BRISBANE AIRPORT

BALMORAL SHORT-TERM NOISE MONITORING

REPORT NO. 17141-A1
VERSION 1.0

JULY 2022

PREPARED FOR

BRISBANE AIRPORT CORPORATION PTY LTD
11 THE CIRCUIT
BRISBANE AIRPORT QLD 4008

DOCUMENT CONTROL

Version	Notes	Status	Date	Prepared	Reviewed	Approved
1.0	-	Final	21/07/2022	Adam Bioletti		ADB

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GLOSSARY OF TERMS

L_{Amax}	The maximum noise level over a sample period is the maximum level measured during the sample period. For aircraft noise, the maximum noise level is measured using slow response.
RNP-AR	Required Navigation Performance Authorisation Required (RNP-AR) is a precision arrival or departure procedure which uses satellite navigation. RNP-AR is typically developed to provide a shortened arrival procedure (as is the case at Brisbane Airport).
ILS	Instrument Landing System is a radio navigation system. ILS is typically available in most weather conditions, including poor conditions that may prohibit some other navigation methods. ILS require a long, straight arrival path.
CNE	Correlated Noise Events (CNE) are events recorded in the noise monitoring data that are correlated with a simultaneous aircraft operation nearby, for which valid air traffic surveillance data has also been collected.

AIRCRAFT TYPES AND ABBREVIATIONS

737-800	Boeing 737–800 (narrow body jet)
737-700	Boeing 737-700 (narrow body jet)
737-300	Boeing 737-300 (narrow body jet)
717-200	Boeing 712-200 (narrow body jet)
A320-200	Airbus A320-200 (narrow body jet)
A330-300	Airbus A330-300 (wide body jet)
A350-900	Airbus A350-900 (wide body jet)
F100	Focker 100 (narrow body jet)
F70	Focker 70 (narrow body jet)
DH8D	DeHavilland Dash 8 (turbo propeller)
SF34	Saab 340 (turbo propeller)
BE20	Beech 200 Super King Air (turbo propeller)
B350	Beech 350 Super King Air (turbo propeller)

1 INTRODUCTION

Brisbane Airport operates a north-south oriented parallel runway system. The system comprises the legacy runway, Runways 01R/19L, and the new runway, Runways 01L/19R.

Brisbane Airport Corporation (BAC) engaged Envirosuite to undertake short-term noise monitoring in Balmoral in response to community concerns that noise levels from the permanent noise monitor in Bulimba are not representative of noise levels in the elevated Balmoral area. SoundIN Pty Ltd (SoundIN) has been engaged by BAC to review and analyse the results of that noise monitoring. This report details the results of that analysis.

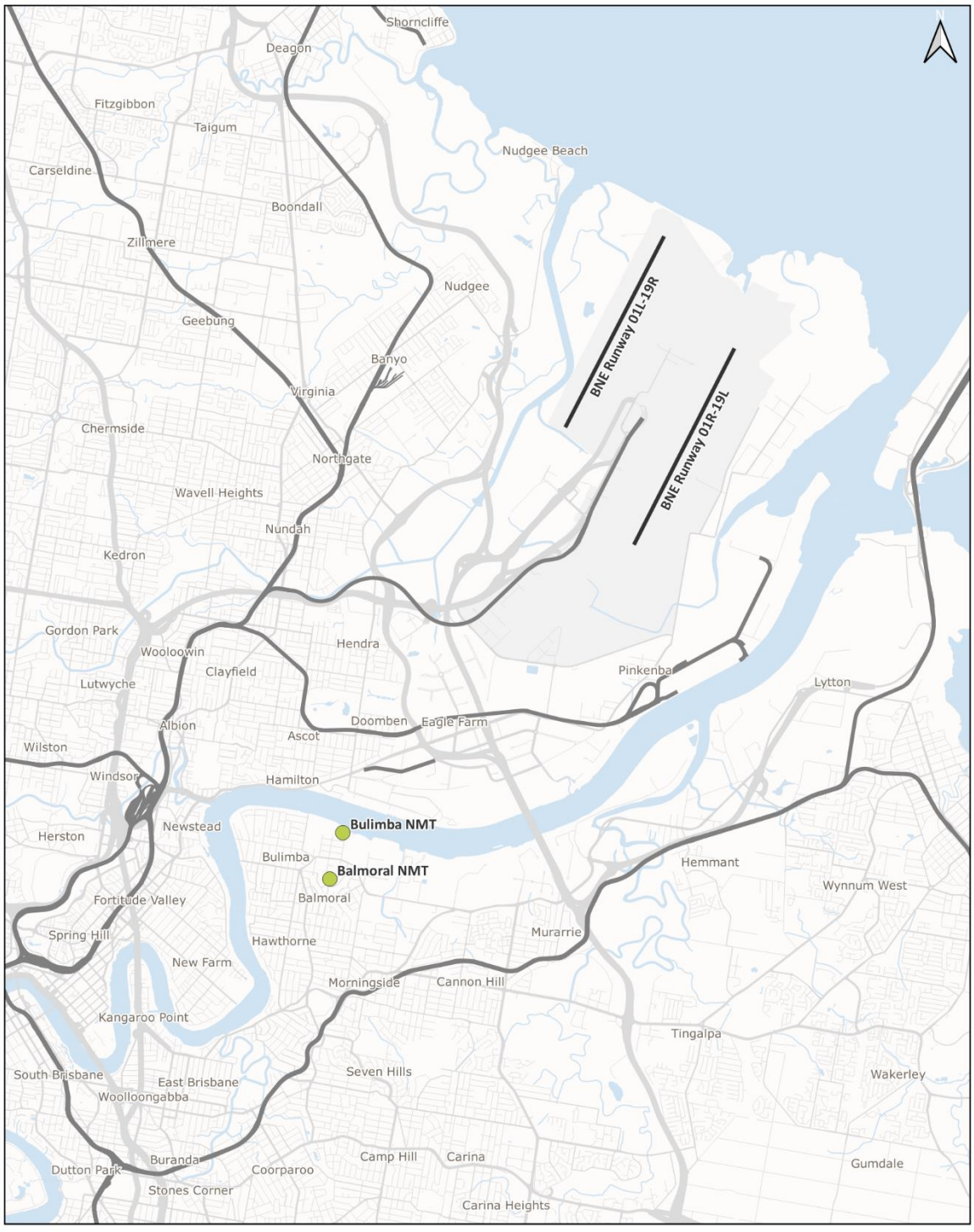
Short-term noise monitoring is periodically undertaken by BAC at locations surrounding the airport based on community feedback. This short-term noise monitoring augments the permanent Noise and Flight Path Monitoring System (NFPMS) operated by Airservices Australia (Airservices).

