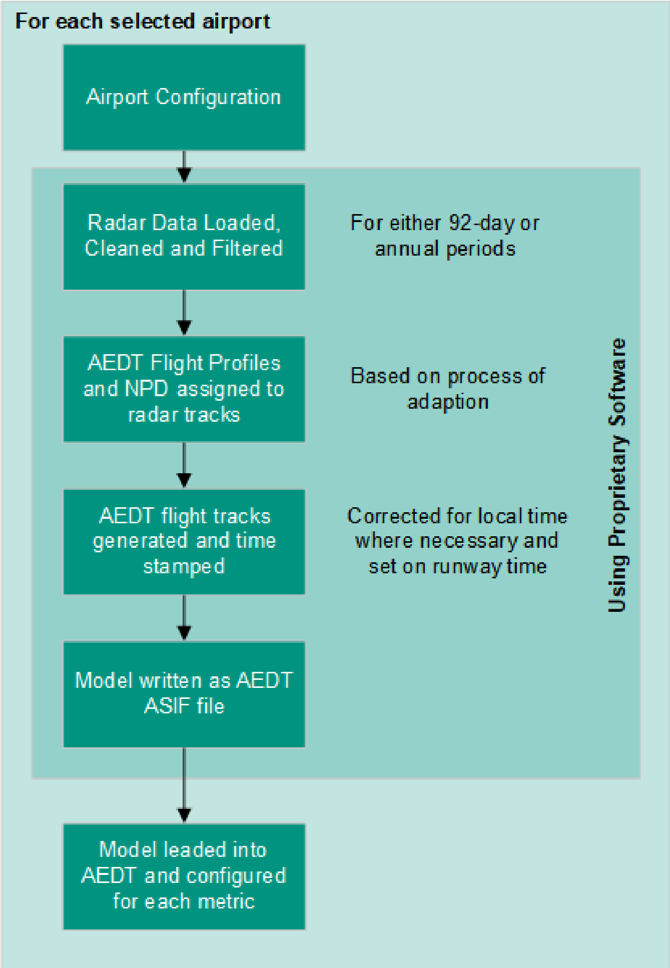
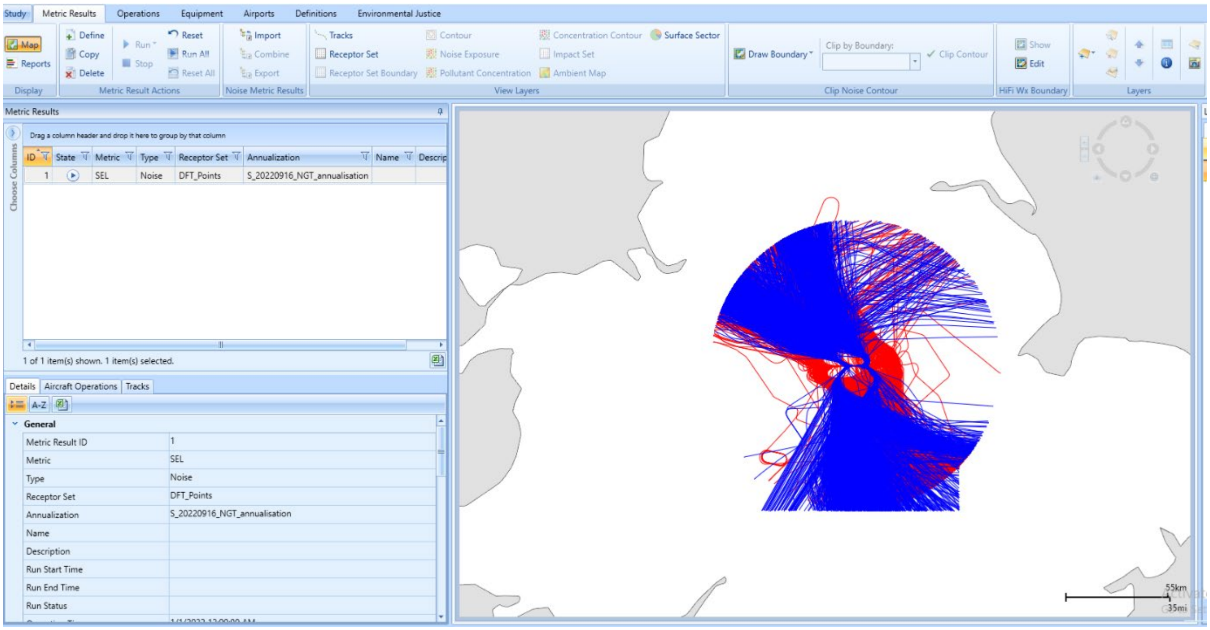


Figure D15 presents an example of an imported AEDT model for the study. This shows all radar tracks within the model. This means that for each selected airport, the study has used the actual ground tracks, thus reducing both uncertainties relating to ground track positions in low noise areas and reducing uncertainties introduced by noise modellers.

Figure D15: Example of Model in AEDT



The noise calculations for the subjective study for each of the L_{Aeq} and N60 noise metrics set out in Table D2 have taken place at discrete points. For each selected airport a set of points were provided by the project team.

