Directorate of Airspace Policy

Civil Aviation Authority

ERCD REPORT 0204

Review of the Quota Count (QC) System: Re-Analysis of the Differences Between Arrivals and Departures

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SUMMARY

This report describes a study that was undertaken on behalf of the Department for Transport to evaluate the Quota Count (QC) system methodology using current data and noise modelling practices. The results indicate that the QC system remains appropriate as a practical means of classifying the noise impact of arriving and departing aircraft.

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GLOSSARY OF TERMS

A-weighted	A filter that is applied to the output of the microphone within a sound level meter to simulate the way the sensitivity of the human ear varies with sound frequency, broadly being more sensitive to high frequencies than low. With this filter, the meter output is A-weighted sound level.
CAEP	(ICAO) Committee on Aviation Environmental Protection.
dB	Decibel units describing sound level or changes of sound level.
dBA	Units of sound level on the A-weighted scale.
EPNdB	The measurement unit for EPNL.
EPNL	Effective Perceived Noise Level. Its measurement involves analyses of the frequency spectra of noise events as well as the duration of the sound.
ERCD	Environmental Research and Consultancy Department of the Civil Aviation Authority.
ICAO	International Civil Aviation Organisation.
Leq	Equivalent continuous sound level: the level of a notional steady sound that over a given period of time would have the same A-weighted acoustic energy as the fluctuating noise.
Lmax	The maximum sound level measured during an aircraft fly-by.
NTK	Noise and Track Keeping monitoring system. The NTK system associates radar data from air traffic control radar with related data from both fixed (permanent) and mobile noise monitors at prescribed positions on the ground.
SEL	Sound Exposure Level generated by a single aircraft at a particular point. This accounts for the duration of the sound as well as its intensity.
SOR	Start-of-roll: The position on a runway where aircraft commence their take-off runs.

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1. INTRODUCTION

1.1 The Quota Count (QC) system was introduced as part of a new night restrictions regime for Heathrow, Gatwick and Stansted in 1993 (**Ref 1**). Aircraft movements (arrivals or departures) count against a noise quota for each airport according to their QC classifications. The method by which QC classifications are determined was based on a 1991 analysis of aircraft noise data that was then available[1]. The QC classification is intended to reflect the contribution made by an aircraft to the total noise impact around an airport, the latter being expressed by the total Quota Count - the sum of the QC classifications of all arrivals and departures. Classifications are assigned separately for arrivals and departures.

1.2 QC classifications measure noise in relative terms: a QC/2 aircraft is deemed to have twice the impact of a QC/1 aircraft, a QC/4 aircraft has four times the impact and so on. The QC classifications of aircraft are determined from their certificated noise levels, which are measured in EPNdB. Although certificated EPNLs can fall anywhere within a wide range, they are grouped for practical QC purposes into 3 EPNdB-wide bands (although the highest and lowest bands are unlimited). Because a 3 EPNdB difference in noise level corresponds to a two-fold difference in noise energy, successive QC classifications increase by multiples of 2.

1.3 However, for reasons to be reviewed, arrivals contribute less to the total noise impact than departures - for the same certificated EPNLs. To allow for this, the arrival EPNLs are adjusted downwards by 9 EPNdB to achieve QC classifications that are comparable with those for departures.

1.4 This 9 EPNdB adjustment has attracted criticism. At least in part, this is because it suggests the noise of arriving aircraft is given less weight than that of departures, despite the fact that actual noise levels under the descent path can be just as high, if not higher.

1.5 It has also been recognised that the 1991 analysis was limited in various ways, not least because the data were mainly obtained in the 1980s when aircraft noise contours were dominated by Chapter 2 aircraft. Aircraft fleets and the ways in which aircraft are flown have now changed significantly and it was agreed that a necessary part of the next review[2] of the night restrictions regime would be to carry out a study to re-evaluate the QC classification methodology using up-to-date data and modelling practices. This report describes the work carried out for the Department for Transport by ERCD.

2 THE BASIS OF THE QC RATING SYSTEM

2.1 That QC classifications are designed to indicate the contributions individual aircraft make to the total noise impact around an airport has already been noted. 'Impact' is the aggregate adverse effect of the noise on people and it is quantified by taking

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[1] The 1991 analysis was carried out by the CAA's Directorate of Operational Research and Analysis (DORA), which later became known as the Environmental Research and Consultancy Department (ERCD). Although not reported at the time, relevant parts of the 1991 analysis have been reproduced in this document.

[2] The Government currently review the night restrictions regime for Heathrow, Gatwick and Stansted approximately every five or six years and intend to consult on the next night restrictions regime by the end of 2003.

account of noise exposures and the numbers of people affected. Thus, for example, for the designated London airports, annual reports prepared by ERCD give the numbers of people residing within 16-hour (0700-2300) Leq contours representing low, medium and high levels of aircraft noise impact.

2.2 Although, at present, no comparable Leq contours for night-time are published, a basic precept of the 1993 night restrictions scheme was that it should effectively 'cap' night-time noise exposures as they would be indicated by Leq contours. The contribution a single aircraft movement (arrival or departure) makes to those contours depends on the total noise energy emitted - and that in turn can be defined by its 'noise footprint' - the greater the energy, the larger the footprint. Footprints graphically compare the noise impact potentials of different aircraft; if dwellings were spread uniformly within the footprints the numbers of residents encompassed would be directly proportional to the footprint areas.

2.3 Like Leq contours, noise footprints are lines of constant noise level on the ground. But for one single aircraft movement, that noise level is expressed for example in EPNL or A-weighted Lmax or SEL, not Leq which describes average noise exposure generated by the entire aircraft fleet using the airport. Leq contours can be thought of as an aggregation of individual footprints from an average day's (or night's) traffic.

2.4 Before 1993, night traffic quotas were based on aircraft 'night noise (NN) categories'. These were linked directly to noise footprint areas that were calculated using the then current CAA noise contour model from data supplied by the aircraft manufacturers (and checked by the CAA's Noise Certification Group). But practical experience led to the conclusion that an alternative scheme was required that was more transparent and more easily administered. As a matter of policy therefore, the aircraft QC classifications introduced in 1993 were based on official certificated noise levels because these are (i) generally considered to be reliable indicators of aircraft noise performance, (ii) available for practically every civil transport aircraft operating in the western world, (iii) openly published and therefore readily applied by administrators of the scheme, and (iv) correlated with noise footprint areas which, as before, were taken to be appropriate measures of 'noise impact'. (In principle, SELs could also be calculated from the same certification test data, but as these are not required by the regulations, they are not usually available.)

2.5 To understand why and how the certificated noise levels are correlated with footprints it is necessary to consider how arrival and departure noise is specified under the aircraft noise certification procedure (**Ref 2**). There are three 'reference points': *approach*, under the descent path 2000 m before landing threshold; *lateral* (or sideline), at the point where noise is greatest on a line 450 m to the side of the initial climb after lift-off; and *flyover*, under the departure climb path, 6500 m from Start-of-Roll (SOR). These are shown in **Figure 1** in relation to illustrative noise footprint components. Test aircraft perform prescribed arrival and departure procedures past microphones located at these reference points. Noise levels in EPNdB are measured under stringent test conditions which are subject to the scrutiny of the certificating authorities. The measurements are repeated a number of times to ensure that the mean values are accurate.

2.6 The 1991 study focussed on the relationships between footprint areas and noise levels at the certification reference points under normal operating conditions at the London airports - not the certificated noise levels. For arrivals, footprint areas were found to be highly correlated with the level La at the approach reference point. For departures a high correlation was achieved when the sideline and flyover levels, Ls and Lf were simply averaged, the result being referred to as the 'departure' noise level Ld = (Ls + Lf)/2. The results of the 1991 analysis are illustrated in **Figure 2**.

2.7 This was generated using the then current version of the CAA noise contour model ANCON (**Ref 3**). Along with the 90 dBA SEL footprints[3] and their areas, the model also defined the corresponding noise levels at the three reference points. The noise levels (on the footprint boundaries and at the reference points) were expressed in A-weighted SEL, the basic 'building block' of the official contour modelling metric Leq, not EPNL. In **Figure 2**, each point plotted on the graph shows the average footprint area and average reference point noise level of one specific aircraft type or category - as classified for the purposes of noise contour modelling. Straight lines fitted the points very well so it was concluded that the reference point SELs were very good 'predictors' of footprint areas[4].

2.8 Consequently, it was assumed that, for the purposes of classifying aircraft noise, the previously used footprint areas could be replaced by certificated noise levels (used in this way). However, as it was a government requirement that arrivals and departures were 'exchangeable' within the night noise quota - i.e. that replacing an arrival by a departure with the same classification, or vice-versa, should have no net effect on the total noise impact - any classification, whether for an arrival or a departure, should indicate the same footprint area.

