HORIZON
NUCLEAR POWER

WYLFA NEWYDD

ENERGY WORKING FOR BRITAIN

Wylfa Newydd Project

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D13-13 Noise at Marine Ecological Receptors

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Contents

1. Introduction

Horizon Nuclear Power Wylfa Limited (Horizon) is proposing to develop a new Nuclear Power Station, the 'Wylfa Newydd Power Station', on land west of Cemaes on Anglesey.

The Power Station Site is near to the Cemlyn Bay Site of Special Scientific Interest, Anglesey Terns/Morwenoliaid Ynys Môn Special Protection Area (SPA), Bae Cemlyn/Cemlyn Bay Special Area for Conservation and North Anglesey Marine/Gogledd Môn Forol candidate Special Area for Conservation, although only the Cemlyn Bay Site of Special Scientific Interest and Anglesey Terns SPA are sensitive to noise effects as they support the tern colony on islands within the Cemlyn Lagoon. At Cemlyn Bay, a shingle bar forms a barrier between a tidal lagoon and the open shore. Islands within the tidal lagoon are used by breeding tern species.

Cemlyn Bay qualifies under Article 4.1 of Directive 2009/147/EC ('The Birds Directive') by supporting populations of European importance of the following species listed on Annex I of the Directive during the breeding season:

- arctic tern *Sterna paradisaea*
- common tern *Sterna hirundo*
- roseate tern *Sterna dougallii*
- sandwich tern *Sterna sandvicensis*

To support the Wylfa Newydd Project, Horizon is preparing an Environmental Statement and a Habitats Regulations Assessment both of which consider the potential for construction noise to affect terns during the breeding season which can span from April to August.

Consultation responses from Natural Resources Wales and Isle of Anglesey County Council indicate that previous noise modelling and assessments undertaken in respect of human disturbance is not considered to fully explore the potential implications for disturbance of breeding terns for the following reasons.

- It does not reflect the potential worst-case short-term construction noise in respect of the breeding terns.
- It does not consider the potential impact of impulsive construction noise on the breeding terns.
- It does not consider the potential effects of noise from blasting on the breeding terns.

The noise modelling has considered each of the issues above in detail, and has issued four technical reports as detailed below.

- A methodology for predicting 'boundary-case' short-term (five minute) construction noise effects at tern receptor locations has been proposed, and is included as appendix D to this document.
- Preliminary and detailed methodologies for estimating impulsive construction noise effects at tern receptor locations have been proposed, and is included as appendix E to this document
- A methodology for predicting audible maximum noise levels and infrasound from construction blasting has been proposed, and is included as appendix E to this document. Surface blast trials have been undertaken enabling a comparison of measured versus predicted maximum levels, and these are detailed in appendix F to this document.

This appendix explains how these methods have been implemented for the Environmental Statement, and details a baseline noise survey undertaken beside the tern colony. This report does not detail how noise modelling in support of the human noise assessments has been conducted; further information on that topic is available in appendix B6-2 (Noise and vibration modelling and assessment methodology report) (Application Reference Number 6.2.21) of the Environmental Statement.

2. Glossary

Term	Definition
Air overpressure	A pressure wave in the atmosphere produced by a detonation of explosives. Air overpressure consists of both audible and infrasound energy, is measured in pascals and is normally reported in dB(Lin).
Air pressure pulse (APP)	A component of air overpressure caused by the direct displacement of rock at the face (a piston like movement of the rock mass which causes an air pressure wave).
Airblast	Alternative term for air overpressure, primarily used in U.S. literature.
A-weighting	The human ear demonstrates increased sensitivity at some frequencies compared to others. The A-weighting network applies filters to the signal processing of a sound level meter to mimic the response of the human ear at each frequency.
Boundary-case	A modelling scenario in which one or more inputs are at, or beyond, their limit value.
Blast	The action of breaking and displacing rock by means of explosives, also known as a 'shot'.
Blasthole	A hole drilled into rock and/or other materials within which explosives are placed. The explosives may be 'decked' at different levels within the blast hole, and the blasthole is backfilled with stemming material after the placement of the explosives.
BSI	British Standards Institution
Confinement	Constraining effect of the environment on the explosive charge. The confinement of a charge depends on the characteristics of the surrounding rock and free faces, the distance from the blasthole to the free face, the amount of rock being broken and other factors. No general system has been devised for quantifying confinement.
dB(A)	A-weighted decibel. See: 'A-weighting' and 'decibel'.
Decibel (dB)	A scale for comparing the ratios of two quantities, including sound pressure and sound power. The difference in level between two sounds S_1 and S_2 is given by $20 \bullet \log10(S_1/S_2)$. The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20µPa.
Deck (or Decking)	Vertically positioning an explosive charge within a blasthole so as to separate it from other explosive charges in the same borehole, using stemming material or an air cushion.
Delay	The predetermined interval of time between the sequential detonation of explosive charges.
Equivalent continuous sound pressure level (L_{eq})	The notional steady sound level which, over a stated period of time, would contain the same amount of acoustic energy as the fluctuating sound measured over that period. The period of time over which this quantity is evaluated is normally added to the sub-script notation, as shown in the following examples: $L_{eq,5min}$, $L_{eq,1\text{-}hour}$, $L_{eq,8\text{-}hours}$.
Free-field	An environment in which there are no vertical reflective surfaces within the

	frequency region of interest
Frequency	Sound consists of vibrations transmitted to the ear as rapid variations in air pressure. The more rapid the variations in air pressure, the higher the frequency of the sound. Frequency is defined as the number of pressure fluctuations per second and is expressed in Hertz (Hz).
Gas release pulse	A component of air overpressure which results from blast gases escaping through rock fractures and venting at the face.
ISEE	International Society of Explosives Engineers
ISO	International Organization for Standardization
L_{Aeq}	A-weighted equivalent continuous sound pressure level. See 'A-weighting' and 'equivalent continuous sound pressure level'. It is normal to indicate the time period over which this noise descriptor has been assessed in the subscript as per the following examples: $L_{Aeq,5min}$ (five minutes), $L_{Aeq,1\text{-}hour}$ (one hour).
$L_{AF,max}$	A-weighted maximum sound level measured with the sound level meter set to a fast (125ms) response. See 'A-weighting' and 'maximum sound level'.
L_W	See Sound Power Level.
Maximum instantaneous charge weight	The maximum weight of explosive detonated in any delay, measured in kg.
Maximum sound level	The maximum sound level (L_{Amax}) is the highest time-weighted sound level measured during a short period. The time constant of the measure is usually either **F**ast (125ms) or **S**low (1s), and it is usual to identify the time constant in the notation – e.g. $L_{AF,max}$ indicates the A-weighted maximum sound level was measured with the fast time-weighting. Where no time weighting is provided, normal convention is to assume a fast time weighting (i.e. L_{Amax} implies $L_{AF,max}$).
Noise emission	Used to describe the noise levels generated by, and other characteristics of, a noise source.
Rock pressure pulse	A component of air overpressure caused by vibrating ground close to the receptor.
Sound Power Level	Sound Power Level (L_W) is a logarithmic measure of the sound power as a relation to the threshold of hearing which is intended to make the range of sound powers encountered in environmental acoustics into a more manageable range of values (i.e. 0 to 160dB). The Sound Power Level expresses the sound power relative to a reference value (W_0) of one Pico Watt (10^{-12} Watts) according to the following formula: $L_w = 10 \cdot \lg (W/W_0)$ dB
Stemming release pulse	The stemming release pulse is the component of air overpressure which results from blast gases escaping up the blasthole through the stemming material.
SWL	Notation for Sound Power Level

3. Receptors

For the assessment of noise effects on the four species of terns listed above, eight receptor points have been defined.

The terns nest on two islands in the Cemlyn Bay lagoon, within the SPA, and receptor 1 has been placed in the noise model at the location of the larger island. The British National Grid reference for this receptor is 233068, 393322 and the height has been set to one metre above ground. Receptor 2 has been placed at the edge of the SPA closest to the Power Station Site, (at a height of five metres above ground, as the terns would be in flight at this location).

Sandwich terns leave the nest site to forage, and generally pass around the headland between Cemlyn Bay and Cemaes Bay (see results of baseline tracking surveys in appendix D13-7 seabird baseline report, Application Reference Number: 6.4.89). Receptors 3, 5, 6 and 8 are located approximately along this flight path, at five metres above the sea. Arctic and common terns have been shown from baseline tracking surveys to forage more to the north and west than sandwich terns and so the most sensitive species for assessment of effects from noise is likely to be sandwich tern.

Occasionally, sandwich terns will forage within Porth-y-pistyll and Porth y Wylfa, and therefore receptors have been included in these locations. These receptors are set to a relative height of five metres above the sea level in the digital terrain model (receptor 4 is at Porth-y-pistyll and receptor 7 is at Porth y Wylfa). Figure 1 shows the location of the noise sensitive receptor points i.e. where the terns will possibly be sensitive to disturbance, and the British National Grid references for the receptors are provided in Table below.

Table 1 : British National Grid Coordinates of receptor points

Receptor	X	Y
1	233068	393322
2	233616	393090
3	233591	393737
4	234462	393800
5	234246	394107
6	235160	394647
7	236031	394182
8	236389	394572

3.1.1 Distances to receptors

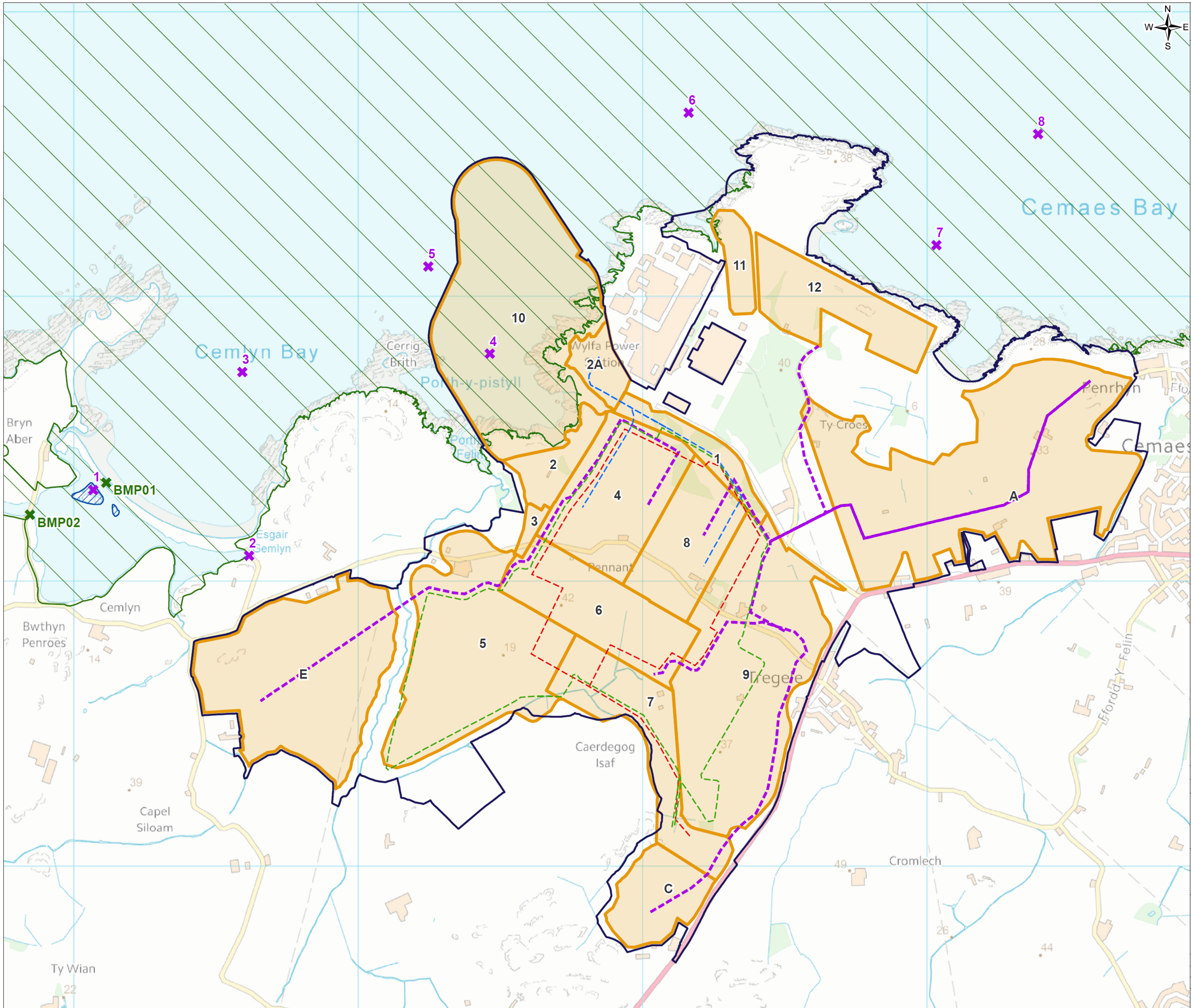
For the construction noise and vibration assessments, the Wylfa Newydd Development Area has been divided into 16 construction zones which are shown on figure 1.