These points included the exact geographic location of the subject study participants address along with a greater number randomly selected locations. The points provided were indexed only by an identifier number, with no other information (e.g. address, postcode etc.) provided with the points. This approach was adopted to ensure that no personal information was being exchanged, for compliance with the General Data Protection Regulation (GDPR).

The results of the calculations have therefore provided both an overall level of noise at each point for each metric along with the facility to ascertain modelled event levels from each of the aircraft tracks held within the model at the exact locations of the subject survey participants.

2.1.8 Calculation of Overflight Metrics

Table D2 includes a series of overflight metrics which have been included within the subjective study. The overflight metric is a non-acoustic metric. Although some acoustic considerations were part of the development of the metric, the metric itself is purely geometrical based on the altitude of an aircraft above ground level, and the ‘elevation angle’ to which a receptor on the route observes the aircraft. This is illustrated in Figure D1.

Two variants of overflight have been produced for this study using two separate elevation angles: 48.5 degrees and 60.0 degrees. These elevation angles are set out in the CAA’s CAP1498, however overflight data generated using an elevation angle of 48.5 degrees is required by the CAA when carrying it its duties as part of airspace changes[28]. Furthermore, as outlined in Table D2, overflight data has been generated

[28] CAA CAP1616i: Environmental Assessment Requirements and Guidance for Airspace Change Proposals (2023) Paragraph 1.40

for operations for the 92-day summer period, and where aircraft are at or below 4,000ft and 7,000ft.

Overflight calculations have been carried out at the same calculation points for each selected airport as discussed in Section 2.1.7. The resultant unit for the overflight metric is a simple count of the number of aircraft events that meet the various overflight definitions used.

The calculation of overflight has directly utilised radar data from the selected airports and has been calculated using terrain datasets as described in Section 2.1.6. This data has been filtered in the same manner for the calculation of the L_{Aeq} and N60 metrics with respect to local times.

General Information on Noise and Overflight Metrics

This section provides some general information on the noise and overflight metrics utilised and summarised within the study and its technical report.

Modal Split

Modal split is used to describes the amount of time that an airport is operating in a certain runway mode or direction. In the UK modal split is often described based on operating direction, typically through the percentage of operations occurring in easterly or westerly direction.

The use of actual radar data and operations in the modelling described in Section 2.1.4 means that the runway operations and associated modal split reflect actual conditions in 2022 i.e. the 'actual' modal split.

Airport noise assessments can use what is described as a 'standard' modal split. This is where the modal splits in the relevant assessment periods are averaged over time (usually between 10 and 20 years). This is to address variations in runway use that can occur from year to year due to variations in wind directions to support the identification of trends in airport noise exposure statistics. A standard modal split is also used to support forecasts.

The use of an actual modal split and the associated approach to generating noise metrics for this study is based on the context of the annoyance questions raised in the mainstage questionnaire. These questions (Q3, Q4, Q5, Q6, Q19, and Q20) are qualified by *"Thinking about this summer"* where in supporting the participant "this summer?" means "the period from mid-June to mid-September 2022."

As such, the questions relating to annoyance are designed to reflect the noise exposure and events that occurred in summer 2022 and are thus best represented by an 'actual' modal split. The modal split for the 92-day and annual noise metrics for 2022 as modelled for the subjective study are set out in Table D3 and Table D4 respectively. Both tables present the total number of modelled operations for the 8-hour night-time summer average and annual average periods.

Table D4: Modal Splits and Number of Operations Modelled for the Sampled Airports for the Subjective Study ($L_{Aeq,8h}$, 92-day 2022 Summer Average)

Airport	Number of Operations		Actual Modal Split	
	West	East	West	East
BRS	2167	1230	64%	36%
EMA	4812	1972	71%	29%
GLA	1504	465	76%	24%
LGW	5739	3996	59%	41%
LHR	4857	2290	68%	32%
LTN	2813	1731	62%	38%
MAN	7113	1410	83%	17%
STN	4459	3073	59%	41%

Table D5: Modal Splits and Number of Operations Modelled for the Sampled Airports for the Subjective Study (L_{night}, 2022 Annual Average)

Airport	Number of Operations		Actual Modal Split	
	West	East	West	East
BRS	5552	2717	67%	33%
EMA	18524	5725	76%	24%
GLA	3741	1283	74%	26%
LGW	14907	8239	64%	36%
LHR	17680	6510	73%	27%
LTN	9815	4661	68%	32%
MAN	17992	4175	81%	19%
STN	11706	6795	63%	37%

Noise Metric Bandings

The technical report contains a number of figures and tables where noise metrics are presented. The following commentary is provided on these:

- All N60 metrics have been prepared so that where events are equal to or greater than 60dB L_{ASmax} this counts as an N60 event
- Where integers are provided for noise and overflight values in the technical report, the lowest of any range represents a greater than or equal to condition
- Unless otherwise stated, integers are provided for noise and overflight values in the technical report, the highest of any range represents a less than condition

Why have noise contours not been prepared for the subjective study?

The modelling methodology coupled to the number of metrics required for this study has made it impractical to produce noise contours. As outlined in Section 2.1.7, calculations have been made at the exact locations of the subjective study participants. This has allowed the analysis of noise exposure in 2022 against the responses to the questionnaire to be made.