The short-term monitoring detailed in this report was undertaken for the purposes of:

- Recording the aircraft noise levels at the Balmoral site from aircraft arriving and departing from Brisbane Airport;
- Recording the relative altitude of aircraft overflying the Balmoral area;
- Comparing measured noise levels from the Balmoral site with those measured at the permanent NFPMS noise monitor site located nearby at Bulimba.

Brisbane Airport and the Balmoral and Bulimba noise monitoring sites are indicated in **Figure 1-1**.

Figure 1-1 Site Locality



2 NOISE MONITORING DESCRIPTION

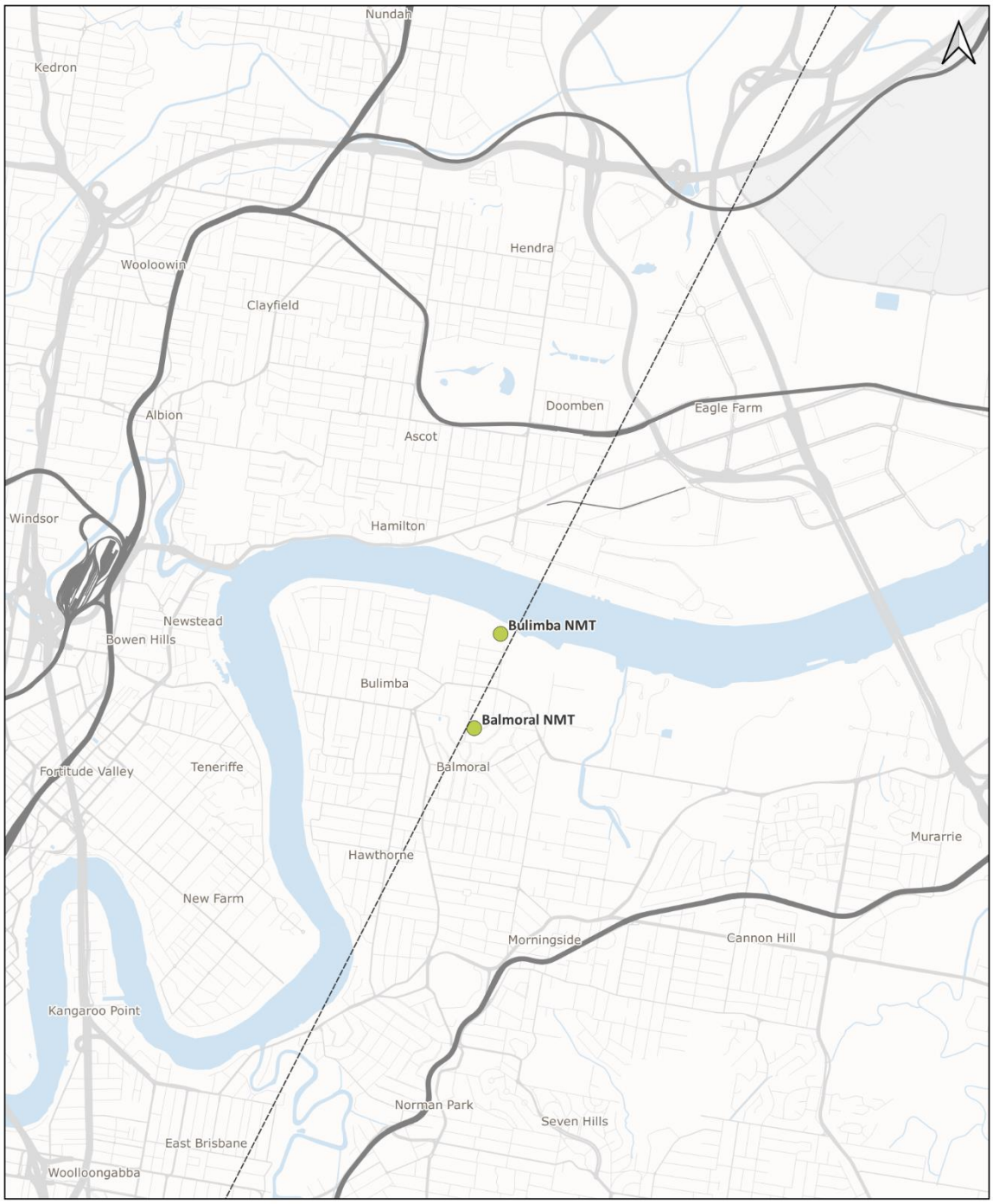
2.1 Details of the Short-Term Noise Monitor Deployment