2.9 **Figure 2** showed that, for a given numerical value of SEL, Ld is associated with a substantially larger footprint than La and thus a larger impact. This is because the approach reference point is much nearer to the aircraft flight path than the lateral and flyover points - see **Figure 3**. Whilst arriving aircraft descending on a 3-degree glide path pass 120 m (394 ft) over the approach reference point, departing aircraft are further away from the lateral and flyover reference points. The slant distance to the lateral point is usually close to 550 m (1800 ft). Over the flyover reference point the height varies considerably. In certification conditions it is around 300 m (1000 ft) for 4-engined aircraft and 600 m (2000 ft) for twin-engined aircraft. Thus compared with arrivals, noise from departing aircraft typically travels between 3 and 5 times as far before reaching the reference points. Thus even if the amounts of noise energy generated by the aircraft were the same during arrival and departure (i.e. the same footprint areas) the noise levels at the departure reference points would be between about 8 and 13 dB less than the level at the approach reference point because of the greater distance travelled by the noise.

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[3] 90 dBA SEL, equivalent to around 80 dBA Lmax or 95 EPNdB, was recognised as a significant threshold - of both annoyance and sleep disturbance.

[4] The footprint areas are plotted on a logarithmic scale so it is log (area) that is proportional to SEL.

2.10 This difference had somehow to be accounted for by the system. It was handled by subtracting a fixed differential of 9 EPNdB from the approach EPNL to calculate a qualifying noise level for arrivals[5]. Thus, in summary, the two qualifying levels were:

For departures: Ld = [EPNL(lateral) + EPNL(flyover)]/2

For arrivals: La = EPNL(approach) - 9

The QC ratings were then assigned according to the following table:

Qualifying level	QC Classification
Greater than 101.9 EPNdB	16
99 - 101.9 EPNdB	8
96 - 98.9 EPNdB	4
93 - 95.9 EPNdB	2
90 - 92.9 EPNdB	1
Less than 90 EPNdB	0.5
Less than 87 EPNdB	Exempt[6]

3 RE-ANALYSIS OF THE RELATIONSHIP BETWEEN CERTIFICATED NOISE LEVELS AND QC CLASSIFICATIONS

3.1 Critics have asserted that the 9 EPNdB adjustment understates the impact of approach noise for at least three reasons:

(1) the improved climb performance of modern twin-jet aircraft (together with the replacement of many 4-jet aircraft by twins), is likely, on average, to shrink departure footprints;

(2) equating the footprint areas ignores the fact that a substantial part of the departure footprint falls on airport land (unlike approach noise); and

(3) even when their 90 dBA footprint areas are equal in area, noise levels inside the arrival footprints are greater.

All three factors would give more weight to arrival noise impact than is allowed for by the 9 EPNdB adjustment. These concerns have therefore been addressed in the new analysis.

3.2 A further technical limitation of **Figure 2** was that the noise levels at the certification points were operational SELs (averages as defined by the noise contour model) rather than certificated EPNLs (on which the QC classifications are based). At the time, little reliable information was available on the relationship between certificated

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[5] Figure 2 showed that for equal footprint areas, the corresponding levels were more than 10 dBA apart (e.g. reading from the graph, a footprint area of 1 km^2 corresponds to an approach level of 94 dBA but a departure level of about 83 dBA). An adjustment of 9 EPNdB was adopted so as not to understate the relative significance of approach noise and because it is an integer multiple of the QC class interval of 3 EPNdB.

[6] Exempt aircraft are those which, on the basis of their noise certification data, are classified at less than 87 EPNdB and, in the case of jet aircraft, also have a maximum certificated take-off weight not exceeding 11,600 kg.

EPNLs and operational SELs at the certification points and it could only be assumed that the slopes and spacing of the lines in **Figure 2** would be replicated if the noise levels could have been plotted as EPNLs instead. This difference has also been investigated in the new analysis.

3.3 A basis of the original analysis which has been retained is that noise 'impact' can be defined in terms of footprint area. This measure is not unique; numerous alternatives could be envisaged. However none are considered to be better; footprints provide clear and simple illustrations of the patterns of noise around aircraft flight paths and the enclosed areas are firmly related to noise energy which in turn defines the contributions single aircraft movements make to the Leq contours. Footprints are commonly used in scientific and technical literature for comparing the noise performance of different aircraft types. In this analysis, as before, the 90 dBA SEL footprints were used. Research published since the original analysis was completed (**Ref 4**) has confirmed that this level is a significant threshold of sleep disturbance and is thus a logical criterion for this study.

3.4 The resources which now allow a much more relevant and accurate analysis to be conducted than in 1991 include (i) a substantially enhanced aircraft noise model (**Ref 5**) and its associated database, (ii) a comprehensive NTK-derived database linking certificated EPNLs to actual aircraft movements and (iii) a Geographic Information System (GIS) graphics package for describing the airport boundaries. There are two key differences from the original analysis.

1) The aircraft types and categories are entirely Chapter 3, many of them high performance twins. In 1991 aircraft that dominated the noise exposures around the airports were Chapter 2 types with substantially different performance and noise characteristics.

2) The reference point noise levels are determined from official certificated noise levels in EPNL, not A-weighted SELs from the same noise model that produced the footprints.

3.5 In practice, the noise footprints generated by a particular aircraft, like the noise levels at particular points under the flight path, vary markedly from flight to flight - due to variations in aircraft weight and weather conditions. And different operators of the same aircraft type often use different operating procedures; these too can have a strong influence on the footprints. Thus, even if it were possible to determine footprints for individual flights (and this is quite impracticable), their enclosed areas would vary enormously. It is thus necessary to consider averages.

3.6 As before aircraft are categorised by type, i.e. by manufacturer and model and in some cases by variant. The categories are 20 of those represented in the ANCON database as follows:

Boeing 737-300
Boeing 737-600
Boeing 737-800
Boeing 747-200 Chapter 3
Boeing 747-400
Boeing 757-200 (with PW2037/2040 or RB211-535C engines)
Boeing 757-200 (with RB211-535E4 engines)
Boeing 767-200
Boeing 767-300
Boeing 777-200
BAe 146
Canadair Regional Jet
Airbus A310
Airbus A319/320/321
Airbus A330
Airbus A340
Embraer Regional Jet
Chapter 3 executive jets
Fokker 100
Boeing MD11

These aircraft represent the majority (86%) of aircraft movements at the designated airports Heathrow, Gatwick and Stansted.

3.7 For each of these type categories, ANCON (Version 2.2) was employed to calculate the average 90 dBA SEL footprints for arrivals and departures at each of the three airports. The results differ between airports because the mix of aircraft variants, operators (and hence operating procedures) and weights differ. In fact, the ANCON database is constructed and maintained to represent the average type at each airport as accurately as possible. The data describes the mean flight profile - the variations of height, speed and engine power along the flight track - and the noise emission as a function of power, for arrivals and departures. The footprints calculated using ANCON represent the best possible estimates of the contribution of each aircraft type to the current total noise impact around the airports.

3.8 Certificated noise levels are available from the certification authorities (e.g. the FAA in the USA and the CAA in the UK) for each individual aircraft type, model and variant (including engine fit). Particular ANCON categories (or classes) usually embrace more than one aircraft variant whose certificated EPNLs differ (although precautions are taken to ensure that the grouped variants have very similar noise performance characteristics). To take proper account of this, the average EPNLs for each ANCON class were calculated as weighted averages of the official certificated levels for each of the variants. The weighting was the number of movements of the variant expressed as a percentage of all movements of the type at the airport. The actual certificated levels for each individual aircraft were identified via its tail number.

3.9 **Figure 4** shows the 'raw' results for all three airports plotted together. The vertical axis, as before is the gross footprint area; i.e. no account has been taken of airport land within the footprints. This updates **Figure 2** in that (a) it covers the current aircraft fleet which is very different from that analysed in 1991 and (b) the current ANCON model is more reliable than its predecessor. Also it overcomes one of the limitations of the 1991 analysis by expressing the aircraft noise levels (horizontal axis) in terms of actual (average) certificated EPNLs for each ANCON class rather than average operational SELs.

3.10 There are many more data points in **Figure 4** than in **Figure 2** but these are also more scattered. The additional scatter, which was expected, is caused by two main factors:

(1) Different derivation of reference point noise level. In the 1991 analysis (**Figure 2**), these were SELs calculated using the same noise model that was used to generate the SEL footprints. Thus the reference event levels and the footprint areas had a common source. In the new analysis (**Figure 4**), the sources are independent: the footprint areas were calculated using ANCON but the reference point levels are average certificated noise levels in EPNL determined by the aircraft manufacturer via standard noise certification procedures. As in-service operating procedures are different from those used for certification, so certificated EPNLs differ from the operational EPNLs that would be comparable with the SELs in **Figure 2**. Operating procedures also vary between aircraft types and between operators.