The minimum distances between each construction zone and each receptor are presented in Table below.

Table 2 : Minimum separation distances between construction zones and receptors in meters.

Construction zone	Receptor							
	1	2	3	4	5	6	7	8
Zone 1	1,863	1,376	1,313	481	820	1,006	1,018	1,547
Zone 2	1,458	952	967	367	723	1,082	1,300	1,805
Zone 2A	1,728	1,299	1,137	269	566	785	1,174	1,651
Zone 3	1,516	932	1,105	545	905	1,468	1,641	2,160
Zone 4	1,582	1,011	1,180	455	806	1,083	1,121	1,648
Zone 5	1,182	576	921	627	937	1,651	1,832	2,354
Zone 6	1,488	886	1,157	656	1,015	1,576	1,588	2,110
Zone 7	1,764	1,147	1,493	1,031	1,393	1,875	1,819	2,340
Zone 8	1,910	1,318	1,533	803	1,147	1,199	1,120	1,648
Zone 9	2,157	1,546	1,793	1,061	1,413	1,411	1,114	1,638
Zone 10	1,299	914	674	0	97	586	1,188	1,631
Zone 11	2,338	1,901	1,729	859	1,006	360	646	1,068
Zone 12	2,437	1,990	1,832	961	1,156	483	256	768
Mound A	2,517	2,005	1,970	1,113	1,407	1,086	504	791
Mound C	2,327	1,731	2,198	1,818	2,181	2,569	2,319	2,828
Mound E	673	182	795	903	1,114	1,981	2,278	2,792

FIGURE 1



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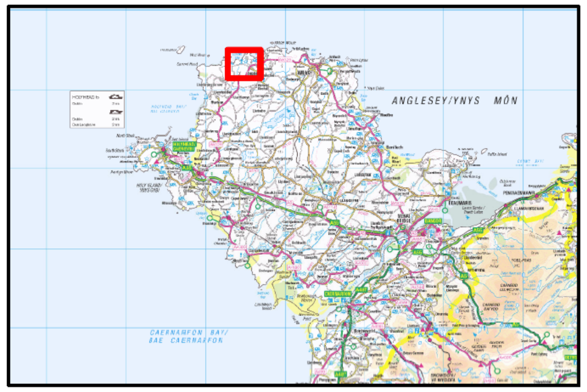
Legend

- Wylfa Newydd Development Area
- Anglesey Terns/Morwenoliaid Ynys Môn Special Protection Area
- Construction zones
- Tern nesting islands
- Tern receptors
- Baseline noise measurement locations
- Haul route for earthworks
- Haul route for concrete distribution
- Haul route for other vehicles
- Bus circulation route



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	JUL 17	Initial Issue	AD	SW	BM	BM

Client

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Project

WYLFA NEWYDD PROJECT
ENVIRONMENTAL STATEMENT

Drawing Title

NOISE SENSITIVE RECEPTORS, CONSTRUCTION ZONES AND MEASUREMENT LOCATIONS

Scale @ A3	1:13,000	DO NOT SCALE
Jacobs No.	60PO8077	
Client No.		

Drawing No.

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4. Baseline noise measurements

Attended baseline noise measurements and observations of the tern colony were conducted in parallel, to identify relationships between existing noise levels and the responses of the terns. Each noise measurement and observation lasted approximately two hours, and in total 25 noise measurements were undertaken. The number of observations was greater than this, but the weather was not suitable for noise measurements during all observations.

The majority of the baseline noise levels were measured on the shingle ridge to the north of the larger island where the terns nest. A smaller number of measurements were taken from the side of the road around the west side of Cemlyn Bay.

4.1 Locations

The British National Grid coordinates of the shingle ridge measurement position are 233113, 393348 and it is located approximately 44m from the larger island and 92m from the smaller island. This location has been given the identifier BMP01.

The roadside measurements were undertaken at British National Grid coordinates 232845, 393235, which is approximately 190m from the larger island, and approximately 290m from the smaller island. This location has been given the identifier BMP02.

The noise measurement locations, and the nesting islands within Cemlyn Bay, are shown on Figure 1.

4.2 Equipment

An 01dB Duo integrating-averaging sound level meter was used for the noise measurements. This equipment complies with the requirements of Class 1 of International Electrotechnical Commission 61672-1:2002 – Electroacoustics - Sound level meters - Part 1: Specifications [RD1].

The sound level meter was set to simultaneously measure and log the following statistical noise descriptors at one second intervals:

- $L_{AF,max}$ (maximum noise levels, fast time response);
- L_{Aeq} (ambient noise level);
- L_{A10} (index used to quantify road traffic noise), and
- L_{A90} (background noise level).

The body of the sound level meter was placed within a protective case, whilst the microphone was mounted on a tripod at a height of approximately 1.5m above ground level, near the top of the shingle ridge as shown in Plate 1 below.

Plate 1: Noise monitoring equipment at shingle ridge

From the 17 May 2017 to 25 May 2017, the equipment was fitted with a standard outdoor windshield provided by the manufacturer. After this a high performance windshield was used, due to a deterioration in weather conditions and an increase in wind speeds.

4.3 Calibration

The calibration of the sound level meter was checked with a 01dB Cal 21 field calibrator immediately before and after the noise monitoring each day.

The sound level meter was calibrated in accordance with IEC 61672-3:2006 [RD2] by a United Kingdom Accreditation Service accredited calibration laboratory within the preceding two years. The field calibrator was calibrated at a competent laboratory to national standards within the preceding 12 months. Calibration certificates for this equipment are included in appendix A.

4.4 Weather

The weather conditions during each measurement were recorded and are displayed on the noise measurement record sheets in appendix B.

4.5 Observations

The times at which noise-generating events occurred were recorded by the survey team. Typical sources of short duration noise were Royal Air Force jets and helicopters flying over (or near) the measurement location, road traffic on the nearby road and distant shooting noise. Observations of the tern colony behaviour were made throughout the noise measurement, noting their responses to both auditory and visual stimuli.

4.6 Results

The noise measurement sheets which present a summary of the measured levels and notes on noise sources are presented in appendix B. Analysis of the noise levels measured over the study shows a decline in all of the time averaged metrics (L_{Aeq}, L_{A10}, L_{A90}) over the study period. This does not appear to be primarily affected by weather conditions, or noise sources in the wider environment, but to the numbers of nesting birds at the two islands which decreases over time as shown in Figure below.

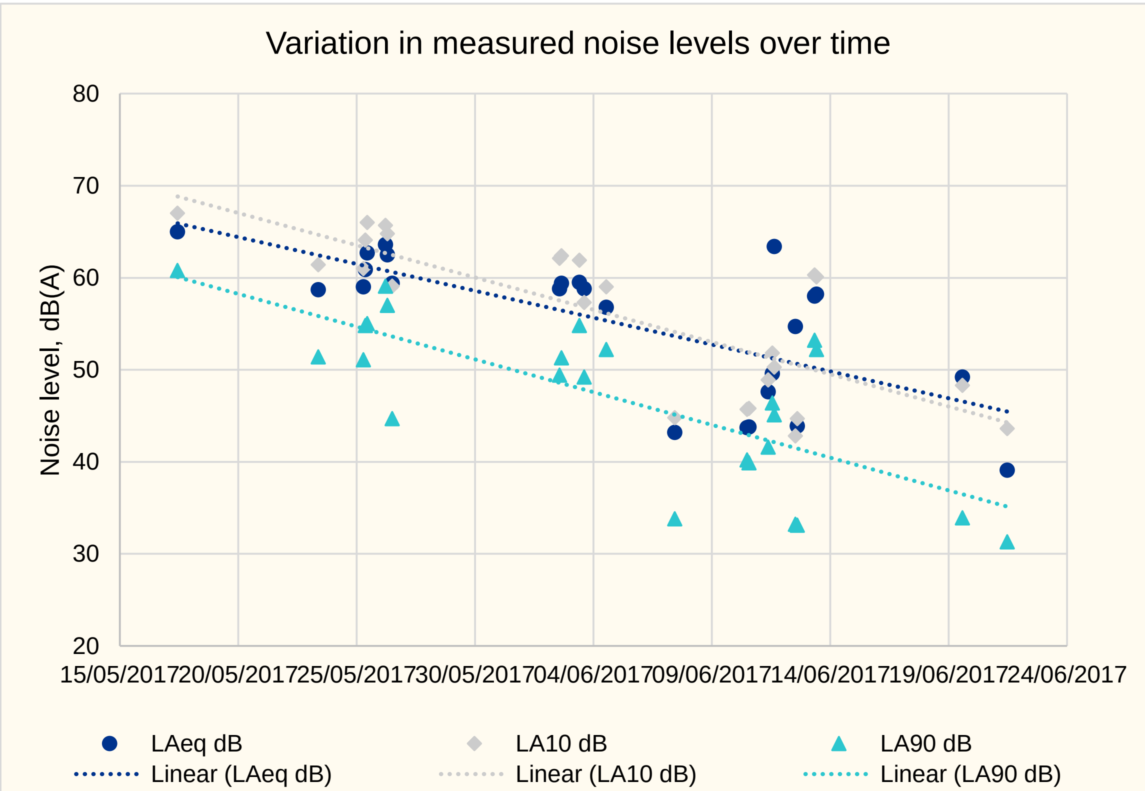


Figure 3: Variation in measured noise levels over time, dB(A)

It can be seen that the measured L_{Aeq} ranged between 65.0dB for the first measurement of the survey, and 39.1dB during the final measurement of the survey.

When examining the reactions of the terns to impulsive noise events ($L_{AF,max}$), which are described on the measurement data sheets in appendix B, only events with a known audible trigger have been included. Whilst elevated noise levels are associated with, for instance, the presence of predator or threat species, it is important to distinguish that the elevated noise levels are due to the reaction of the terns, and are not the reason for the reaction.

Similarly, the events related to unknown stimuli have been excluded, as it is not clear whether the terns were reacting to visual, audible, or other stimuli.

The average $L_{AF,max}$ noise level of events to which the terns displayed no reaction is 72.6dB $L_{AF,max}$. There was only one disturbance event attributed to noise which caused a reaction below this level, which was due to a white van towing orange and red canoes. The noise level associated with this event was 69.7dB $L_{AF,max}$. It is considered that this may also have been a source of visual stimuli in addition to noise stimuli.

5. Short-term construction noise predictions

5.1 Method

The report detailing the short-term construction noise prediction methodology is included as appendix C to this document, but for convenience the key aspects are summarised below.

The construction noise prediction method set out in BS5228-1:2009+A1:2014 [RD3] is used to calculate the upper bound of possible short-term (five minute) noise levels at the tern receptor locations from the construction works.

The construction of the Power Station Site would involve the following main construction phases.

- Enabling Works;
- site grading;
- deep excavation;
- rock processing;
- Marine Works;
- construction of Unit 1 and Unit 2;
- concrete production and transportation;
- outfall tunnel construction; and
- Site Campus construction.

Noise modelling has been undertaken at four points in time during the construction of the Wylfa Newydd Project, each representative of a three month period (one quarter of a year) for the human noise assessments presented in volume D6 (Noise and vibtation) (Application Reference Number:6.4.6). The periods modelled have the highest combination of construction activities and number of plant/machinery in use, and due to the overlapping nature of the construction activities, are representative of the highest noise emissions during the various phases of construction.

The model which results in the greatest noise emissions at the receptors is that for the third quarter of 2020. During this period, the following activities would be active: site grading, deep excavations, outfall tunnelling, Marine Works to create the Marine Off-Loading Facility, site logistics, the construction of the Site Campus, concrete production together with its distribution and pouring, the cranage of materials and equipment, and the use of mobile lifts to access structures that have been built. The movements of dredgers, tugs and other vessels associated with the Wylfa Newydd Project within construction zone 10 are also included in the construction noise model for 2020. This model has been used as the basis for the short-term construction noise modelling presented in this section.

The sources of noise emissions within the model are consistent with those presented in appendix D6-1 (noise model inputs and outputs) (Application Reference Number: 6.4.23) of the Environmental Statement for the 2020 Q3 construction noise model, except that input data have been modified to represent a bounding-case scenario as follows.