The following details of the noise monitor deployment are pertinent.

- The Balmoral short-term monitor was installed in the most elevated area of Balmoral.
- The permanent NFPMS Bulimba noise monitor is located just to the south of the river, in Taylor Street.
- Monitoring was undertaken at the Balmoral site from 30 July to 8 October 2021. The duration of this monitoring (10 weeks) is considered sufficient to collect a representative sample of operations from Brisbane Airport, including variations in operating modes, aircraft flown, and weather conditions.
- The Balmoral noise monitor was at an elevation approximately 40 m above the permanent Bulimba noise monitor. The Balmoral site was approximately 1 km farther away from the airport than the Bulimba site. Both sites are approximately located on the extended centreline of the new runway.
- The monitor captured both arrival and departure operations. Operations in the area are primarily associated with the new runway, though occasional operations on the legacy runway were also captured.
- The short-term noise monitoring consisted of noise monitor terminal equipped with AU-2000 Outdoor Smart Microphone (S/N: RR01ZPL9). The microphone was verified in conformance with IEC 61672-1 before the deployment.
- Self-calibration checks on the noise monitor terminal occurred daily on time, and the monitor had maintained within the calibration range throughout the entire deployment period.

Figure 2-1 demonstrates the locations of the noise monitoring sites.

Figure 2-1 Noise Monitoring Sites



BALMORAL SHORT-TERM NOISE MONITORING

NOISE MONITORING SITES

LEGEND

- Noise Monitoring Sites
- Indicative Extended Runway 01L/19R Centreline

Note: Locations of features are indicative only and are shown solely to demonstrate features pertinent to the noise assessment.

2.2 Aircraft Noise Event Detection

Noise events exceeding a defined threshold were automatically identified by the noise monitoring terminal and noise level data saved. Events which were correlated with a simultaneous aircraft operation nearby were automatically identified as aircraft noise events. These events are described as correlated noise events (CNE). The noise level data and aircraft operation data for these events were subsequently associated and saved for post-processing and analysis.

To permit the correlation of aircraft events with measured noise events, a three-dimensional cylinder-like capture zone at Balmoral deployment site established in the processing software. The capture zone was defined by a circular radius 2,500 m, projected 2,500 m (8200 ft) up from the monitor site.

Similarly, the capture zone employed for the permanent noise monitor at Bulimba has a circular radius of 3,000 m and a vertical projection of 4,000 m (13,123 ft).

The larger capture zone of the permanent Bulimba monitor could potentially result in capture and association of more aircraft noise events, being those farther from the noise monitor. The impact of this is nullified in the comparative analysis detailed in section 4 of this report, because only aircraft noise events that are detected at both monitors are used.

The automated noise monitoring system requires several criteria to be met in order to classify an aircraft noise event. These criteria relate to the validity of recorded noise level and air traffic control (ATC) surveillance data, the proximity of aircraft (i.e. within the relevant capture zone) and that the noise level, duration and rise and fall accords with that of an aircraft noise event.

In this way, the system is able to automatically eliminate most extraneous noise events. However, it is possible that some aircraft noise events are not recorded. Most often these are due to the absence of valid ATC surveillance data, or due to the aircraft noise levels being insufficient to satisfy the defined thresholds for noise level and duration.

3 BALMORAL NOISE MONITORING RESULTS

3.1 Correlated Aircraft Departure Operations

Table 3-1 presents a summary of the correlated aircraft departure noise events at the Balmoral site.