(2) Different footprint and noise event level metrics. In **Figure 2** the footprints and arrival and departure event levels were defined in the same SEL units. In **Figure 4** they are different; the footprints are still calculated in SEL (the basic 'building block' of Leq) but the event levels are in EPNL (used for certification). EPNL and SEL are highly correlated noise level metrics but they are not identical and the differences (EPNL-SEL) vary somewhat.

3.11 Aside from the higher scatter, another difference in the new diagram is that the best-fit straight (regression) lines have smaller slopes: 0.90 vs 0.92 for arrivals and 0.67 vs 0.91 for departures. The small difference for arrivals is probably just a consequence of the greater scatter of the data. However, the difference for departures is substantial and suggests a fundamentally different relationship between the reference point noise levels and the footprint areas; namely that the footprint areas grow less rapidly with source noise energy than previously.

3.12 This is primarily a result of differences between operational and certification departure climb profiles - which have grown because of the improved performance of modern aircraft. For certification, the test aircraft takes off and climbs as quickly as possible. But just before reaching the flyover point, the engine power is cut back sufficiently to maintain a safe rate of climb but also to minimise the flyover noise. In normal operation, aircraft cut back as soon as possible to minimise engine wear and tear but not usually as deeply as for certification - in order to reach economical cruising height as efficiently as possible. This generally means that the operational flyover noise level is higher than in certification. Differences tend to be greater for smaller, less noisy aircraft, which generally have two engines and are therefore capable of climbing relatively steeply after take-off and can therefore achieve relatively low flyover EPNLs under certification procedures.

3.13 Confirmation of this comes from the results of the EPNL monitoring study (**Ref 6**) to compare operational and certificated noise levels. **Figure 5** plots average operational EPNLs at the flyover reference point with the certificated flyover EPNLs for 20 aircraft types. (In this case only the operational levels are averaged - over a large number of measurements; the aircraft are specific model variants at specific certificated weights which have unique certification EPNLs.) The differences between operation and certification are the vertical displacements of the data points from the diagonal (equality) line. These evidently tend to increase at lower EPNLs.

3.14 The differences between **Figures 2 and 4** would suggest that the differential - between departures and arrivals - is now greater for smaller footprints:

	1991 ANALYSIS	NEW ANALYSIS
Difference at 10 km^2	11 dBA	11 EPNdB
Difference at 1 km^2	11 dBA	14 EPNdB

The likely explanation for this is that the climb performance of the earlier jets was generally poorer than today's and, moreover, did not differ so markedly between lighter short range aircraft and heavier long range types.

3.15 But, like **Figure 2**, **Figure 4** also disregards the effect of airport land; those parts of the footprints that lie within the airport boundaries and may be considered not to have a community impact. This is corrected in **Figure 6** in which net footprint areas are overlaid on the gross areas plotted in **Figure 4**. For each airport, footprints were calculated for nominal straight-out departure tracks from each runway (for both directions). Net areas were calculated by subtracting any enclosed airport land area from the gross figures. The results were then averaged across all runways. Thus each 'net' datapoint in **Figure 6** represents one aircraft type at one airport. Of course very small noise footprints fall mostly within the airport boundary so that their net areas approach zero. To avoid the severe non-linearities which this introduces into the relationships between net footprint area and EPNL, areas of less than 0.1 km^2 have been omitted from **Figure 6** and the corresponding regression analysis.

3.16 It is apparent that the area correction has a substantial effect upon the mean relationships, especially for departures where much of the noise generated during the take-off and initial climb falls on airport land. The adjustment is thus greater for quieter aircraft for which the take-off noise represents a greater proportion of the total footprint areas. As a consequence, the two net area regression lines are essentially parallel (the slopes are 1.03 for departures and 1.09 for arrivals) and their horizontal separations at 1 km^2 and 10 km^2 are equal at 9 EPNdB (to the nearest decibel).

3.17 It is therefore concluded that when the deficiencies of the original analysis (identified at the beginning of this section) are remedied, the mean relationships between certificated EPNLs and the net 90 dBA SEL footprint areas are quite consistent with those inherent in the QC system, namely a doubling of impact per 3 EPNdB and a difference of 9 EPNdB for arrivals and departures. This does not mean that this new analysis confirms the integrity of the original analysis. Rather it appears to have demonstrated that the effects of two deficiencies of the original study, namely (i) the neglect of airport land and (ii) the unjustified assumption that certificated EPNLs and operational SELs are equivalent footprint indicators, turn out to be somewhat self-cancelling. However, a residual difference is that whereas the existing 'differential' of 9 EPNdB was adopted as a cautious application of a measured 11 dBA, the measured mean differential is now truly 9 EPNdB. This 2 EPNdB shift may be attributed to the fact that the reductions of departure noise achieved by modern Chapter 3 aircraft have not been matched by equal reductions of approach noise.

3.18 It is equally obvious that the scatter of the new data points in **Figures 4 and 6** is substantially greater than that of the original data in **Figure 2** so that, inevitably, the fit of the regression lines is less good (meaning that deviations of individual aircraft from the means are generally larger). Without changes to the noise certification procedure itself, the correlation could only be improved by using a much more elaborate index of footprint area than the simple 'qualifying EPNLs'. This index would have to take detailed account of variations in aircraft operating procedures and differences between airport layouts. Although theoretically possible, it would be too complex for routine application by airport staff and others administering the QC system and to explain to the public.

3.19 Despite the inherent variance, the results of this analysis indicate that the existing QC system remains appropriate as a practical means of classifying aircraft noise impact for quota purposes - insofar as it is thought unlikely that any alternative simple-to-determine classifications would better indicate the footprint-based noise impact of modern aircraft.

3.20 **Figure 6** summarises the evidence that would support the continued use of the existing QC system, i.e. the slope of the lines that makes 3 EPNdB correspond to a two-fold change of QC number and a 9 EPNdB separation between the arrival and departure lines. However, it is necessary to consider how this might best be presented in order to convey to the affected parties, as clearly as possible, the strengths and weaknesses of the system.

3.21 One way is illustrated in **Figure 7** which is a replotted 'scatter diagram' of net footprint area against reference EPNL. For arrivals, the reference EPNL is the certificated approach level and, for departures, it is the arithmetic average of the certificated lateral and flyover levels. Two envelopes of area vs. EPNL are drawn to encompass most of the data points (those which fall significantly below the departure envelope are in the QC 'exempt' category). The upper boundaries of the envelopes can be taken as nominal linear relationships between footprint area (again presented on a logarithmic scale) and 'reference EPNL'. These lines equate a net footprint area of 10 km^2 to the upper boundary of the QC/2 band for which the reference EPNLs are 96 EPNdB for departures and 105 EPNdB for arrivals. The corresponding area limits for adjacent bands change by factors of 2; i.e. 1.25, 2.5, 5, 10, 20 and 40 km^2 for QC ratings QC/0 (Exempt), QC/0.5, QC/1, QC/2, QC/4 and QC/8 respectively. These numbers simply illustrate normalised trends (statistical best-fit lines are shown in **Figure 6**); the 5 EPNdB-wide envelopes highlight the large variations of net footprint area within any QC class. As stressed above, this is an unavoidable consequence of the imperfections of noise certification and the vagaries of normal day-to-day aircraft operations.

4 COMPARISON OF ARRIVAL AND DEPARTURE FOOTPRINTS FOR THE SAME QC CLASSIFICATION

4.1 The updated analysis described above has still taken no explicit account of noise level variation within the footprints and it is evident that, given the different 'qualifying' EPNLs, levels within the 90 dBA footprints must - at least somewhere - be greater for arrivals than for departures.

4.2 To show that this is indeed the case, some illustrative arrival and departure footprints have been calculated for both 2-engine and 4-engine aircraft flight profiles and are compared in **Figures 8 to 11**. The four figures depict some westerly departures and easterly arrivals at the three airports. For each QC category, these have the same net areas for both arrivals and departures. They are specific to particular airports and runway directions and assume straight flight tracks. The outer 90 dBA SEL footprints have, variously, net areas of 2, 4, 8 and 16 square km (which lie towards the upper limits of QCs 0.5, 1, 2 and 4 in **Figure 7**).

4.3 In each diagram footprints are drawn at 1 dBA SEL intervals, starting from the outer one of 90 dBA SEL. Departure footprints are coloured green, arrivals blue. Those coloured red show where arrival noise reaches higher levels than departure noise. Over airport land only the outermost footprint is shown.