- The on-times associated with construction plant, which represent the proportion of the assessment period during which the machine would operate at, or near, full load have been increased to 100%. Therefore, no on-time corrections have been applied to construction noise sources.

- Within the construction zones which are closest to the receptor points, the point sources representing individual construction plant are located near the closest boundary of each working area to the tern receptor locations. This spatial distribution of construction plant is considered exceedingly unlikely and would result in the highest possible noise levels at receptors 1 to 8 shown in figure 1 above.

The construction plant list used for the noise modelling, showing the numbers, types, locations and working periods of construction plant (grouped by the activities they would be conducting) is presented in appendix D6-1 (Application Reference Number: 6.4.23).

In summary, the modified inputs to the BS5228-1:2009+A1:2014 [RD3] methodology to calculate a short duration are as provided in Table .

Table 3 : Worst case short-term ($L_{Aeq,5min}$) noise model inputs

Input	Model input
On-time corrections	100% on-time assumed for all plant
Traverse length corrections for mobile plant	None
All plant operating continuously	Yes
Construction plant located close to the Power Station Site boundary closest to receptors	Yes
Proportion of soft ground	Land: 50%; Water: 0%

This approach results in predictions that represent the highest continuous equivalent noise levels that could theoretically occur for short periods of time, rather than typical noise levels over a quarter as presented in volume D6. Although theoretically possible, it is very unlikely that all the construction plant would ever be situated at the construction zone boundaries closest to receptors 1 to 8 simultaneously, and therefore these noise levels should be considered bounding-cases, which would not occur in practice.

This short-term ($L_{Aeq,5min}$) noise prediction methodology was proposed to Natural Resources Wales in 2016, and later discussed at a technical workshop held on Thursday 16 March 2017.

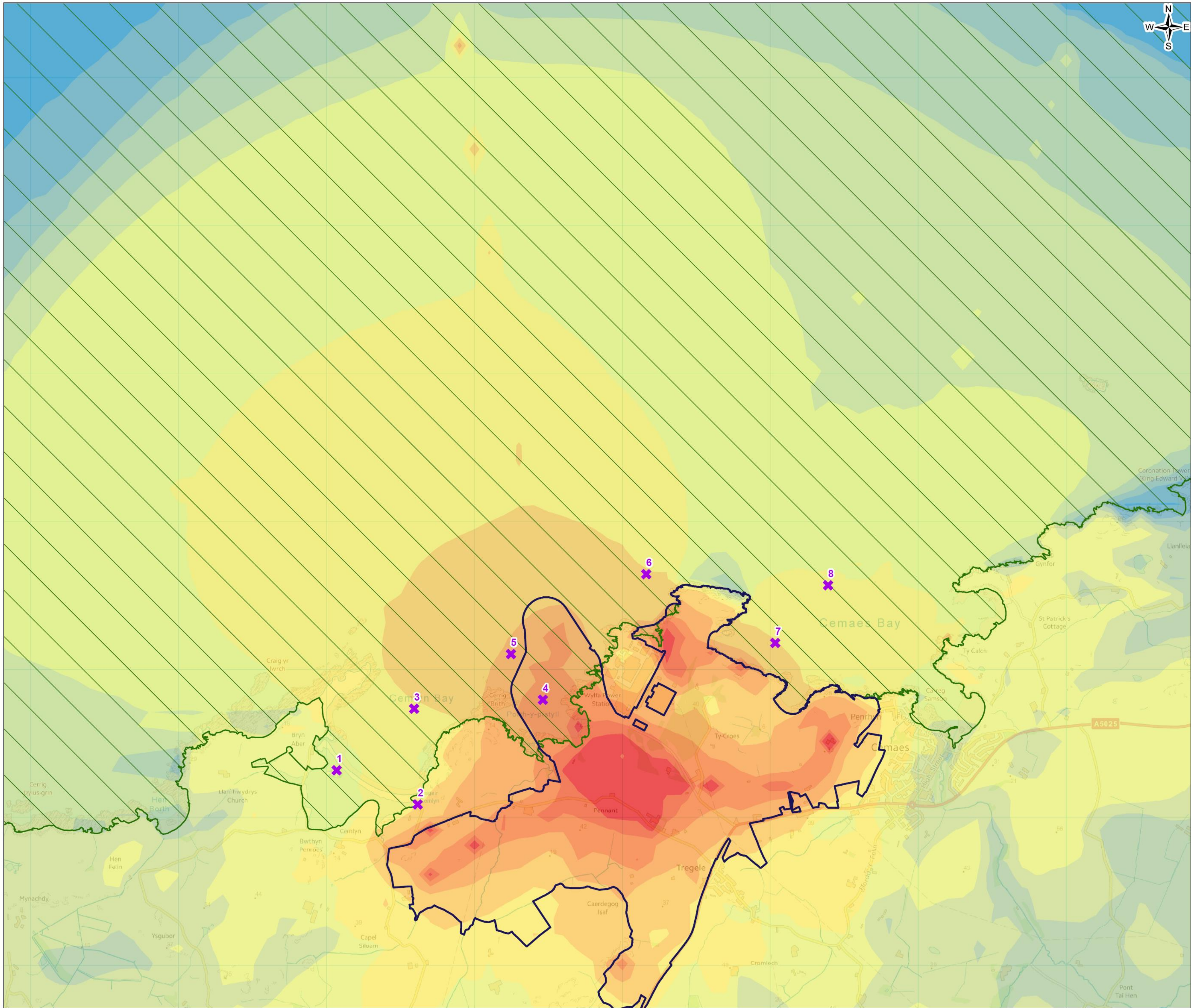
5.2 Results

The predicted worst case short-term ($L_{Aeq,5min}$) noise levels due to construction noise alone at receptors 1-8 are set out in Table below. Figure 2 shows the predicted noise levels over a wider area.

Table 4 : Predicted free-field construction noise levels, dB $L_{Aeq,5min}$

Month	Receptor							
	1	2	3	4	5	6	7	8
2020 Q3	58.6	64.6	64.3	75.7	71.0	65.3	64.8	61.4

It can be seen that the greatest noise level predicted at the tern nesting islands (receptor 1) is 58.6dB $L_{Aeq,5min}$. Noise levels at the edge of the SPA closest to construction zone E (receptor 2) are around 6dB higher. The highest noise levels occur at receptor 4, which is expected as this receptor is located within construction zone 10 where the Marine Off-Loading Facility would be constructed.



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0 125 250 500 750 1,000 1,250 metres

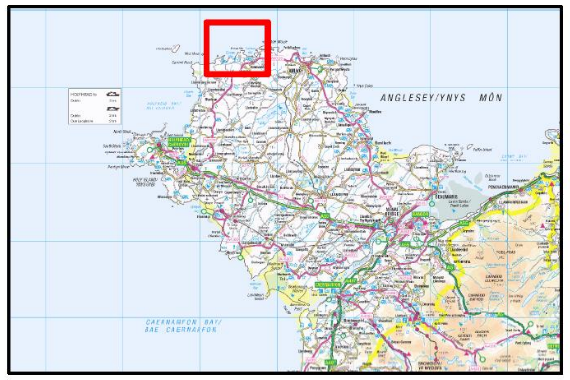
FIGURE 2

Legend

- Wylfa Newydd Development Area
- Anglesey Terns/Morwenoliaid Ynys Môn Special Protection Area
- Tern receptors

Bounding-case construction noise levels, dB $L_{Aeq,5min}$

- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90



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0	JUL 17	Initial Issue	AD	SW	BM	BM

Client

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Project

WYLFA NEWYDD PROJECT
ENVIRONMENTAL STATEMENT

Drawing Title

PREDICTED BOUNDING-CASE SHORT-TERM NOISE LEVELS, DB $L_{AEQ,5MIN}$

Scale @ A3	1:25,000	DO NOT SCALE
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6. Impulsive noise

6.1 Method

The report detailing the impulsive noise methodology is included as appendix D to this document, but for convenience the key aspects are summarised below.

For the impulsive noise calculations, a modified version of the BS 5228-1:2009+A1:2014 [RD3] methodology is used. The modifications applied are as follows.

- Sound power levels for equipment relate to measured $L_{AF,max}$ levels rather that LAeq levels.
- No corrections are applied for plant on-time, shift duration or traverse lengths.
- All sources are considered to be static point sources.
- No barrier/screening attenuations are applied.
- A downwind propagation correction of +2dB is applied in accordance with BS 8233-1:2014 [RD4] to account for potential atmospheric refraction effects.
- The contributions of multiple sources are not summated; $L_{AF,max}$ noise levels are assessed over a 125ms (1/8th of a second) timeframe, and it is considered very unlikely that more than one impulsive noise event would occur within such a short timeframe.

All construction plant are assumed to be located at the closest point of the construction zones to the receptor(s).

The BS 5228-1:2009+A1:2014 [RD3] methodology does not account for the following attenuation effects.

- Source directivity (the standard assumes that the noise emission of source initially occurs uniformly in all directions from the point of origin).
- Reflection of sound waves due to turbulence (scattering) which reduces noise levels at the receptor.
- Terrain effects due to surface roughness, terrain profiles or vegetation, which can reduce noise levels at the receptor.
- Atmospheric absorption effects which reduce noise levels at the receptor.

As the methodology does not include the above sound attenuation mechanisms, which can significantly reduce sound propagation, it is anticipated that it will provide a conservative estimate of impulsive noise levels at receptors from the activities considered.

6.2 Sound Power Levels

Appendix C of BS 5228-1:2009+A1:2014 [RD3] provides current sound level data on site equipment and site activities. Whilst the majority of the data are based on L_{Aeq} measurements, there are a number of $L_{AF,max}$ noise levels that are of interest. These are presented in appendix C to this document. It should be noted that not all the equipment listed is representative of that which would be used for the Power Station Site construction works; the list is provided to give an indication of typical $L_{AF,max}$ noise levels that may be generated on site.

The item for which the highest impulsive noise level is listed is a dump truck (reference C6.13) with a broadband value of 92dB $L_{AF,max}$ at 10m, which equates to a sound power level of 120dB L_{AW}. However, if the maximum value from each frequency band is considered, a spectrum that equates to a sound power level of 121dB L_{AW} is obtained. This value is used as a source sound power level for the preliminary calculations of vehicle movements on the site, and represents an unrealistic worst case.

It is noted that there is no $L_{AF,max}$ data in appendix C of BS 5228-1:2009+A1:2014 [RD3] that relates to piling, or using a breaker attachment on an excavator to break rock (commonly referred to as 'breaking' or 'peckering'). However, sound power data relating to the $L_{AF,max}$ indicator for this activity is presented in the noise assessment of a bridge realignment scheme in Australia [RD5]. This report also presents data for a rock crusher which would be amongst the construction plant used within the Power Station Site (123dB SWL).

6.3 Results

The results of the impulsive noise predictions are presented below in Table .

Table 5 : Predicted free-field maximum sound levels, dB $L_{AF,max}$

Activity	Receptor							
	1	2	3	4	5	6	7	8
Impact piling in construction zone 10	57.7	60.8	63.4	N/A	80.3	64.6	58.5	55.7
Mobile plant in construction zone E	58.4	69.8	57.0	55.9	54.1	49.1	47.8	46.1
Mobile plant in construction zone 5	53.5	59.8	55.7	59.1	55.6	50.6	49.7	47.6
Mobile plant in construction zone 3	51.4	55.6	54.1	60.3	55.9	51.7	50.7	48.3
Mobile plant in construction zone 2	51.7	55.4	55.3	63.7	57.8	54.3	52.7	49.9
Mobile plant in construction zone 2A	50.2	52.7	53.9	66.4	59.9	57.1	53.6	50.6
Mobile plant in construction zone 11	47.6	49.4	50.2	56.3	54.9	63.9	58.8	54.4
Mobile plant in construction zone 12	47.3	49.0	49.7	55.3	53.7	61.3	66.8	57.3
Mobile plant in construction zone A	47.0	49.0	49.1	54.1	52.0	54.3	61.0	57.0
Rock breaking in construction zone 1	52.6	55.2	55.6	64.4	59.7	57.9	57.8	54.2
Rock breaking in construction zone 2	54.7	58.4	58.3	66.7	60.8	57.3	55.7	52.9
Rock breaking in construction zone 3	54.4	58.6	57.1	63.3	58.9	54.7	53.7	51.3
Rock breaking in construction zone 4	54.0	57.9	56.6	64.8	59.9	57.3	57.0	53.7
Rock breaking in construction zone 6	54.5	59.1	56.7	61.7	57.9	54.0	54.0	51.5
Rock breaking in construction zone 7	53.1	56.8	54.5	57.7	55.1	52.5	52.8	50.6
Rock breaking in construction zone 8	52.4	55.6	54.3	59.9	56.8	56.4	57.0	53.7
Rock breaking in construction zone 9	51.3	54.2	52.9	57.5	55.0	55.0	57.1	53.7
Rock breaking in construction zone 10	55.7	58.8	61.4	N/A	78.3	62.6	56.5	53.7
Rock breaking in construction zone 12	50.3	52.0	52.7	58.3	56.7	64.3	69.8	60.3

7. Air overpressure

7.1 Method

A methodology for predicting audible maximum noise levels and infrasound from construction blasting has been proposed, and is included as appendix E to this document. For convenience, the key aspects of this method are presented in this section.