Table 3-1 Summary of Correlated Aircraft Departure Noise Events at Balmoral

Aircraft [1]	Number of CNE	Average L_{Amax} - dB(A)	90th Percentile L_{Amax} [2] - dB(A)	Standard Deviation of L_{Amax}	Average Slant Distance [3] - feet	10th Percentile Slant Distance [3,4] - feet
737-800	315	70.1	72.2	2	3499	2879
A320-200	97	70.5	72.8	2.4	3413	2827
F70	64	69	71.5	2.9	3752	3218
737-700	29	68.5	69.6	1.5	3769	3320
F100	24	69.1	71.9	2.7	3877	3212
A330-300	16	71.6	76.5	3.8	4469	2625
737-300	13	69.9	73.4	3.5	4172	2856
A350-900	12	64.4	69.2	3.9	4412	2654
767-300	11	71	72.8	1.9	4688	4085
717-200	8	67.3	70.3	2.8	3730	3455
All Jet	621	69.8	72.5	2.8	3658	2907
All Turboprop	7	61.5	63.6	1.5	4095	3636

Note: 1. Presentation of individual aircraft types in Table 3-1 is limited to the ten aircraft types with the most correlated departure events.
2. The 90th percentile L_{Amax} presents the loudest 10% of events.
3. Slant distance is the nearest three-dimensional distance from the aircraft to the noise monitoring terminal.
4. The 10th percentile slant distance presents the nearest 10% of events.

The following can be observed from the noise monitoring results.

- Many aircraft demonstrate similar average noise levels around 70 dB(A).
- Narrow body jets are most prevalent (737-800, A320-200, F70, 737-700, F100, 737-300, 717-200 and others not shown), representing 89% of the total correlated aircraft departures for fixed-wing aircraft (i.e. excluding helicopters).
- Some wide body jets (A330-300, A350-900) appear to vary in noise level and slant distance more greatly than narrow body jets. This may be due to the varying missions these aircraft depart on – e.g. short haul domestic ranging to medium-long haul international. It must be noted that some of the apparent variation may be owing to the relatively small sample size for these aircraft.
- The loudest aircraft departure events, as demonstrated by the 90th percentile L_{Amax}, are associated with the A330-300.
- The newest generation aircraft in the list, A350-900, demonstrated substantially lower noise levels than older generation aircraft of a similar size (e.g. A330-300).

3.2 Correlated Aircraft Arrival Operations

Table 3-2 presents a summary of the correlated aircraft arrival noise events at the Balmoral site.

Table 3-2 Summary of Correlated Aircraft Arrival Noise Events at Balmoral

Aircraft [1]	Number of CNE	Average L_{Amax} - dB(A)	90th Percentile L_{Amax} [2] - dB(A)	Standard Deviation of L_{Amax}	Average Slant Distance [3] - feet	10th Percentile Slant Distance [3,4] - feet
737-800	563	72.0	74.0	2.7	1565	1391
DH8D	294	68.5	71.9	3.4	1654	1394
A320-200	162	70.6	73.9	3.9	1678	1404
F70	92	68.8	70.8	1.9	1437	1394
737-700	57	70.0	72.4	3.7	1649	1390
BE20	56	67.1	69.9	2.9	1830	1452
F100	48	69.1	70.5	1.2	1529	1403
SF34	35	67.1	71.0	3.5	2539	1434
B350	31	67.4	69.8	2.4	1562	1467
A350-900	29	73.8	75.4	1.2	1436	1423
All Jet	**1087**	**71.1**	**74.3**	**3.5**	**1620**	**1394**
All Turboprop	**495**	**68.1**	**71.7**	**3.5**	**1747**	**1396**

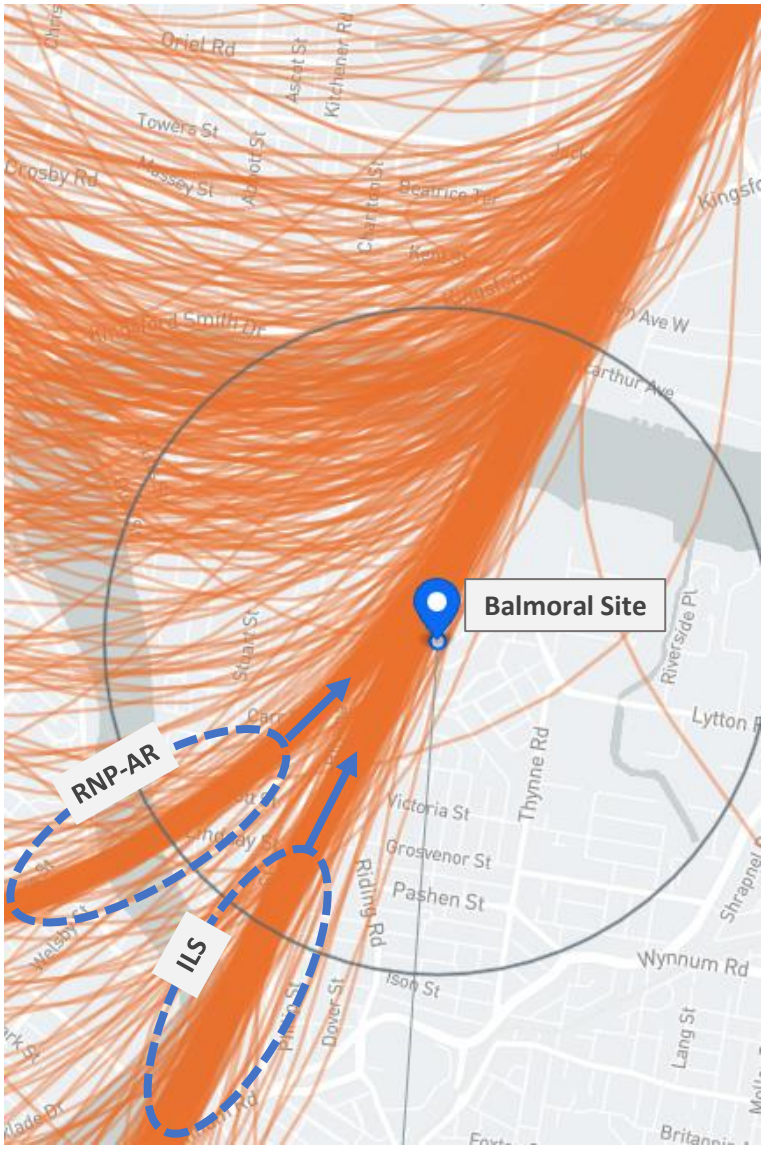
Note:
1. Presentation of individual aircraft types in Table 3-2 is limited to the ten aircraft types with the most correlated departure events.
2. The 90th percentile L_{Amax} presents the loudest 10% of events.
3. Slant distance is the nearest three-dimensional distance from the aircraft to the noise monitoring terminal.
4. The 10th percentile slant distance presents the nearest 10% of events.