4.4 It is evident that the excesses (of arrival SELs over departure SELs) vary in extent and are relatively more significant at lower QCs, i.e. smaller 90 dBA SEL footprints. This is attributable to the greater climb gradients of the smaller (less noisy) aircraft - for these the flyover levels are proportionately lower so that (as their descent gradients are unchanged) the difference between flyover and approach levels increase. **Table 1** gives relevant statistics for the same illustrative footprints depicted in **Figures 8 to 11** - specifically:

(a) the average SELs within the net 90dBA SEL footprints (and the differences), and

(b) the percentages of the footprint areas within which SEL is greater for arrival than anywhere under the corresponding departure footprint.

4.5 The differences between the average levels within the arrival and departure footprints are relatively small and certainly very much less than 9 dBA; they lie in the range from 0.35 to 0.57 dBA for QC/2 and QC/4 operations and from 0.8 to 1.13 dBA for QC/0.5 and QC/1 operations. **Figures 8 to 11** show that locally the excesses reach between 5 and 9 dBA but they are confined to relatively small areas close to the airport boundary. For QC/2 and QC/4 operations the excesses cover less than 4% of the net footprint areas. For the QC/0.5 and QC/1 operations excesses extend further - by up to 16% of the footprint area.

5 CONCLUSIONS

5.1 The limited 1991 analysis from which the QC system was derived has been repeated using modern aircraft data and noise contour methodology. This has shown that the system - the method by which aircraft QC classifications are determined from official certificated noise levels - remains appropriate insofar as it is thought unlikely that any alternative simple-to-determine classifications would better indicate the footprint-based noise impact of modern aircraft.

5.2 The analysis also confirmed that, although arrivals and departures with the same footprint areas (and thus QC classifications) have reference EPNLs which differ by 9 EPNdB on average, the areas within which levels under the approach path exceed those reached under the departure path are relatively small.

5.3 Ultimately the reliability of any classification system based on certification depends on the correlation between certificated and operational noise. This in turn is affected by differences in the aircraft operating procedures followed in certification and normal airline service. These differences inevitably affect the reliability of the QC system. It is possible that might be improved by future amendments to the aircraft noise certification scheme - specifically to change the manner in which flyover noise is determined. ICAO has already established a special CAEP task group to investigate whether and how Annex 16 certification might be improved. It is recognised that there are important lessons for that study from the UK's experience of operating the QC system.

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TABLE 1: AVERAGE LEVELS WITHIN NET 90 dBA SEL FOOTPRINTS
& PERCENTAGE OF ARRIVAL FOOTPRINT IN WHICH MAX DEPARTURE SEL EXCEEDED

Gatwick		Heathrow		Stansted	
QC0.5 (twin): 2 sq km					
26Ldep: Avge SEL, dBA	92.36				
08R Arr: Avge SEL, dBA	93.35				
Difference (Arr - Dep), dB	0.99				
Arrival area at higher level, sq km	0.16				
Percentage of arr footprint area	8.0%				
QC1 (twin): 4 sq km		**QC1 (twin): 4 sq km**		**QC1 (twin): 4 sq km**	
26Ldep: Avge SEL, dBA	92.93	27L dep: Avge SEL, dBA	92.42	23 Dep: Avge SEL, dBA	92.76
08R Arr: Avge SEL, dBA	93.73	09R Arr: Avge SEL, dBA	93.55	05 Arr: Avge SEL, dBA	93.60
Difference (Arr - Dep), dB	0.80	Difference (Arr - Dep), dB	1.13	Difference (Arr - Dep), dB	0.84
Arrival area at higher level, sq km	0.64	Arrival area at higher level, sq km	0.57	Arrival area at higher level, sq km	0.28
Percentage of arr footprint area	15.9%	Percentage of arr footprint area	14.3%	Percentage of arr footprint area	6.9%
QC2 (quad): 8 sq km				**QC2 (quad): 8 sq km**	
26Ldep: Avge SEL, dBA	93.54			23 Dep: Avge SEL, dBA	93.20
08R Arr: Avge SEL, dBA	93.89			05 Arr: Avge SEL, dBA	93.61
Difference (Arr - Dep), dB	0.35			Difference (Arr - Dep), dB	0.41
Arrival area at higher level, sq km	0.14			Arrival area at higher level, sq km	0.24
Percentage of arr footprint area	1.8%			Percentage of arr footprint area	3.0%
QC4 (quad): 16 sq km		**QC4 (quad): 16 sq km**			
26Ldep: Avge SEL, dBA	93.93	27R dep: Avge SEL, dBA	93.74		
08R Arr: Avge SEL, dBA	94.28	09L Arr: Avge SEL, dBA	94.31		
Difference (Arr - Dep), dB	0.35	Difference (Arr - Dep), dB	0.57		
Arrival area at higher level, sq km	0.14	Arrival area at higher level, sq km	0.19		
Percentage of arr footprint area	0.9%	Percentage of arr footprint area	1.2%		