The ISEE Blaster's Handbook [RD6] ('the handbook') advises that for predicting air overpressure, scaling based on the cube root of the maximum instantaneous charge weight (within any 8ms delay) shows less scatter than the more common square root scaled distance used for scaling ground vibration. The cube root scaled distance (SD_3) is given by the following formula.

$$SD_3 = \left(\frac{R}{W^{\frac{1}{3}}}\right)$$

Where

Equation 1

SD_3 = cube root scaled distance factor

R = distance from the blast to a point (m)

W = maximum weight of explosives per delay (kg)

Following from this, the best fit line to calculate the air overpressure from scaled distance is calculated in accordance with the following formula.

$$P = A \times (SD_3)^{-B}$$

Where:

Equation 2

P = air overpressure (millibar)

SD_3 = cube root scaled distance ($m^{-1}\ kg^{1/3}$)

A = intercept of the line at a SD_3 value of 1

B = slope of the line (negative)

The constants for A and B for different types of blasts provided in Table .

Table 6 : ISEE Blaster's Handbook [RD6] site constants and site exponents for types of blasts

Blasting	A	B
Open air (no confinement)	3,589	-1.38
Coal mines (parting)	2,596	-1.62
Coal mines (highwall)	5.37	-0.79
Quarry face	37.1	-0.97
Metal mine	14.3	-0.71
Construction (average)	24.8	-1.1
Construction (highly confined)	2.48	-1.1
Buried (total confinement)	1.73	-0.96

The handbook notes that wind direction will cause air overpressures to be enhanced downwind: "For a 32 kilometer/hour (20mph) wind, an additional 10 to 20 decibels may be received downwind, or a lower 10 to 20 decibels upwind compared to a no wind situation. Mild crosswinds do not have a significant effect, but strong turbulent winds may mask the sound as well as disrupt the continuity of the air overpressures" [RD6].

USBM RI 8485 [RD7] reviews the different frequency spectra associated with different types of airblast previously classified by Siskind [RD8].

- Type 1: this airblast spectrum typically results from line of sight (or near line of sight) propagation conditions between the free face and the receptor.
- Type 2: this airblast spectrum is typically observed at large distances and behind the rock face, as the rock face acts as a barrier to the higher frequencies.
- Poorly constrained: blasts which produce a blowout and a significant stemming release pulse show a greater proportion of sound energy at higher frequencies than for type 1 or type 2 blasts.

The blast spectra associated with the type 1, type 2 and poorly constrained air overpressure frequency distribution are used to determine the A-weighted maximum sound pressure level at environmental receptors.

7.1.1 Type 1 blasts

The diminishing amplitude of the peak spectra with increased frequency associated with a type 1 airblast can be approximated with a straight regression line, as shown in Figure below.

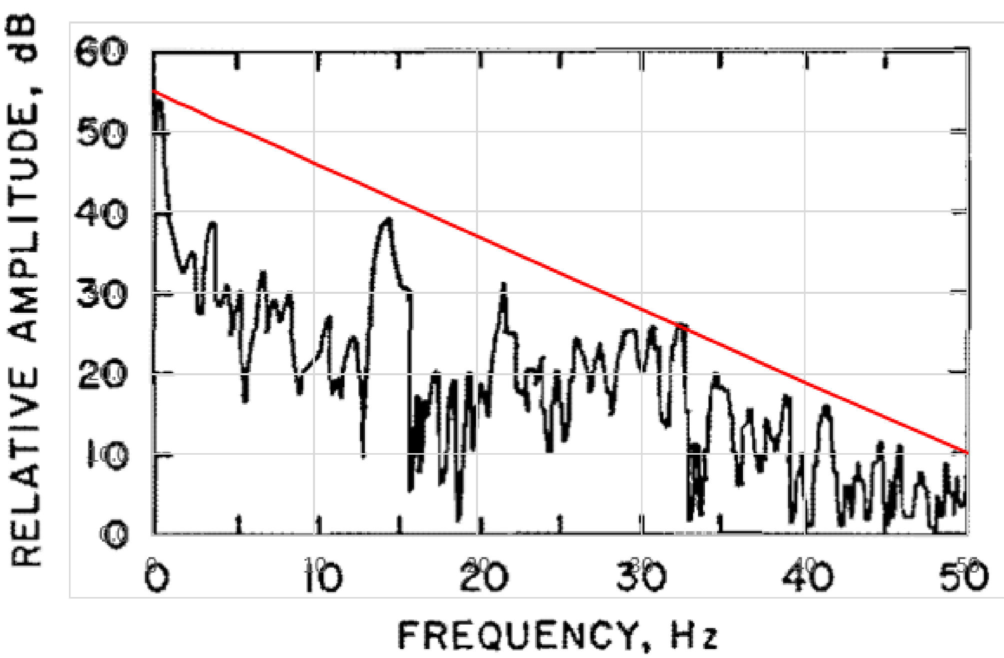


Figure 4 : Amplitude of air overpressure peak spectra vs frequency for a type 1 airblast.

The equation of the line is:

$$y = m\,x + b \qquad \text{Equation 4}$$

Where

m = -0.897959184

b = 55

At 50Hz the value of y is 10.1dB, and this value is assigned to all higher frequencies (i.e. in the absence of further data, it is assumed that there is no further attenuation of the peaks with increased frequency). This yields a spectrum which reduces in magnitude in a linear manner between 0.1-50Hz (by 44.8dB) and then remains constant to 20kHz.

The y-values shown on **Error! Reference source not found.** are relative amplitudes, and therefore this spectrum can be shifted up or down to give a dB(Lin) spectrum with the same total sound energy over the range 1Hz to 20kHz as the broadband air overpressure value predicted using the ISEE method.

The A-weighting network is applied to the dB(Lin) spectrum, and the results logarithmically summated, to arrive at an estimate of the dB $L_{AF,max}$ resulting from the blast at the receptor point.

As the shape of the dB(Lin) spectrum, and the A-weighting values applied at each frequency remain constant, the difference between the dB(Lin) value and the dB(A) value is always the same. For a typical type 1 blast, the A-weighted maximum sound level is 40dB(A) less than the broadband dB(Lin) air overpressure level.

7.1.2 Type 2 blasts

The diminishing amplitude of the peak spectra with increased frequency associated with a type 2 airblast is better approximated by a power curve regression than a straight line, as shown in Figure below.

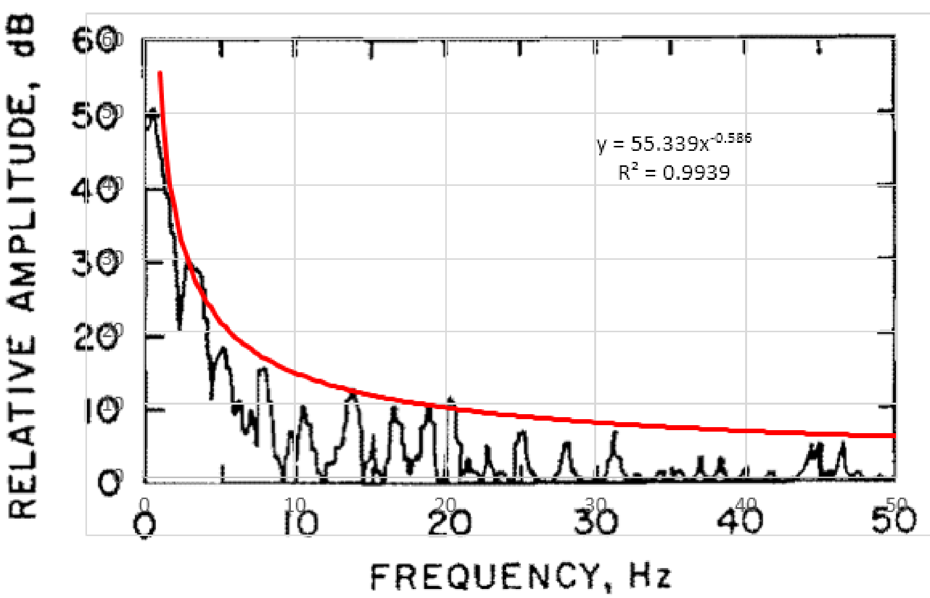


Figure 5 : Amplitude of air overpressure peak spectra vs frequency for a type 2 blast.

The equation of the line is:

$$y = \alpha x^{\beta}$$ Equation 5

Where

α = 55.339

β = -0.558

As with the type 1 blast spectrum, this is shifted up or down until the total sound energy across the spectrum matches the predicted broadband air overpressure level. Applying the A-weighting network to the resulting values, and then calculating the broadband A-weighted value reveals that for a typical type 2 blast, the A-weighted maximum sound level is 43dB(A) less than the broadband dB(Lin) air overpressure level.

7.1.3 Poorly confined blasts

Similarly to a type 1 blast, the diminishing amplitude of the peak spectra with increased frequency associated with a poorly confined airblast can be approximated with a straight regression line, as shown in Figure below.

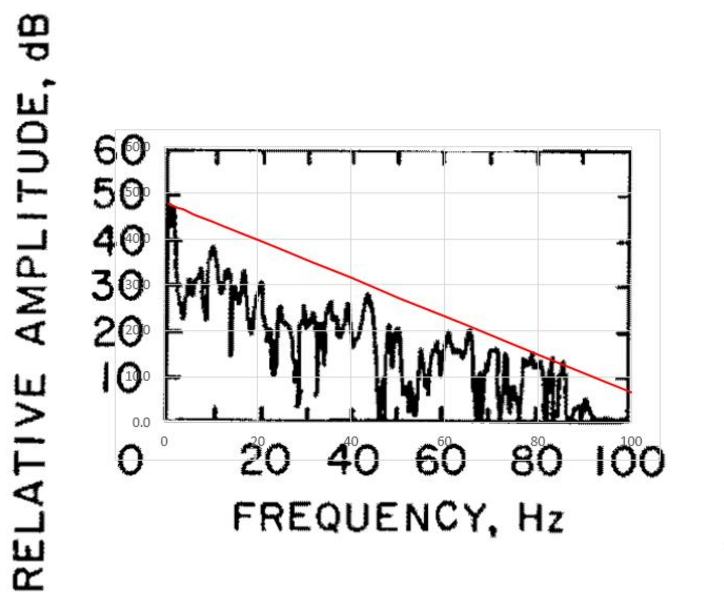


Figure 6 : Amplitude of air overpressure peak spectra vs frequency for a poorly confined blast

The equation of the line is:

$$y = m\,x + b$$ Equation 4

Where

m = -0.414141414

b = 48

Applying the same process described above for the type 2 and type 1 blasts reveals that for a typical poorly confined blast, the A-weighted maximum sound level is 38dB(A) less than the broadband dB(Lin) air overpressure level.

7.1.4 Limitations

The type 1 and unconfined blast spectra presented in USBM RI 8485 [RD7] are intended as typical examples, and do not represent the limit of potential frequency distributions which could occur, which are essentially impossible to define.

The cube root scaled distance model presented in the ISEE Blaster's Handbook [RD6] is based on best fit regression lines, and so it can be expected that around 50% of the blasts would be above these levels.

In USBM RI 8485 [RD7] it is noted that the direction of the receptor relative to the orientation of the free face can make a 5dB to 10dB difference in the magnitude of the air overpressure at the receptor. None of the prediction methodologies reviewed in this report take this potential increase in noise into consideration.

The $L_{AF,max}$ prediction method detailed above does account for the effects of atmospheric absorption or turbulent scattering that would offer additional attenuation of the high frequency components over long distances.

7.2 Review by Isle of Anglesey County Council

A review of the airblast $L_{AF,max}$ prediction method set out above has been undertaken by Amec Foster Wheeler (AmecFW) [RD9] on behalf of Isle of Anglesey County Council. Notwithstanding that all the guidance and standards quoted in the review advise against the prediction of air overpressure because of its inherently unpredictable nature, AmecFW agree with the choice of the methodology, and consider it adequate for the purposes an initial assessment to determine a test blast design that can be fired whilst meeting $L_{AF,max}$ criteria at the tern nesting site. AmecFW have also performed independent calculations which are all within 1dB of those set out in the Horizon methodology [RD10] presented in appendix F to this document.