The following can be observed from the noise monitoring results.

- Many more aircraft arrival events were measured compared to departure events (more than double).
- The most numerous aircraft demonstrate similar average noise levels around 70 dB(A).
- Narrow body jets are most prevalent (737-800, A320-200, F70, 737-700, F100 and others not shown), representing 61% of the total correlated aircraft arrivals for fixed-wing aircraft.
- Turboprop aircraft are also prevalent (DH8D, BE20, SF34 and others nor shown), representing 27% of the total correlated aircraft arrivals for fixed-wing aircraft.

- Wide body jets (A350-900 and others not shown) represent only a small proportion of the total correlated arrivals.
- Significant variation in L_{Amax} is evident for many aircraft, demonstrated by the standard deviation of L_{Amax} and the difference between the 90th percentile and average. This can likely be attributed to the existence of two arrival procedures in and around the Balmoral area – a procedure using satellite navigation called Required Navigation Performance Authorization Required (RNP-AR) and an Instrument Landing System (ILS) procedure – resulting in different proximities to the noise monitoring site. This is evident in the variations in slant distance.

Figure 3-1 Aircraft Arrivals and the Balmoral Site



4 COMPARISON BETWEEN BALMORAL AND BULIMBA SITES

One of the primary objectives of the short-term noise monitoring at Balmoral was to facilitate a comparison of measured noise levels with those measured at the permanent NFPMS noise monitor site located nearby at Bulimba.

Comparison of noise levels and slant distances for the two locations was undertaken on a subset of the correlated noise events, for which correlation existing at both the Balmoral and Bulimba monitoring sites. These events are referred to as mutually correlated noise events.

Statistical descriptors of these events were determined for both sites. These may differ slightly from the equivalent descriptors presented in the previous sections, which consider all correlated noise events from the Balmoral monitoring site.

In addition to the overall statistical descriptors for each, the difference in noise level and slant distance between the Balmoral and Bulimba sites was determined for each mutually correlated noise event. These differences were analysed, and statistical descriptors produced.

The following sections present the results of the comparison between the Balmoral and Bulimba sites.

4.1 Mutually Correlated Departure Operations

Table 4-1 presents a summary of the mutually correlated aircraft departure noise events.

Table 4-1 Summary of Mutually Correlated Aircraft Departure Noise Events

Aircraft	# CNE	Average LAmax - dB(A)		Average L_{Amax} Difference	Standard Deviation of L_{Amax} Difference	Average Slant Distance [2] - feet		Average Slant [2] Difference
		Balmoral	Bulimba			Balmoral	Bulimba	
737-800	292	70.2	71.0	-0.7	1.0	3452	3259	193
A320-200	89	70.5	71.3	-0.8	1.6	3396	3202	194
F70	61	69.0	69.2	-0.3	2.2	3746	3645	101
737-700	28	68.5	68.5	0.0	0.9	3784	3627	157
F100	23	69.4	70.1	-0.6	1.1	3759	3672	86
A330-300	16	71.6	72.7	-1.1	2.6	4469	4404	64
737-300	12	70.5	71.0	-0.5	1.2	3950	3888	62
717-200	8	67.3	68.4	-1.0	1.0	3730	3568	163
B763	8	71.0	71.9	-0.9	0.8	4688	4548	140
A332	7	71.9	73.0	-1.1	0.9	3953	3738	215
A350-900	7	66.9	68.3	-1.4	1.4	3425	3317	108
All Jet	**573**	**70.0**	**70.7**	**-0.7**	**1.4**	**3583**	**3419**	**164**