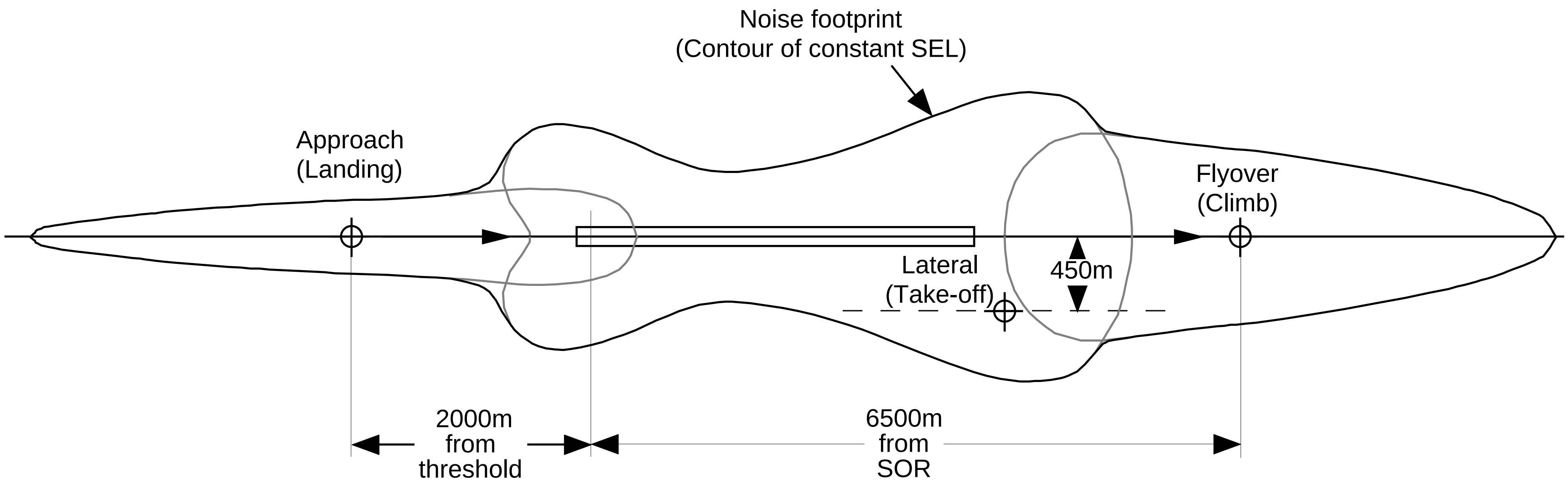


FIGURE 1 - AIRCRAFT NOISE CERTIFICATION MEASUREMENT POINTS IN RELATION TO ILLUSTRATIVE NOISE FOOTPRINTS

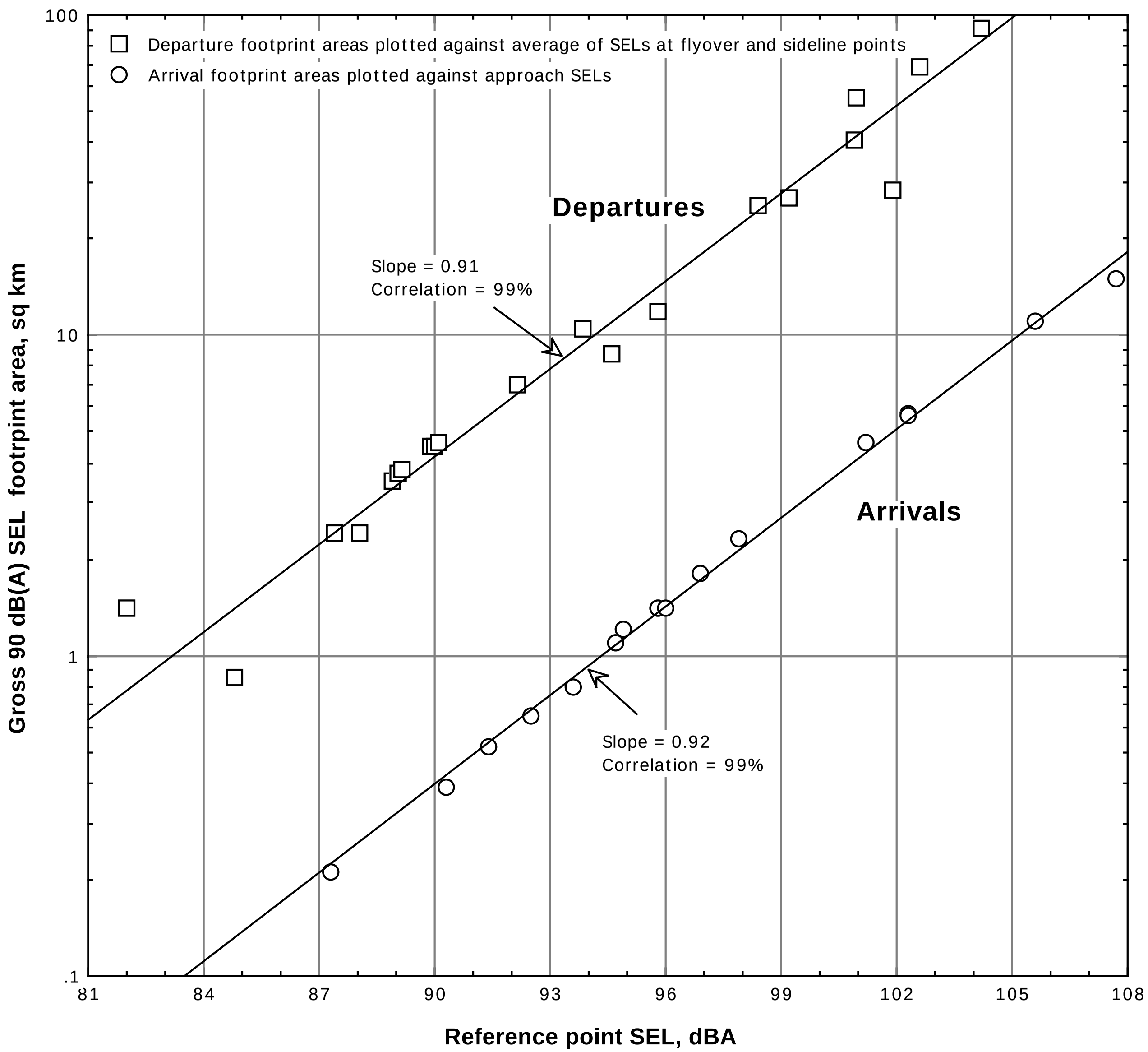


FIGURE 2: RELATIONSHIPS BETWEEN IN-SERVICE AVERAGE GROSS FOOTPRINT AREAS AND AVERAGE SELs AT CERTIFICATION POINTS: 1991 ANALYSIS