The AmecFW review recommends that, in the first instance, predictions be based on both the ISEE construction (average) and construction (highly confined) site constants and exponents, with the frequency spectra correction derived for blowouts and unconfined blasts. AmecFW also recommend that a trial blast be undertaken and measured using a minimum of eight sound level meters at varying distances from the blast site.

7.3 Trial blast

To provide an initial validation of the $L_{AF,max}$ blasting noise prediction method detailed above, noise monitoring was conducted during trial surface blasts and the results compared to predictions of the blasts. The report detailing the trial blasts is included in appendix F to this document, but for convenience the key findings are summarised below.

Three trial surface blasts, each consisting of five individual shots, were conducted within the Wylfa Newydd Development Area on the 28 and 29 March 2017. The resulting $L_{AF,max}$ noise levels were measured using sound level meters at 11 locations, ranging between 243m and 1,648m distant from the blast site. The locations were selected to provide upwind, crosswind and downwind noise measurements from the blast site.

The sound level meters used for the noise measurements were "01dB Duo" integrating-averaging models which comply with the requirements of Class 1 of IEC 61672-1:2003 – Electroacoustics - Sound level meters - Part 1: Specifications [RD11] with a frequency response down to 2Hz. Wind speeds and directions were logged at 1s intervals during the trial blasts using ultrasonic weather stations at two locations during the trials.

In response to stakeholder consultation, ecologists also observed the resonse a colony of black-headed gulls (*Chroicocephalus ridibundus*) at Cemlyn lagoon during the trial blasts. A three-hour watch was undertaken each day, including the time before, during and after the trial blasts in order to observe and identify any behaviour changes that indicated whether birds present were disturbed during the blasts. Surveyors observed the birds constantly during the watch periods and used a recording form to capture the types/categories of disturbance, behaviour and reactions (see full methodology of observations in appendix D13-7, Application Reference Number: 6.4.89). No reactions were observed at noise levels of less than 68.2dB $L_{AF,max}$.

The majority of the upwind and crosswind measured noise levels were below the predictions for the same events. A greater proportion of the downwind measurements exceed the uncorrected predictions, but only one measurement exceeded the predictions by more than 10dB. This is at the lower end of the 10dB to 20dB range that is proposed for wind direction or temperature inversion corrections.

On the basis of the measured results, it is considered that the $L_{AF,max}$ blasting noise prediction method performed well. However, as a small number of crosswind (23%) and upwind (6%) results exceeded the predictions, it is considered prudent to add a +5dB uncertainty correction to the predictions going forward.

7.4 Prediction Results

The predicted $L_{AF,max}$ noise levels at distances up to 1,700m from the blast site are presented below in Table 7 and Table for highly confined and average confinement blasts respectively.

The predictions include a +10dB $L_{AF,max}$ correction for face orientation towards the receptors, and are based on a type 2 blast frequency spectrum for the highly confined blasts and a type 1 frequency spectrum for average confinement blasts. While this differs slightly from the approach recommended by AmecFW [RD9] (use of the frequency spectrum associated with unconfined blasts for all predictions), the predictions include a +5dB correction for uncertainty, which provides a similar effect.

Table 7 : Predicted $L_{AF,max}$ noise levels due to highly confined blast, dB

Distance, m	Maximum instantaneous charge weight, kg					
	150	125	100	75	50	25
100	85.8	85.2	84.5	83.6	82.3	80.1
200	79.2	78.6	77.9	77.0	75.7	73.5
300	75.3	74.7	74.0	73.1	71.8	69.6
400	72.6	72.0	71.3	70.4	69.1	66.9
500	70.4	69.9	69.2	68.2	67.0	64.7
600	68.7	68.1	67.4	66.5	65.2	63.0
700	67.2	66.7	65.9	65.0	63.7	61.5
800	66.0	65.4	64.7	63.8	62.5	60.3
900	64.8	64.3	63.5	62.6	61.3	59.1
1,000	63.8	63.2	62.5	61.6	60.3	58.1
1,100	62.9	62.3	61.6	60.7	59.4	57.2
1,200	62.1	61.5	60.8	59.9	58.6	56.4
1,300	61.3	60.7	60.0	59.1	57.8	55.6
1,400	60.6	60.0	59.3	58.4	57.1	54.9
1,500	60.0	59.4	58.7	57.7	56.5	54.2
1,600	59.3	58.8	58.0	57.1	55.8	53.6

Distance, m	Maximum instantaneous charge weight, kg					
	150	125	100	75	50	25
1,700	58.8	58.2	57.5	56.5	55.3	53.1
1,800	58.2	57.6	56.9	56.0	54.7	52.5
1,900	57.7	57.1	56.4	55.5	54.2	52.0
2,000	57.2	56.6	55.9	55.0	53.7	51.5

Table 8 : Predicted $L_{AF,max}$ noise levels due to average confinement blast, dB

Distance, m	Maximum instantaneous charge weight, kg					
	150	125	100	75	50	25
100	108.8	108.2	107.5	106.6	105.3	103.1
200	102.2	101.6	100.9	100.0	98.7	96.5
300	98.3	97.7	97.0	96.1	94.8	92.6
400	95.6	95.0	94.3	93.4	92.1	89.9
500	93.4	92.9	92.2	91.2	90.0	87.7
600	91.7	91.1	90.4	89.5	88.2	86.0
700	90.2	89.7	88.9	88.0	86.7	84.5
800	89.0	88.4	87.7	86.8	85.5	83.3
900	87.8	87.3	86.5	85.6	84.3	82.1
1,000	86.8	86.2	85.5	84.6	83.3	81.1
1,100	85.9	85.3	84.6	83.7	82.4	80.2
1,200	85.1	84.5	83.8	82.9	81.6	79.4
1,300	84.3	83.7	83.0	82.1	80.8	78.6
1,400	83.6	83.0	82.3	81.4	80.1	77.9
1,500	83.0	82.4	81.7	80.7	79.5	77.2
1,600	82.3	81.8	81.0	80.1	78.8	76.6
1,700	81.8	81.2	80.5	79.5	78.3	76.1
1,800	81.2	80.6	79.9	79.0	77.7	75.5
1,900	80.7	80.1	79.4	78.5	77.2	75.0
2,000	80.2	79.6	78.9	78.0	76.7	74.5

8. References

ID	Reference
[RD1]	International Electrotechnical Commission. 2002. IEC 61672-1:2002 Electroacoustics. *Sound level meters - Part 1: Specifications*. Geneva, Switzerland: International Electrotechnical Commission.
[RD2]	International Electrotechnical Commission. 2006. IEC 61672-3:2006 – Electroacoustics. *Sound level meters - Part 3: Periodic tests*. Geneva, Switzerland: International Electrotechnical Commission.
[RD3]	British Standards Institution. 2014. BS 5228-1:2009+A1:2014. *Code of practice for noise and vibration control on construction and open sites. Noise*. London, UK: British Standards Institution.
[RD4]	British Standards Institution. 2014. BS 8233:2014. *Guide on sound insulation and noise reduction for buildings.* London, UK: British Standards Institution.
[RD5]	Mark Russell. 2012. *Kapooka bridge realignment - Operational traffic and construction - Noise and vibration assessment*. SLR Consulting Australia, Report Number 640.10295. Revision 021. [Online]. [Accessed: 20 Jul 2017] Available: http://www.rms.nsw.gov.au/documents/projects/south-western/kapooka/kapooka-enviro-factors-appendix-e.pdf.
[RD6]	International Society of Explosives Engineers. 2011. *ISEE Blaster's Handbook*. 18th Edition, 18th ed. Ohio, United States of America: International Society of Explosives Engineers.
[RD7]	Siskind, David E, Stachura, Virgil J, Mark S, and Kopp, John W. ND. *Report of Investigations 8485 Structure Response Damage Produced by Airblast from Surface Mining*. Bureau of Mines, United States Department of the Interior, Avondale, Maryland, United States of America [Online]. [Accessed: 20 Jul 2017] Available: http://www.osmre.gov/resources/blasting/docs/USBM/RI8485StructureResponseDamageProducedAirblast1980.pdf.
[RD8]	Siskind, D, E. 1977. *Structure Vibrations from Blast Produced Noise*. Energy resources and excavation technology. Keystone, Colorado, United States of America. p. 1A3-l to 1A3-4.
[RD9]	Ian Hepplewhite. 2017. *Technical note: Review of Proposed Air Overpressure Calculation Methodology*. Shrewsbury, UK: Amec Foster Wheeler.
[RD10]	Jacobs. 2016. 2016. *Predicting air overpressure - Wylfa Newydd Project - Outline methodology for predicting audible noise and infrasound from construction blasting*. Bristol, UK.
[RD11]	British Standards Institution. 2003. BS EN 61672-1:2003 Electroacoustics. *Sound level meters. Specifications*. London, UK: British Standards Institution.

Appendix A. Calibration certificates

Certificate of Calibration

Issued by University of Salford (Acoustics Calibration Laboratory)
UKAS ACCREDITED CALIBRATION LABORATORY NO. 0801

APPROVED SIGNATORIES
Claire Lomax [x]   Andy Moorhouse [ ]
Gary Phillips [ ]   Danny McCaul [ ]

[redacted]

UKAS CALIBRATION
0801

University of Salford MANCHESTER

acoustic calibration laboratory
The University of Salford, Salford, Greater Manchester, M5 4WT, UK
http://www.acoustics.salford.ac.uk
t 0161 295 3030/0161 295 3319 f 0161 295 4456 e c.lomax1@salford.ac.uk

Certificate Number: 02697/5   Date of Issue: 13 May 2016

PERIODIC TEST OF A SOUND LEVEL METER to IEC 61672-3:2006

FOR:	Acoustic 1 The Barns Overdale Manordeilo Llandeilo Carmarthenshire SA19 7BD
FOR THE ATTENTION OF:	Steve Thomas
PERIODIC TEST DATE:	13/05/2016
TEST PROCEDURE:	CTP12 (Laboratory Manual)

Sound Level Meter Details

Manufacturer	01dB	
Model	DUO	
Serial number	10428	
Class	1	
Hardware version	3F2D3D	Application FW: 2.34

Associated Items	**Microphone**	**Preamplifier**
Manu	GRAS	01dB
Model	40CD	PRE22
Serial Number	207168	10129

Test Engineer (initial): GP   Name: Gary Phillips

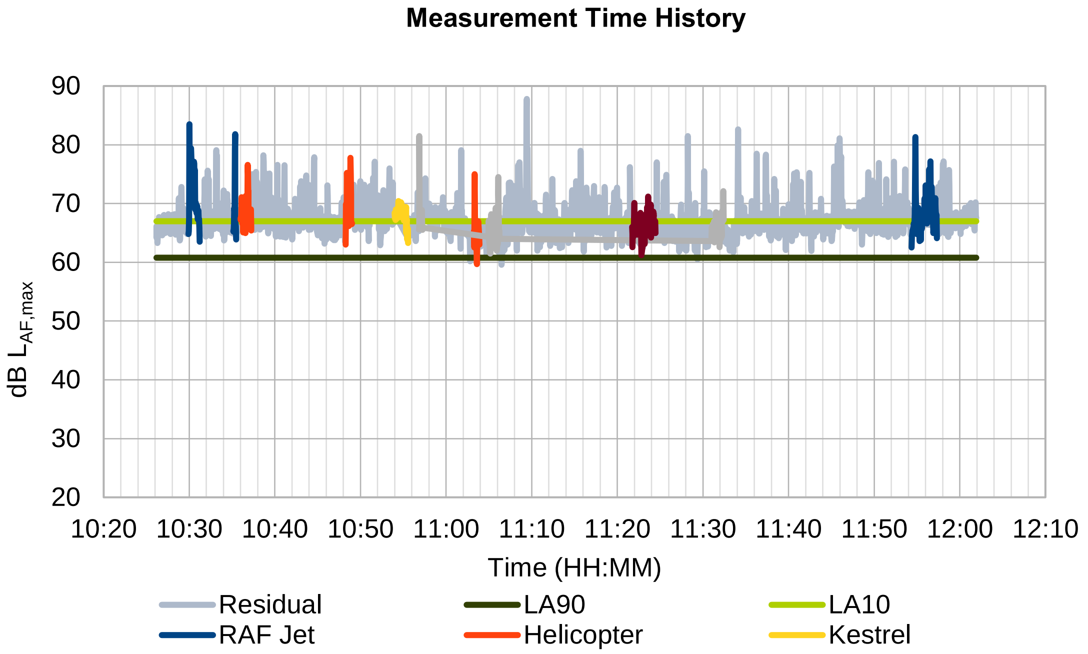
This certificate is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceability of measurement to the SI system of units and/or to the units of measurement realised at the National Physical Laboratory or other recognised national metrology institutes. This certificate may not be reproduced other than in full except with the prior written approval of the issuing laboratory.