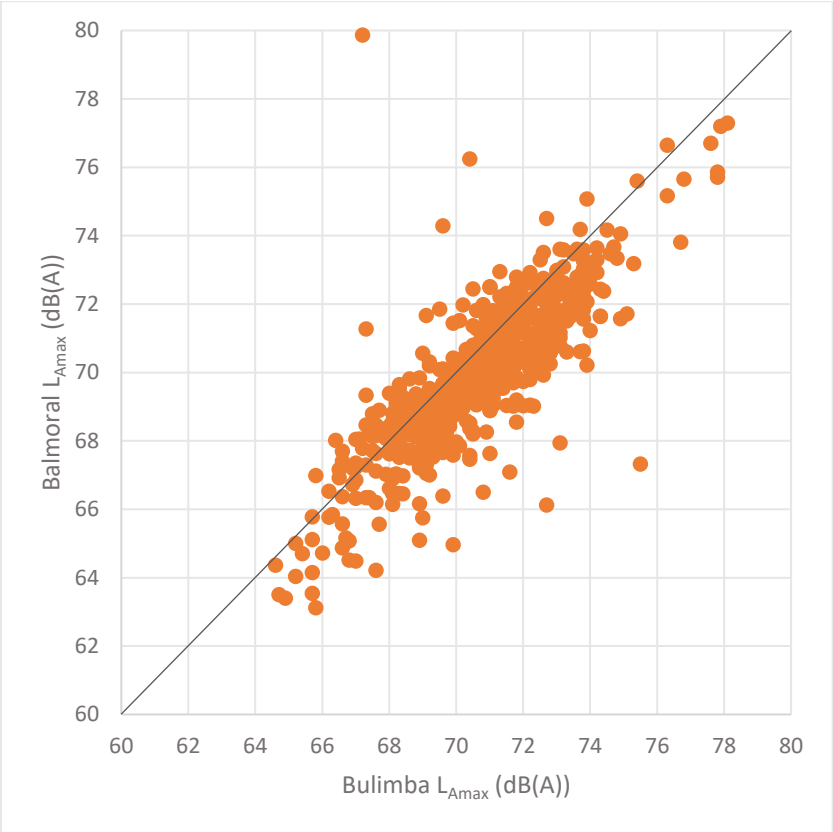
Note: 1. Presentation of individual aircraft types in Table 4-1 is limited to the 11 aircraft types with the most mutually correlated departure events.
2. Slant distance is the nearest three-dimensional distance from the aircraft to the noise monitoring terminal.

The following can be observed from **Table 4-1**.

- Overall, there is no evidence that noise levels from aircraft departures, as described by L_{Amax}, are appreciably louder at the Balmoral site compared to the Bulimba site. Observed average differences for mutually correlated events are in the order 0-1 dB(A), with noise levels being on average very marginally quieter at the Balmoral site. For reference, few people are able to distinguish a noise level difference of less than 2.0 dB(A), and this noise level difference is thus generally considered imperceptible.
- The standard deviation of the L_{Amax} difference is in range of 0.8 to 2.6, with an overall value of 1.4 across all events. This demonstrates that the noise level difference between the sites is not constant and does vary.
- Average differences in slant distance are in the order of 60 to 200 feet, with the aircraft being slightly farther from the Balmoral site. This is due to the majority of operations being very marginally offset from the Balmoral site, compared to being more overhead at the Bulimba site. The slant distance difference is evident in the data, despite the difference in elevations of the two monitoring stations. For reference, the difference in slant distance is negligible in terms of noise propagation and would be expected to change noise levels by less than 0.5 dB(A).

Figure 4-1 presents a comparison of the measured L_{Amax} at the Balmoral and Bulimba sites for each mutually correlated aircraft departure event. In general, measured noise levels are similar at each location and the distribution is consistent with the standard deviation (1.4). There is no evidence of either noisier or quieter events tending to produce more or less noise at Balmoral.

Figure 4-1 Comparison of L_{Amax} at Balmoral and Bulimba for Mutually Correlated Aircraft Departures



4.2 Mutually Correlated Arrival Operations

Table 4-2 presents a summary of the mutually correlated aircraft arrival noise events.

Table 4-2 Summary of Mutually Correlated Aircraft Arrival Noise Events

Aircraft	# CNE	Average LAmax - dB(A)		Average L_{Amax} Difference	Standard Deviation of L_{Amax} Difference	Average Slant Distance [2] - feet		Average Slant [2] Difference
		Balmoral	Bulimba			Balmoral	Bulimba	
737-800	453	72.3	72.1	0.2	1.7	1483	1362	120
DH8D	224	68.7	68.7	0.0	2.6	1566	1404	162
A320-200	130	71.2	71.1	0.1	2.4	1499	1363	137
F70	71	68.8	67.1	1.7	1.9	1441	1389	51
BE20	42	67.4	67.9	-0.5	2.1	1638	1468	170
F100	40	69.2	67.7	1.5	0.9	1426	1389	37
737-700	40	71	70.8	0.1	1.2	1485	1359	126
A350-900	28	73.7	71.1	2.7	1.1	1436	1391	45
SF34	23	67.9	67.8	0.1	2.1	1597	1473	124
B350	22	67.5	67.9	-0.5	2.2	1580	1444	136
DH8A	14	71.2	71.7	-0.5	3.1	1770	1539	231
All Jet	**861**	**71.7**	**71.2**	**0.5**	**2.0**	**1471**	**1369**	**102**
All Turbo-prop	**365**	**68.5**	**68.6**	**-0.1**	**2.5**	**1584**	**1427**	**157**

Note: 1. Presentation of individual aircraft types in Table 4-2 is limited to the 11 aircraft types with the most mutually correlated departure events.
3. Slant distance is the nearest three-dimensional distance from the aircraft to the noise monitoring terminal.