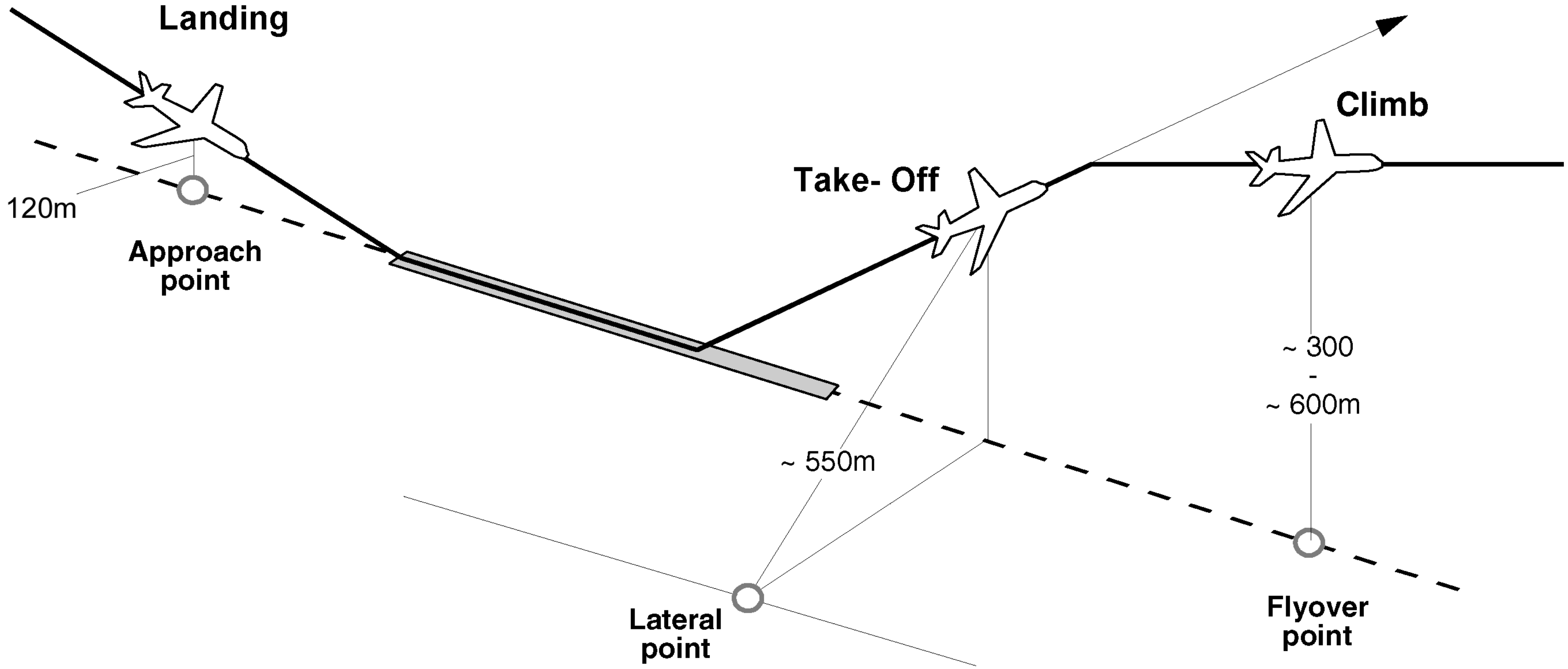


FIGURE 3: DISTANCES BETWEEN THE AIRCRAFT AND THE REFERENCE POINTS

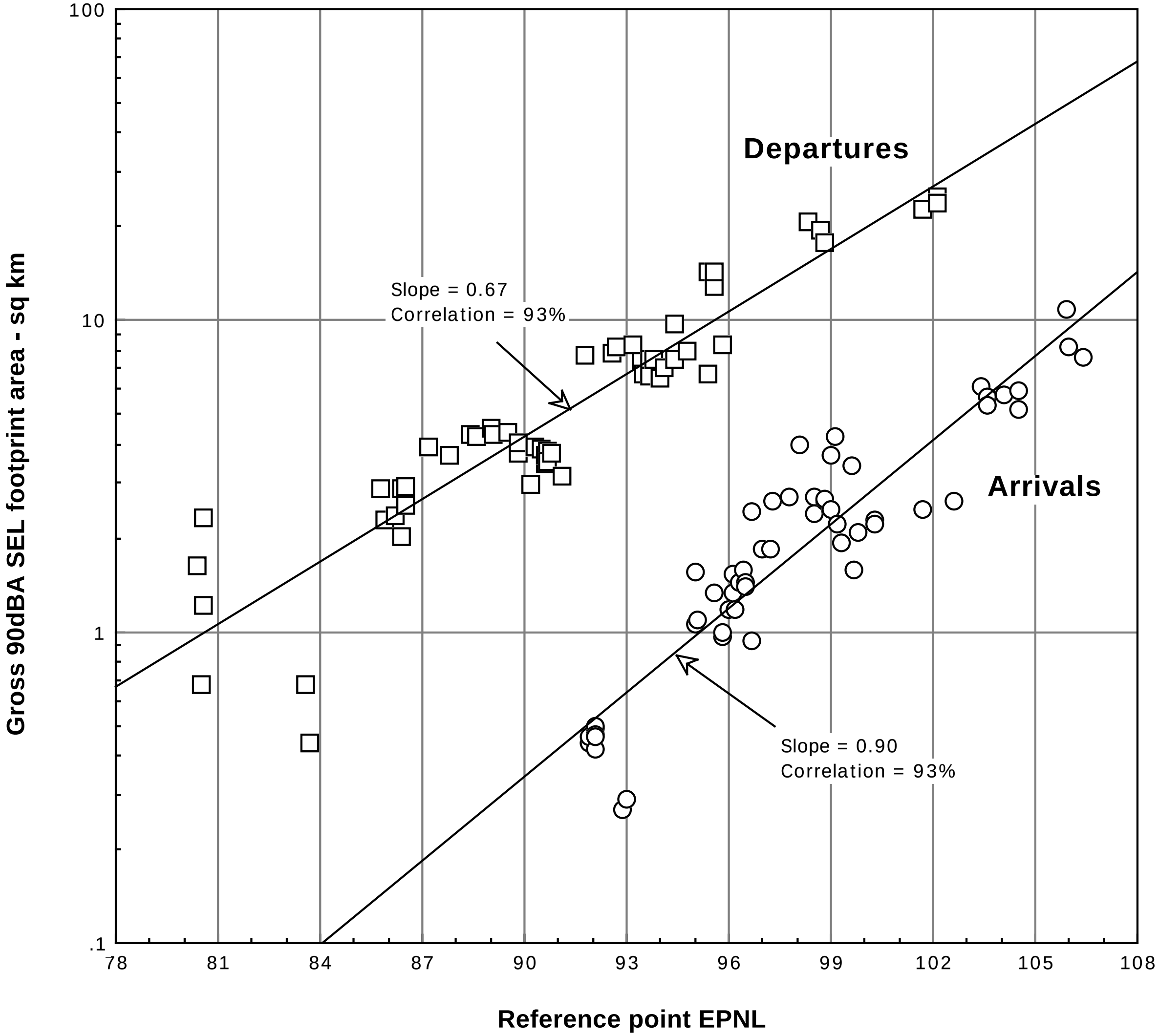


FIGURE 4: RELATIONSHIPS BETWEEN IN-SERVICE AVERAGE GROSS FOOTPRINT AREAS AND AVERAGE CERTIFICATED EPNLS (NEW ANALYSIS)