Appendix B. Noise measurement record sheets

Noise Measurement Record

Measurement Number	**001**	Position	**NMP01**
Start Time	17/05/17 10:26:09	Equipment	01dB Duo S/N: 10426
End Time	17/05/17 12:01:57	Data File(s)	20170517_102609_120157.CMG
Duration (hh:mm:ss)	01:35:48		
Weather	Light winds (force 2/3) from south west. Dry but low cloud.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
RAF Jets	dB $L_{AF,max}$	83.5	00:04:36
Helicopters	dB $L_{AF,max}$	77.8	00:02:44
Kestrel	dB $L_{AF,max}$	70.4	00:01:35
Distant Aircraft	dB $L_{AF,max}$	71.2	00:02:25
Residual	dB $L_{AF,max}$	87.8	01:21:13
Ambient Noise Level	dB $L_{Aeq,T}$	65.0	01:35:48
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	67.0	01:35:48
Background Noise Level	**dB $L_{A90,T}$**	**60.8**	**01:35:48**



Notes

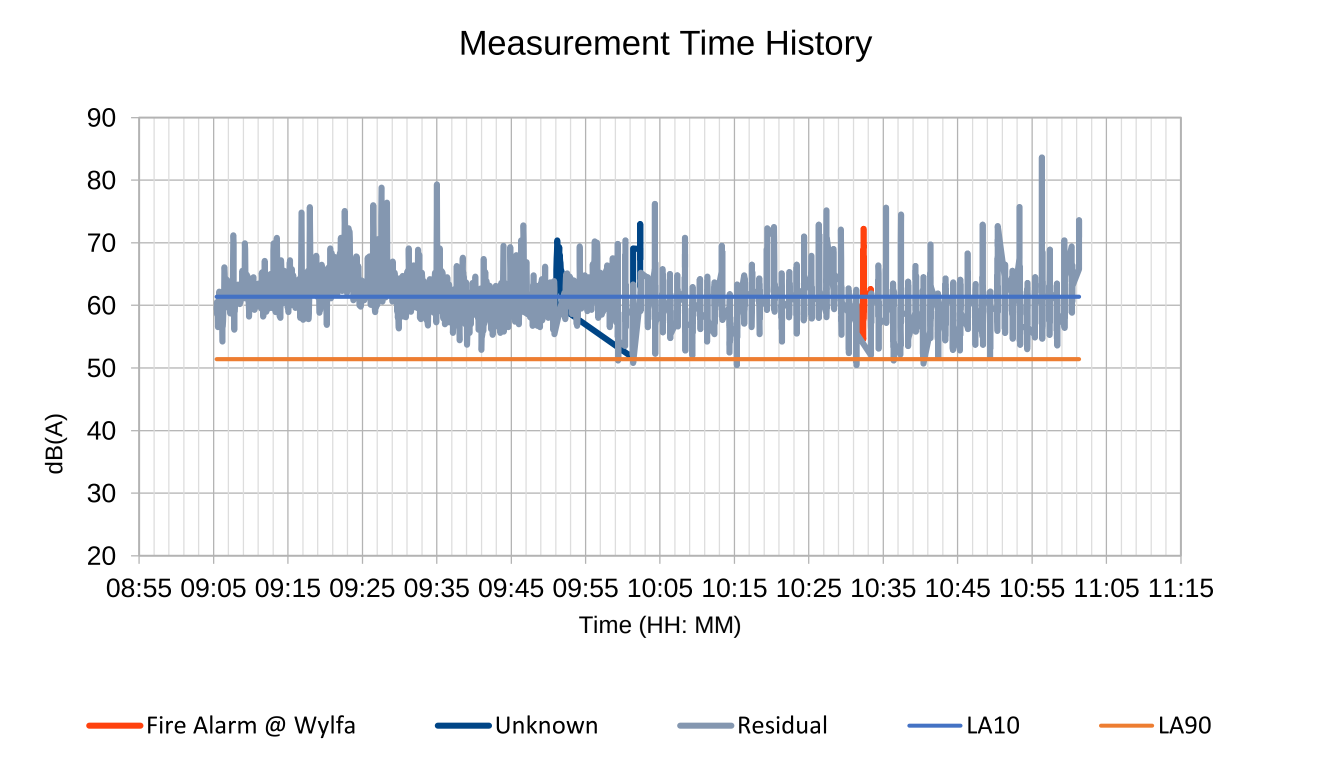
10:29 Hawk flew directly over birds at low altitude (say 500m). No reaction from birds.
10:35 Two Hawk jets in distance (south west), helicopter to East.
10:49 Helicopter approaching Valley in distance. No disturbance.
10:54 Kestrel flew over colony. Birds up. Increased noise from panicked birds.
10:57 Lady moving telescope next to meter. Stays to watch smaller island. Walks over to us at 11:00 for chat.
11:03 Helicopter in distance. No reaction.
11:05 Lady returns to scope and retrieves it.
11:22 Distant aircraft noise. Not visible. No disturbance.
11:24 Another distant aircraft which was not visible. No disturbance.
11:31 Surveyor checks meter and measure distance
11:55 RAF hawk followed by second hawk. From sea towards Valley, slow at 500m or greater. No reaction from birds.
11:57 RAF hawk (perhaps two) above cloud. Not as loud. No reaction from birds.

NMP01-0001

Noise Measurement Record

Measurement Number	**004**	Position	**BMP01**
Start Time	5/23/2017 9:03:47	Equipment	01dB Duo S/N: 10426
End Time	5/23/2017 11:02:2	Data File(s)	20170523_090347_110221.CMG
Duration (hh:mm:ss)	01:56:28		
Weather	Light breeze from SSW. 16-19°C		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	73.0	00:02:06
Fire Alarm @ Wylfa	dB $L_{AF,max}$	72.2	00:01:30
Residual	dB $L_{AF,max}$	83.6	01:52:52
Ambient Noise Level	dB $L_{Aeq,T}$	58.7	01:56:28
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	61.4	01:56:28
Background Noise Level	**dB $L_{A90,T}$**	**51.4**	**01:56:28**



Notes

9.52 Unknown - No reason noted

10.03 Unknown - Same as above

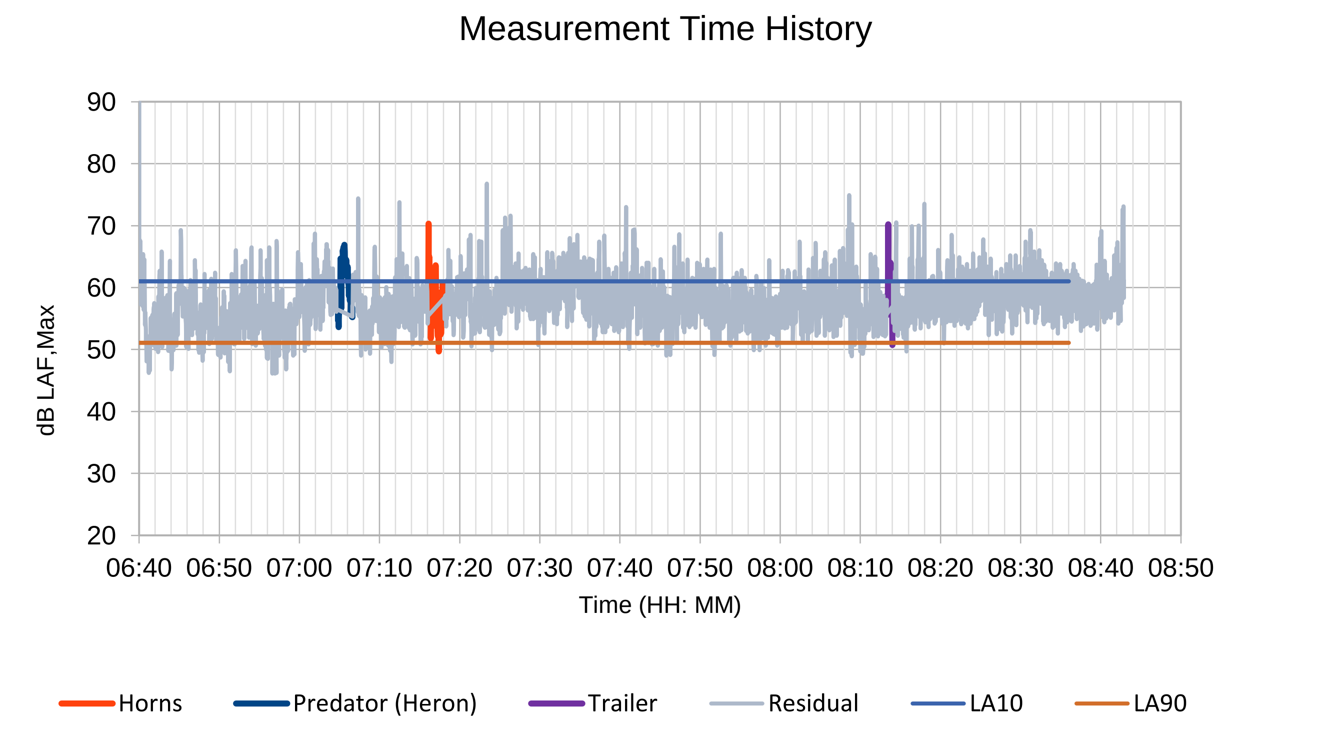
10.33 A (Fire Alarm Test at Wylfa) - Continuous horn sound

BMP01-0004

Noise Measurement Record

Measurement Number	**007**	Position	**BMP01**
Start Time	5/25/2017 6:40:38	Equipment	01dB Duo S/N: 10426
End Time	5/25/2017 8:43:34	Data File(s)	20170525_064038_084334.CMG
Duration (hh:mm:ss)	02:02:56		
Weather	Light breeze (Beaufort force 2) from ENE swinging to NE. 12°C.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Predator (Heron)	dB $L_{AF,max}$	70.4	00:01:56
Horns	dB $L_{AF,max}$	73.3	00:02:00
Trailer	dB $L_{AF,max}$	75.6	00:00:43
Residual	dB $L_{AF,max}$	80.8	01:56:52
Ambient Noise Level	dB $L_{Aeq,T}$	59.0	02:02:56
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	61.0	02:02:56
Background Noise Level	**dB $L_{A90,T}$**	**51.1**	**02:02:56**



Notes

7.06 Predetor: Grey Heron (x1) - All terns raised to 8m and back down

7.18 Vehicle Horns (x2) - Not sure what the people were doing… possibly trying to attract cow? No reaction.

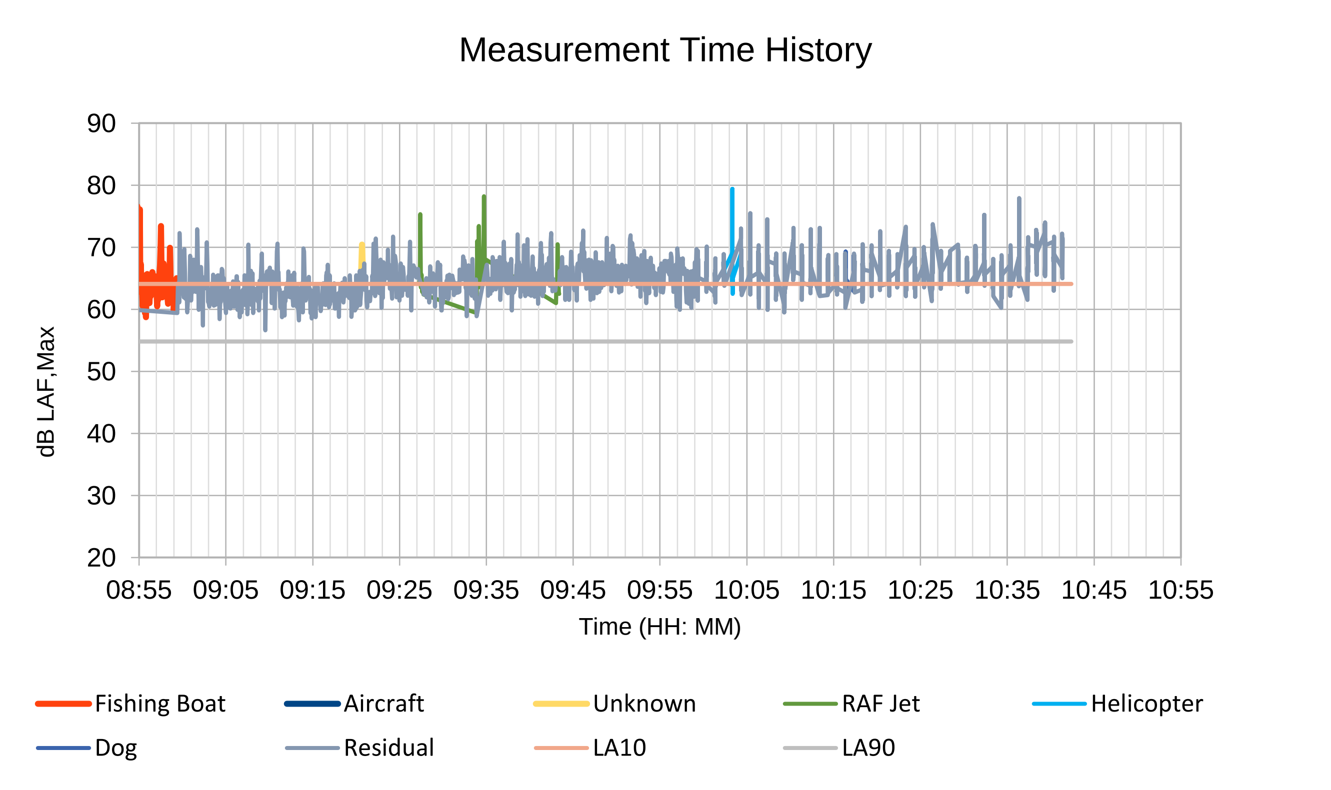
8.14 Tractor trailer - Sounded like a trailer being slammed shut. No reaction.