The following can be observed from **Table 4-1**.

- Overall, there is little evidence that noise levels from aircraft arrivals, as described by L_{Amax}, are appreciably louder at the Balmoral site compared to the Bulimba site. Observed average differences for mutually correlated events are typically in the range -0.5 to 0.5 dB(A).
- The average L_{Amax} difference is negligible among the most prolific aircraft types – 737-800, DH8D and A320-200, which account for approximately two-thirds of the mutually correlated arrival events.
- The F70, F100 and A350-900 demonstrate larger average differences in arrival noise level, with noise levels at Balmoral being marginally higher than Bulimba for each of these aircraft. These three aircraft types account for approximately 11% of mutually correlated arrival events. The largest average difference in L_{Amax} is 2.7, for the A350-900, which is on the verge of perceptibility.

- The average difference in slant distance is in the order of 50 to 200 feet across the presented aircraft. This difference in slant distance would be expected to impact noise levels by approximately 1 dB(A). Note that, although the difference in observed slant distance is similar for both arrivals and departures, arrivals are comparatively lower than departures around the Balmoral and Bulimba monitoring sites and so the difference is more significant (i.e. less than 0.5 dB(A) for departures compared to approximately 1 dB(A) for arrivals).
- The F70, F100 and A350-900 demonstrate the lowest difference in slant distance, of the presented aircraft.

Figure 4-2 presents a comparison of the measured L_{Amax} at the Balmoral and Bulimba sites for each mutually correlated aircraft arrival events. In general, measured noise levels are similar at each location and the distribution is consistent with the standard deviation (2.0 and 2.5 for jets and turboprops, respectively). There is no evidence of either noisier or quieter events tending to produce more or less noise at Balmoral.

Figure 4-2 Comparison of L_{Amax} at Balmoral and Bulimba for Mutually Correlated Aircraft Arrivals

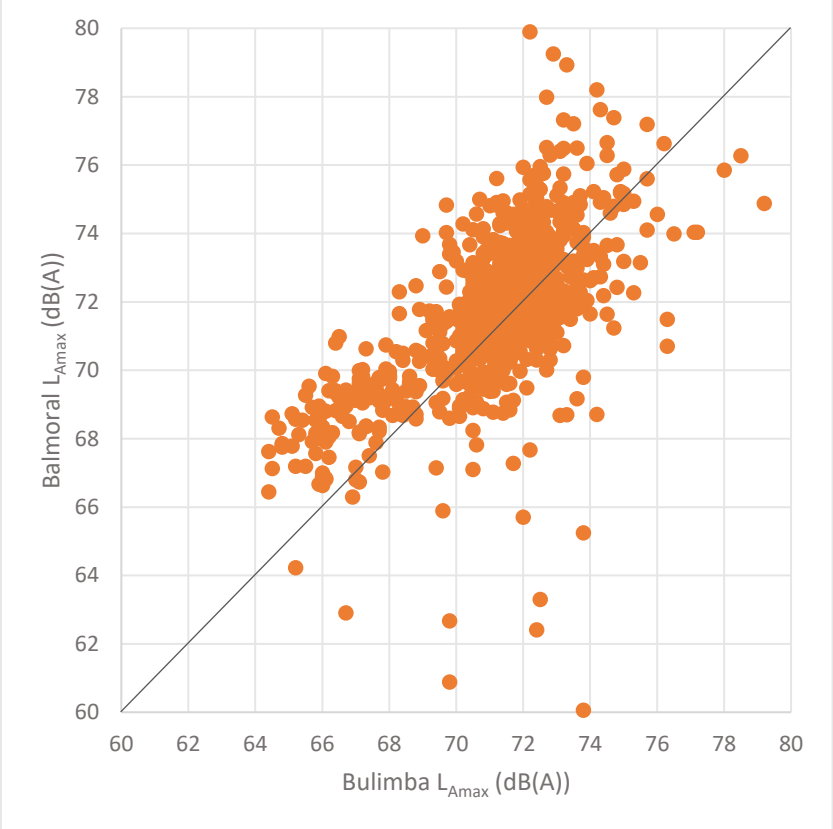
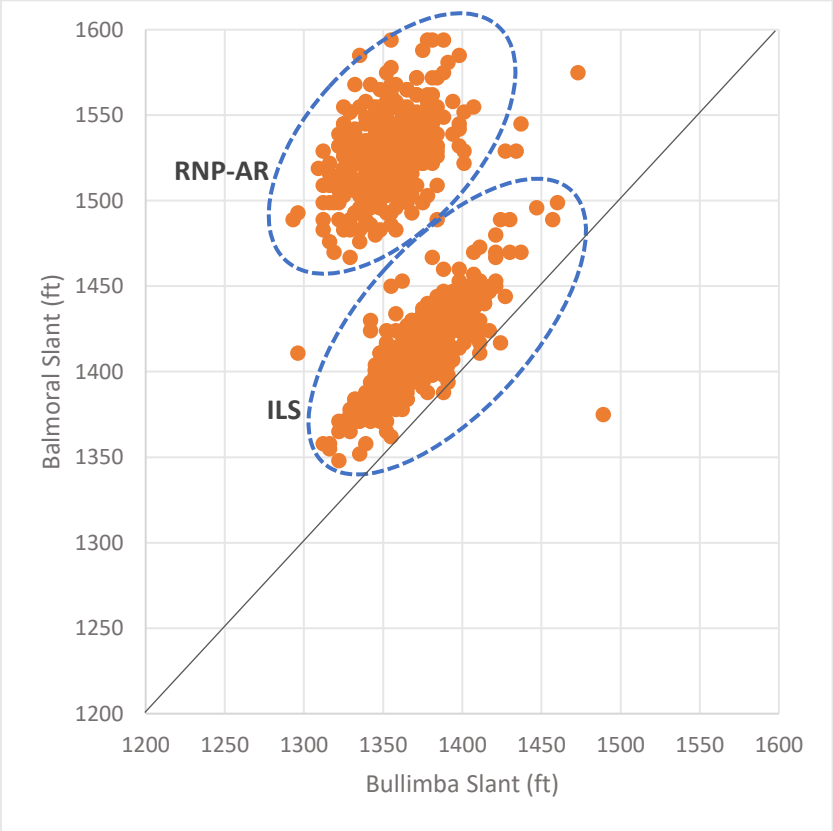