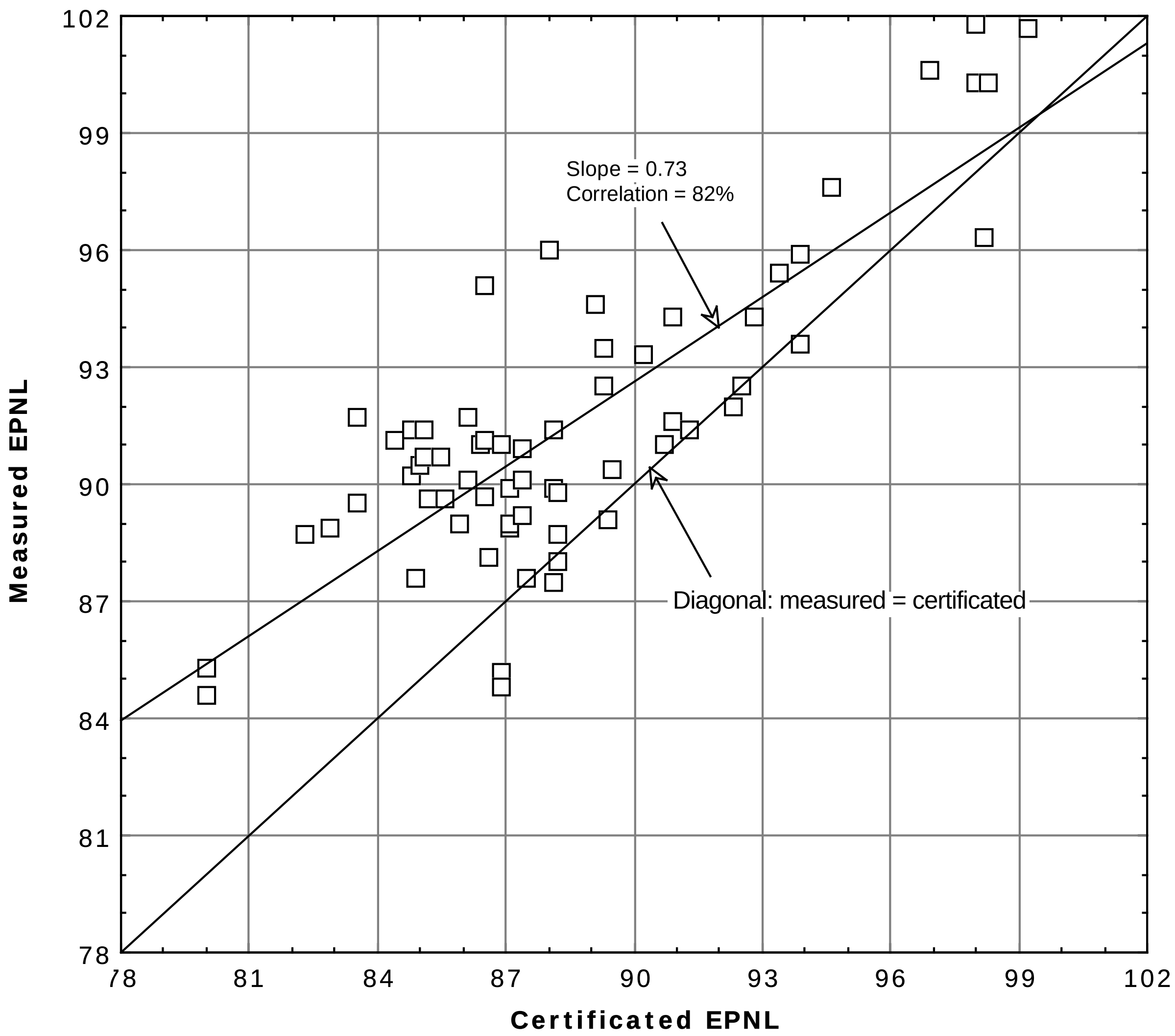


FIGURE 5: RELATIONSHIP BETWEEM MEASURED AND CERTIFICATED FLYOVER EPNLs

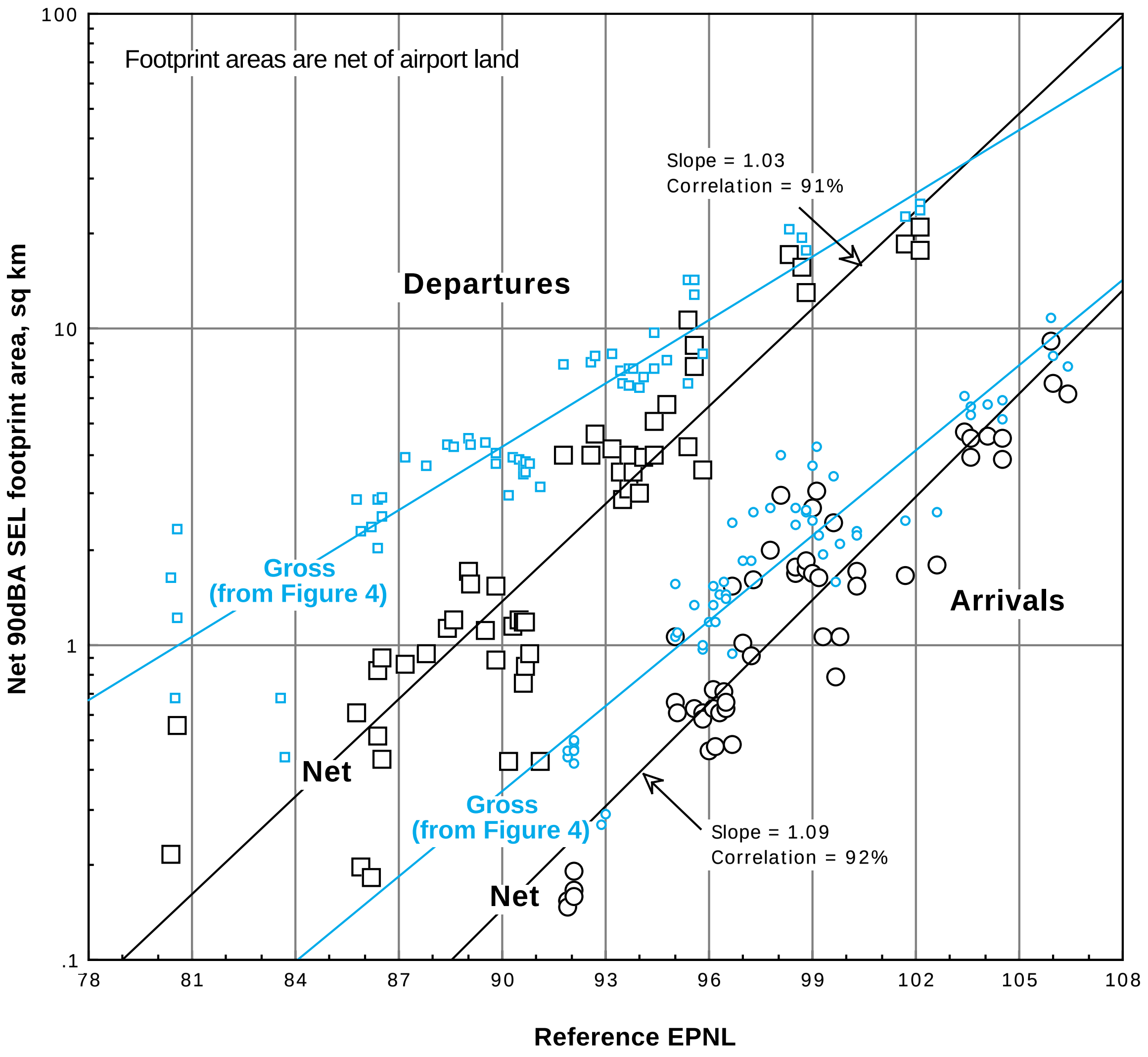


FIGURE 6: COMPARISON OF NET AND GROSS FOOTPRINT AREAS vs REFERENCE EPNLs

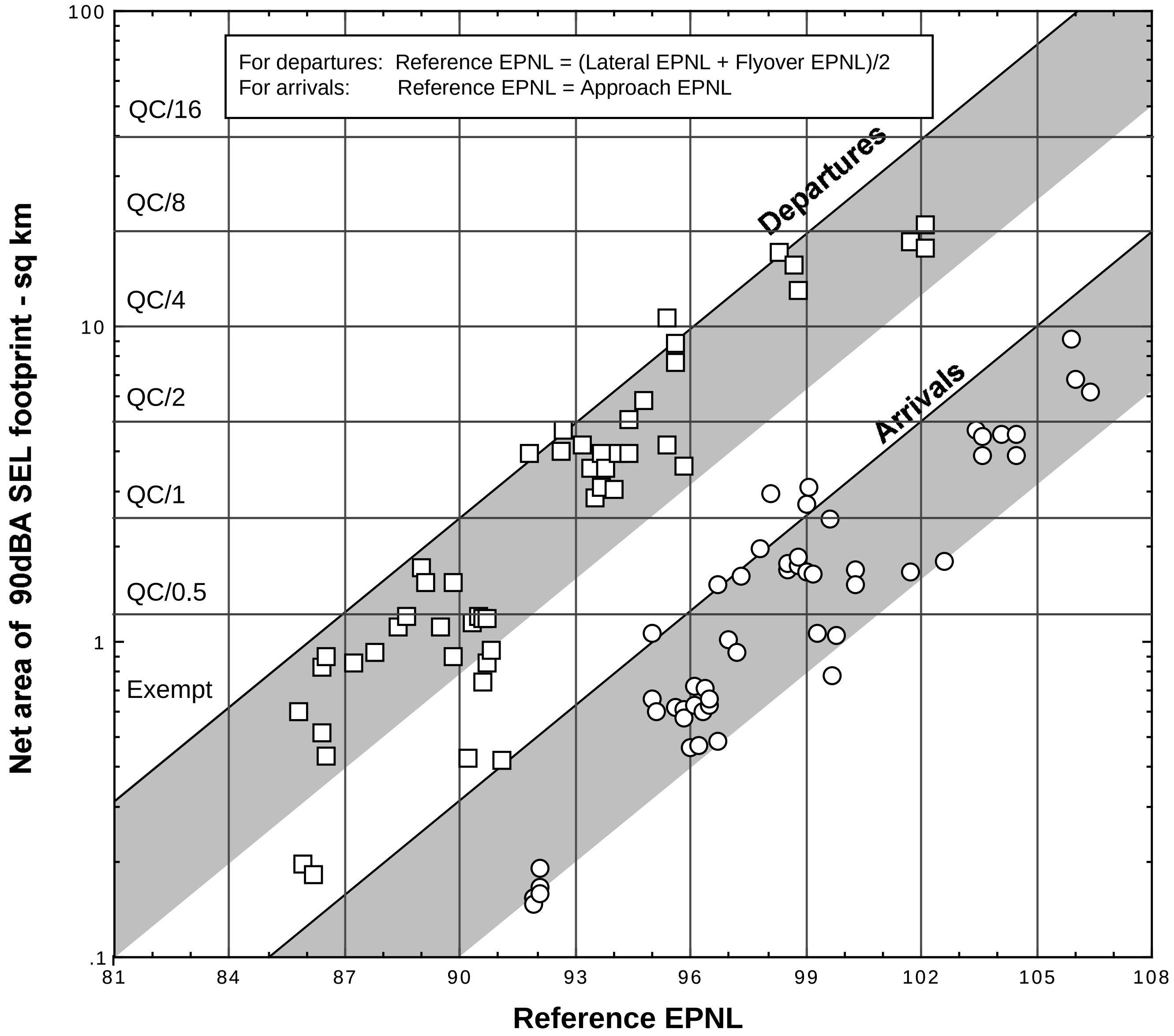


FIGURE 7: RELATIONSHIPS BETWEEN NET FOOTPRINT AREAS AND REFERENCE (CERTIFICATED) EPNLs

FIGURE 8: EXAMPLE QC1 AND QC4 FOOTPRINTS AT HEATHROW

90 dBA SEL contours and higher in 1 dB steps

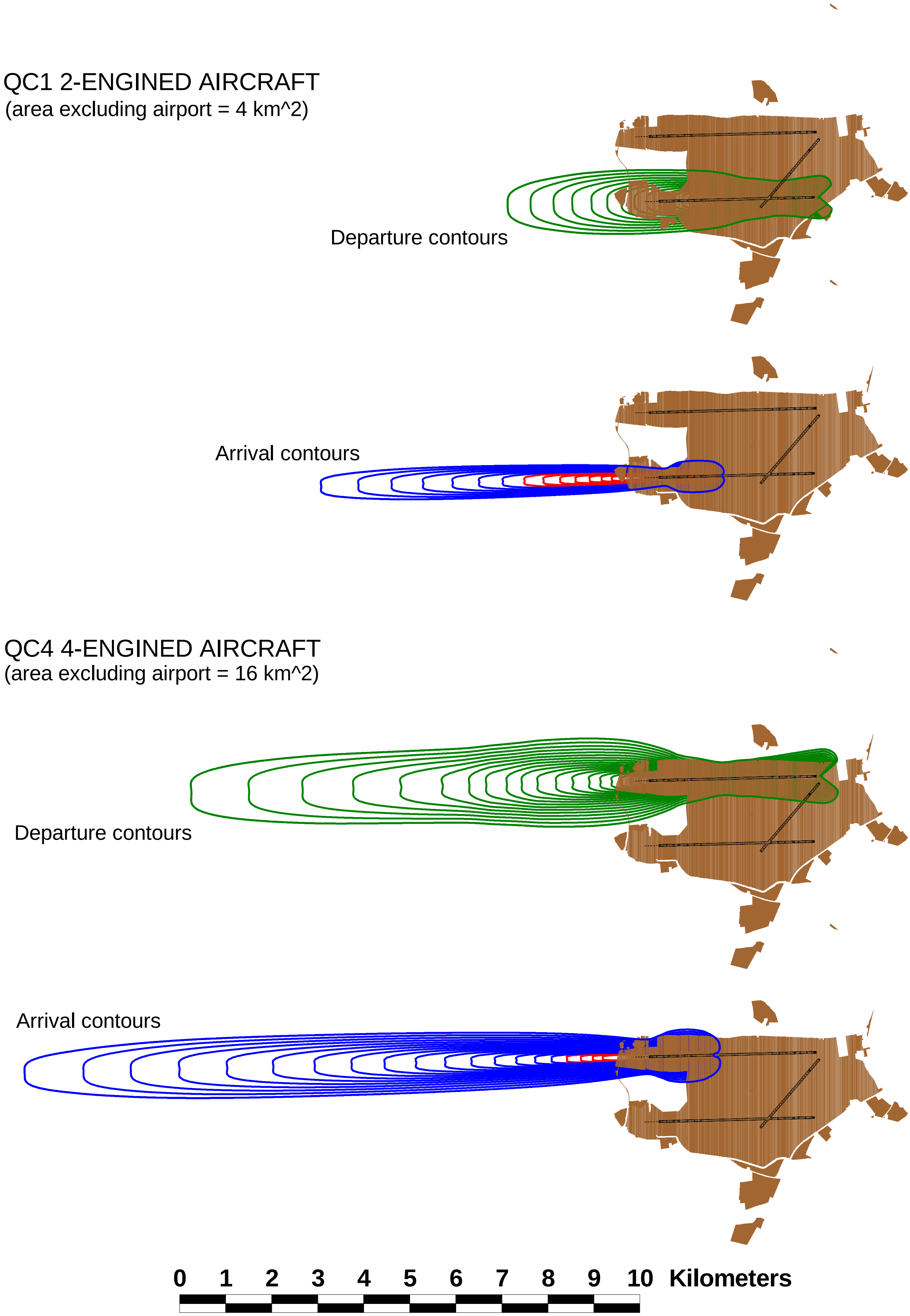
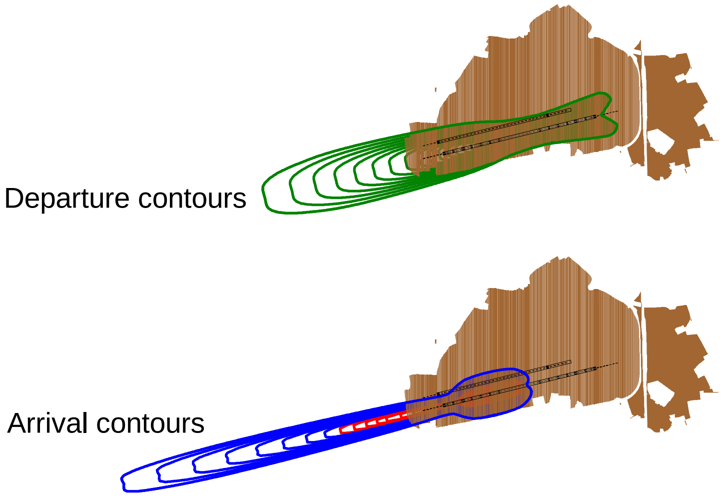