BMP01-0007

Noise Measurement Record

Measurement Number	**008**	Position	**BMP01**
Start Time	25/5/2017 08:43:37	Equipment	01dB Duo S/N: 10426
End Time	25/5/2017 10:43:39	Data File(s)	20170525_084337_104339.CMG
Duration (hh:mm:ss)	01:57:37		
Weather	Light to gentle breeze (Beaufort force 2-3) from NNE. 14-16°C.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Fishing Boat	dB $L_{AF,max}$	76.6	00:04:50
Aircraft	dB $L_{AF,max}$	0.0	00:00:00
Unknown	dB $L_{AF,max}$	70.4	00:00:18
RAF Jet	dB $L_{AF,max}$	78.2	00:02:01
Helicopter	dB $L_{AF,max}$	79.4	00:01:06
Dog	dB $L_{AF,max}$	69.3	00:00:54
Residual	dB $L_{AF,max}$	77.9	0.075324
Ambient Noise Level	dB $L_{Aeq,T}$	60.9	01:57:37
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	64.1	01:57:37
Background Noise Level	**dB $L_{A90,T}$**	**54.8**	**01:57:37**



Notes

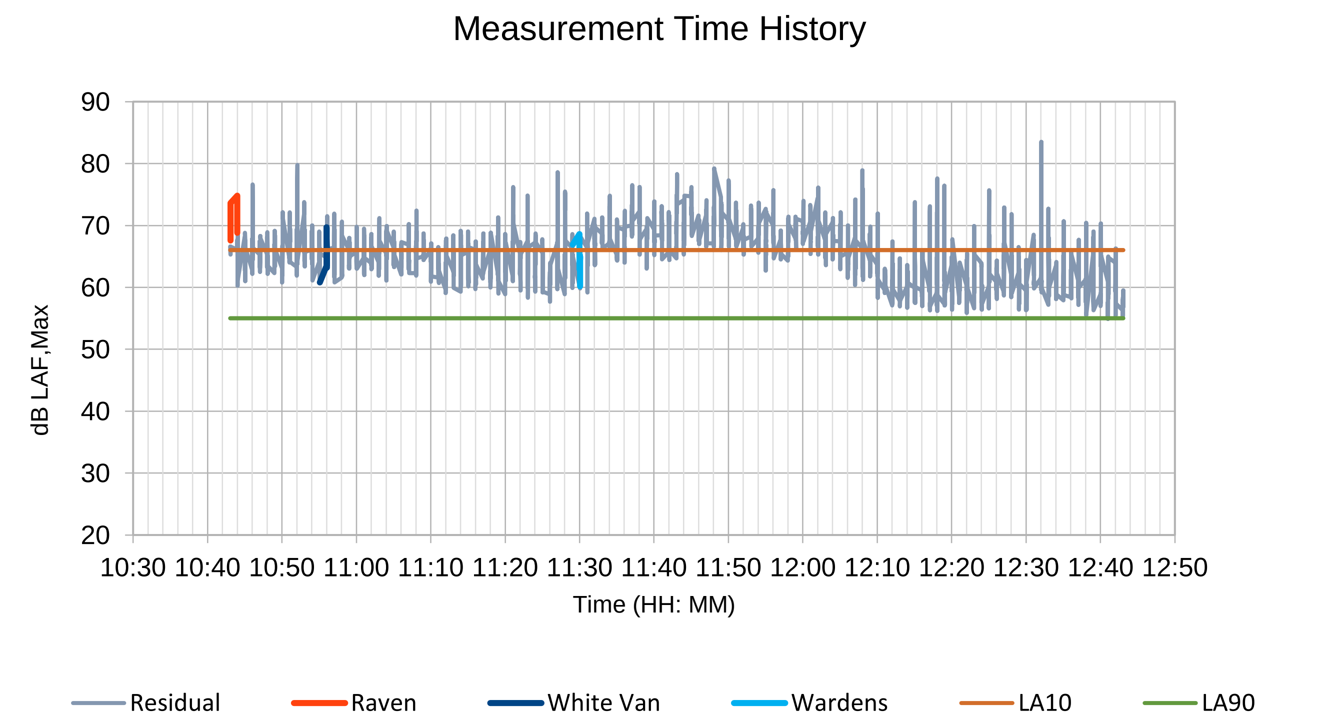
8.56 Fishing boat - Quite loud engine when moving
8.57 Aircraft - Flew up and down at 5m height for 20 seconds
9.21 Unknown - Flew up. Not seen a silent lift off to date
9.27 RAF jet - Quite loud, no disturbance
9.35 RAF jet - Pretty loud when swung to head south east
9.44 RAF jet - Quite loud west to east
10.05 Helicopter - Low hum
10.18 Dog - Mid- pitched bark

BMP01-0008

Noise Measurement Record

Measurement Number	**009**	Position	**BMP01**
Start Time	25/5/2017 10:43:46	Equipment	01dB Duo S/N: 10426
End Time	25/5/2017 12:43:48	Data File(s)	20170525_104346_124348.CMG
Duration (hh:mm:ss)	02:00:02		
Weather			

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Raven	dB $L_{AF,max}$	74.8	00:00:14
White Van	dB $L_{AF,max}$	69.7	00:00:31
Wardens	dB $L_{AF,max}$	68.6	00:00:39
Residual	dB $L_{AF,max}$	83.5	01:58:38
Ambient Noise Level	dB $L_{Aeq,T}$	62.7	02:00:02
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	66.0	02:00:02
Background Noise Level	**dB $L_{A90,T}$**	**55.0**	**02:00:02**



Notes

10.44 Raven - From east to west

10.56 Van - All lifted 8m off ground for 30 seconds and back down

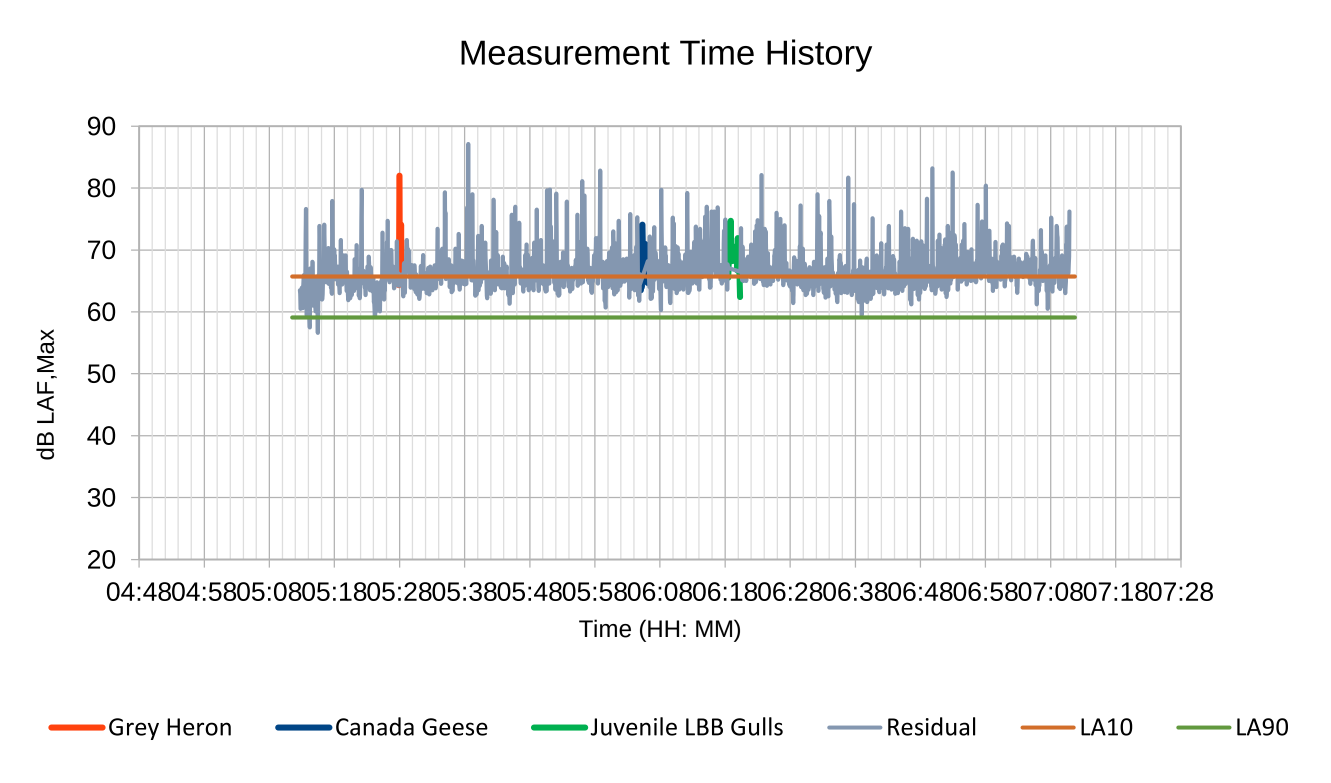
11.30 Wardens - Two wardens from the road and one warden from the ridge went on to the large island to carry out work. As soon as the two from the road entered the water to wade over, every single bird left the large island. The smal island seem unaffected. The birds all flocked and circled the lagoon between 5 and 30 metres height for the duration. Only 30 or so terns flew out to sea. 150 terns landed on small island, and 100 to the eastern bank of the lagoon. The majority of cn and ae stayed in the air. The majority of bh landed and stayed on the water. After 25 minutes the wardens waded back to the road. 5 minutes later they reached land, and as soon as they stepped out of the water, the birds landed in the sea. Maybe this was stress related and overheating. In the 30minutes after the wardens had left, all the terns did their little raise up and down for 20 seconds four times. The flock when we left seemed to be larger than usual indicating the pairs stuck together for a while before heading out to sea.