Figure 4-3 presents a comparison of the measured slant distance at the Balmoral and Bulimba sites for each mutually correlated aircraft arrival event.

There is evidence of two groups of events; presumed to be the RNP-AR and ILS. Note that most aircraft are closer to the Bulimba site than the Balmoral site (i.e. above the diagonal line).

Figure 4-3 Comparison of Slant Distance at Balmoral and Bulimba for Mutually Correlated Aircraft Arrivals



5 CONCLUSION

SoundIN has undertaken an analysis of short-term aircraft noise monitoring at Balmoral.

The following observations have been made in our analysis.

Departure Aircraft Events at the Balmoral Site

- Many departing aircraft produce similar average noise levels of approximately 70 dB(A) at the Balmoral monitoring site.
- The loudest aircraft departure events were associated with A330-300; a wide body jet.
- The newest aircraft, being the A350-900, demonstrated comparatively lower noise levels on departure than an equivalent older generation aircraft of a similar size.

Arrival Aircraft Events at the Balmoral Site

- Many more arrival aircraft noise events were measured, compared to departures.
- Average noise levels for arrivals were similar amongst the most prolific aircraft. These average noise levels were similar to those from departures – approximately 70 dB(A).
- Significant variation in L_{Amax} is evident for many aircraft. This can likely be attributed to the existence of two arrival procedures in and around the Balmoral area – an RNP-AR and an ILS – resulting in different proximities to the noise monitoring site.

Comparison of Departures Between Balmoral and Bulimba Sites

- Overall, there is no evidence that noise levels from aircraft departures, as described by L_{Amax}, are appreciably louder at the Balmoral site compared to the Bulimba site. Observed average differences for mutually correlated events are in the order 0-1 dB(A), with noise levels being on average very marginally quieter at the Balmoral site. For reference, many people are unable to distinguish a noise level difference of less than 3 dB(A) and few people are able to distinguish a noise level difference of less than 2 dB(A). Thus, the noise level difference observed between Balmoral and Bulimba would generally be considered imperceptible.
- The noise level difference between the sites is not constant and does vary.
- Differences in reported slant distances are likely to account for less than 0.5 dB(A) change in the noise level on the ground.

Comparison of Arrivals Between Balmoral and Bulimba Sites

- Overall, there is little evidence that noise levels from aircraft arrivals, as described by L_{Amax}, are appreciably louder at the Balmoral site compared to the Bulimba site. Observed average differences for mutually correlated events are typically in the range -0.5 to 0.5 dB(A).
- The F70, F100 and A350-900 demonstrate larger average differences in arrival noise level, with noise levels at Balmoral being marginally higher than Bulimba for each of these aircraft.
- The average difference in slant distance would be expected to impact noise propagation attenuation by approximately 1 dB(A).

Noting the above, it is reasonable to conclude the following.

- In general, the noise level difference noted between Balmoral and Bulimba sites is unlikely to be perceptible.
- The data demonstrates that noise levels do vary, even for the same aircraft at a similar distance to the receiver. Furthermore, the difference between the two sites also varies from flight to flight.
- It is possible that a local resident, or other receiver, could observe one operation from the Bulimba site, then observe another operation from an identical aircraft at the Balmoral site and experience a different noise level. This difference may be perceptible.