FIGURE 9: EXAMPLE QC0.5 AND QC2 FOOTPRINTS AT GATWICK

90 dBA SEL contours and higher in 1 dB steps

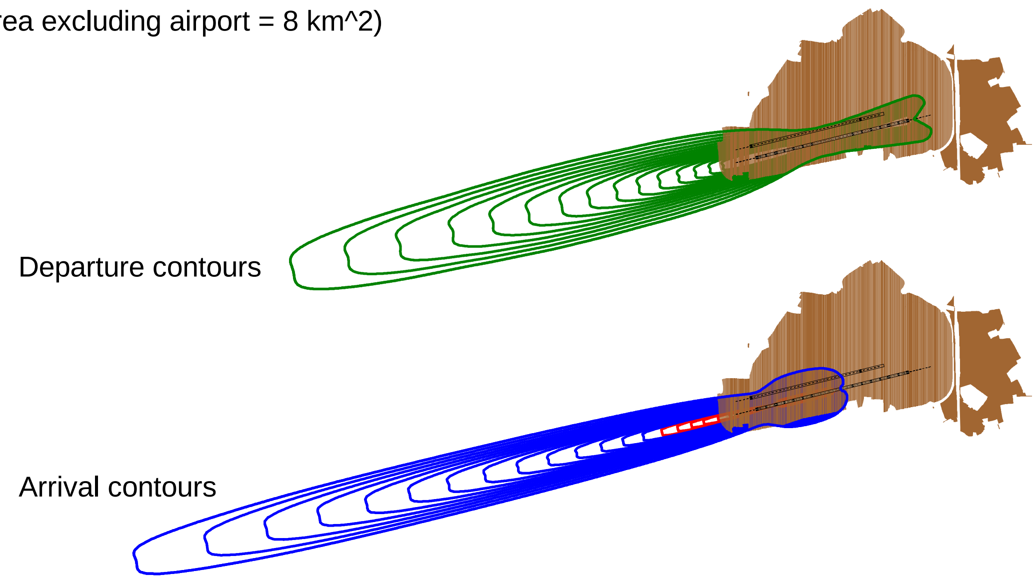
QC0.5 2-ENGINED AIRCRAFT

(area excluding airport = 2 km^2)



QC2 4-ENGINED AIRCRAFT

(area excluding airport = 8 km^2)



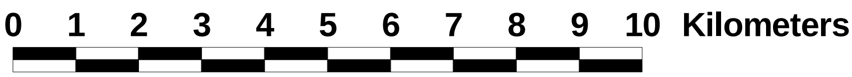


FIGURE 10: EXAMPLE QC1 AND QC4 FOOTPRINTS AT GATWICK

90 dBA SEL contours and higher in 1 dB steps

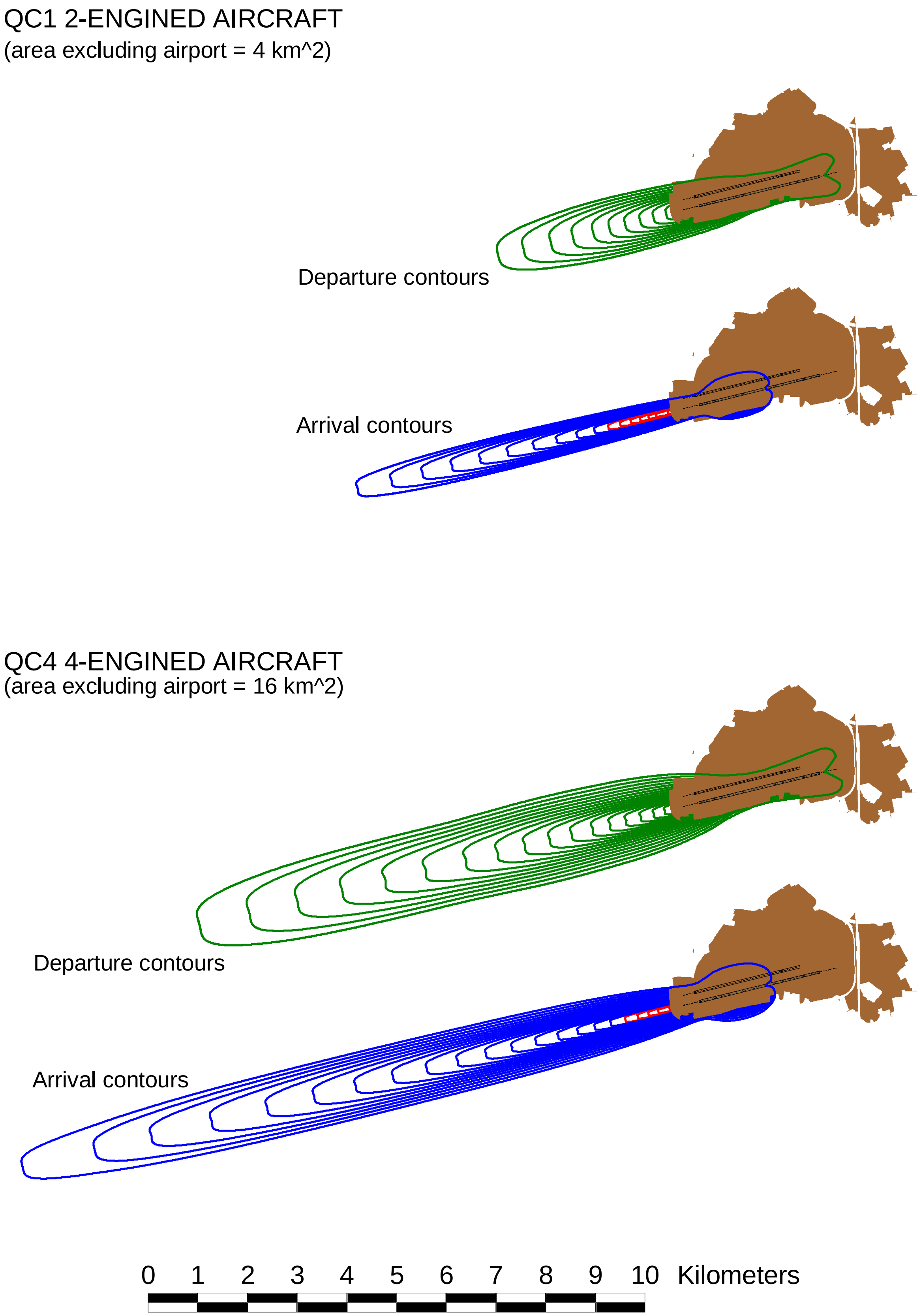


FIGURE 11: EXAMPLE QC1 AND QC2 FOOTPRINTS AT STANSTED

90 dBA SEL contours and higher in 1 dB steps