BMP01-0009

Noise Measurement Record

Measurement Number	**010**	Position	**BMP01**
Start Time	26/5/2017 05:11:32	Equipment	01dB Duo S/N: 10426
End Time	26/5/2017 07:11:45	Data File(s)	20170526_051132_071145.CMG
Duration (hh:mm:ss)	01:58:14		
Weather			

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Grey Heron	dB $L_{AF,max}$	82.0	00:00:24
Canada Geese	dB $L_{AF,max}$	74.1	00:01:09
Juvenile LBB Gulls	dB $L_{AF,max}$	74.7	00:01:49
Residual	dB $L_{AF,max}$	87.1	01:54:52
Ambient Noise Level	dB $L_{Aeq,T}$	63.6	01:58:14
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	65.7	01:58:14
Background Noise Level	**dB $L_{A90,T}$**	**59.1**	**01:58:14**



Notes

5.28 Grey Heron - All birds raised up for 50 seconds and landed

6.05 Non-Predatory: Canada Geese (x2) - All birds raised up for1 minutes and landed

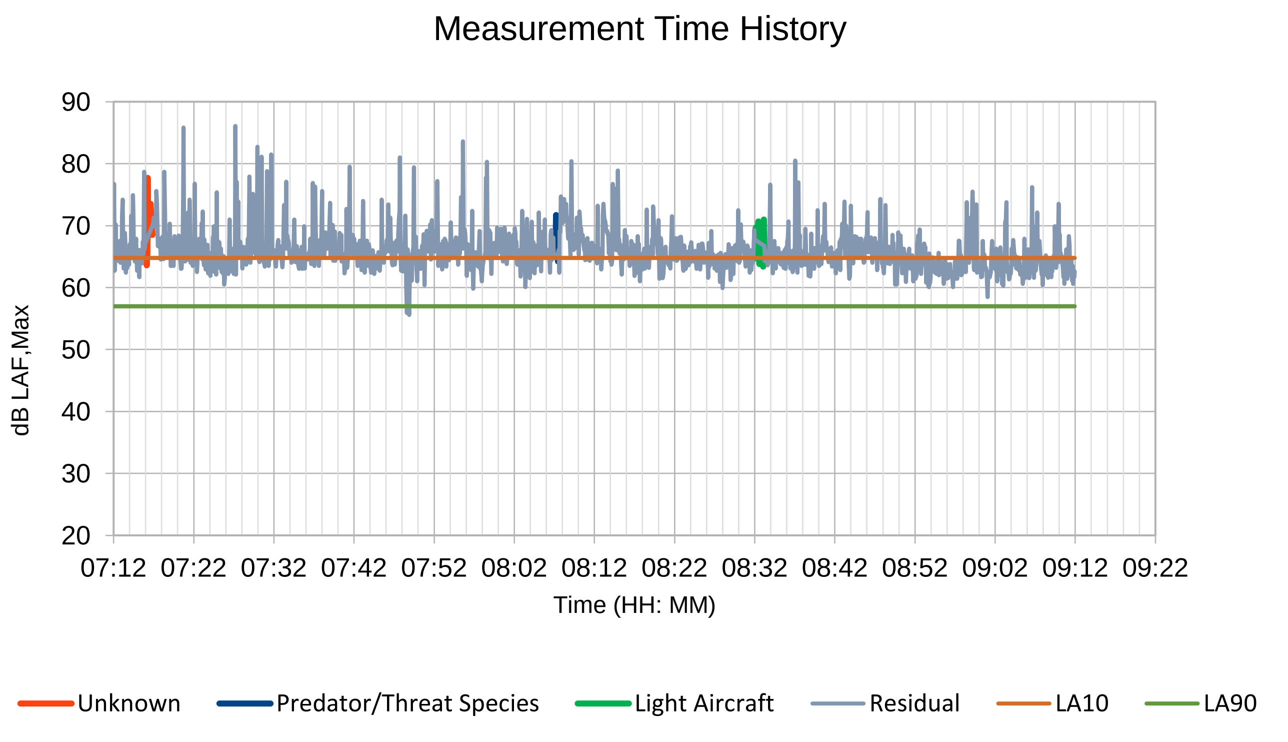
6.19 Juvenile lesser black-backed gulls (x3) - All birds raised up for 94 seconds and landed

BMP01-0010

Noise Measurement Record

Measurement Number	**011**	Position	**BMP01**
Start Time	26/5/2017 07:12:00	Equipment	01dB Duo S/N: 10426
End Time	26/5/2017 09:12:00	Data File(s)	20170526_071200_091200.CMG
Duration (hh:mm:ss)	02:00:00		
Weather	Calm (Beaufort force 0) strengthening to light breeze (force 2) from east. 17-20°C.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	77.7	00:00:58
Predator/Threat Species	dB $L_{AF,max}$	71.7	00:00:32
Light Aircraft	dB $L_{AF,max}$	71.0	00:01:12
Residual	dB $L_{AF,max}$	86.1	01:57:18
Ambient Noise Level	dB $L_{Aeq,T}$	62.5	02:00:00
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	64.8	02:00:00
Background Noise Level	**dB $L_{A90,T}$**	**57.0**	**02:00:00**



Notes

7.16 Unknown - All birds flew up for 30 seconds then landed

8.07 Predator/Threat: great black-backed gull (x2) and juvenile lesser black-backed gull (x) - All birds flew up for around 60 seconds then landed

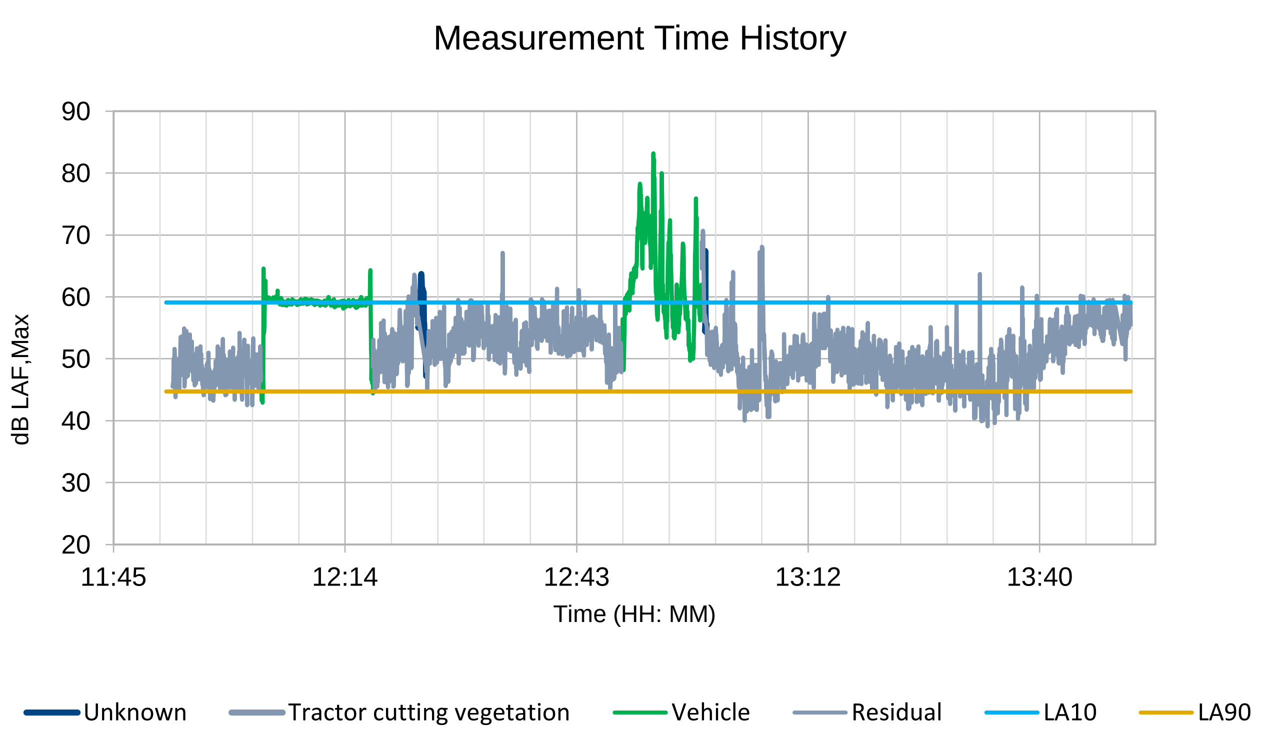
8.32 Light aircraft - Came directly over colony

BMP01-0011

Noise Measurement Record

Measurement Number	**012**	Position	**BMP02**
Start Time	26/5/2017 11:52:09	Equipment	01dB Duo S/N: 10426
End Time	26/5/2017 13:52:09	Data File(s)	20170526_115209_135209_Modified.CMG
Duration (hh:mm:ss)	01:58:21		
Weather	Mod. breeze (Beaufort force 4) decreasing to light breeze (force 2) from east. 26-27°C		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	68.8	00:01:13
Tractor cutting vegetation	dB $L_{AF,max}$	62.4	00:00:13
Vehicle	dB $L_{AF,max}$	87.6	00:23:51
Residual	dB $L_{AF,max}$	71.5	01:33:04
Ambient Noise Level	dB $L_{Aeq,T}$	59.4	01:58:21
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	59.1	01:58:21
Background Noise Level	**dB $L_{A90,T}$**	**44.7**	**01:58:21**



Notes

12.04 Nothing in notes but discussions with surveyor indicate this was probably a car waiting near to the sound level meter with engine running (this measurement position was on the road). Does not influence maximum sound levels for residual noise as engine noise is very constant.

12.24 Unknown - Birds rose to 5m height for 60 seconds and back down

12.19 Nothing in notes but discussions with surveyor indicat this was likely car movements along road passing the sound level meter.

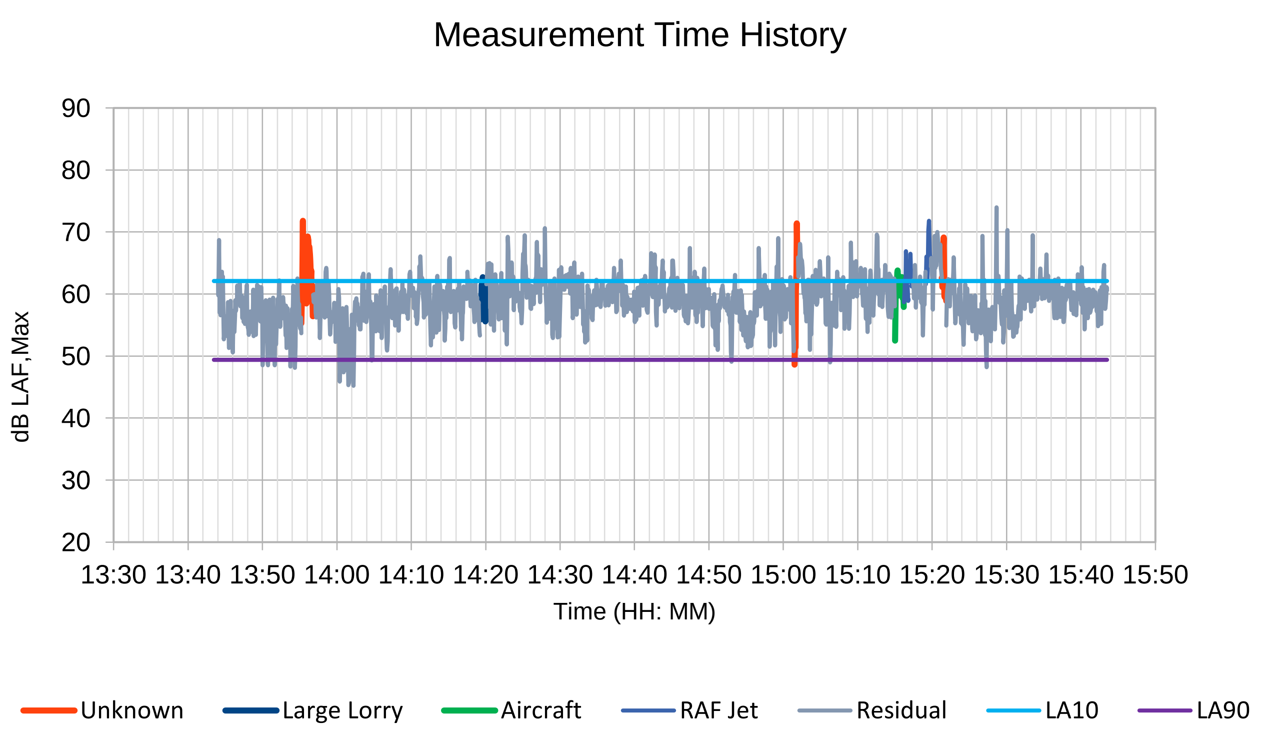
12.59 Unknown - Birds rose to 5m height for 35 seconds and back down

12.30 Tractor cutting vegetation - No reaction to noise or visual

Noise Measurement Record

Measurement Number	**013**	Position	**BMP01**
Start Time	2//6/2017 13:43:30	Equipment	01dB Duo S/N: 10426
End Time	2//6/2017 15:43:32	Data File(s)	20170602_134330_154332_Modified.CMG
Duration (hh:mm:ss)	01:58:01		
Weather	Gentle breeze (Beaufort force 3) declining to light breeze (force 2) from SW. 17-19°C		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	76.9	00:02:38
Large Lorry	dB $L_{AF,max}$	68.3	00:00:46
Aircraft	dB $L_{AF,max}$	67.9	00:01:12
RAF Jet	dB $L_{AF,max}$	73.1	00:01:37
Residual	dB $L_{AF,max}$	78.9	01:51:48
Ambient Noise Level	dB $L_{Aeq,T}$	58.8	01:58:01
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	62.1	01:58:01
Background Noise Level	**dB $L_{A90,T}$**	**49.4**	**01:58:01**



Notes

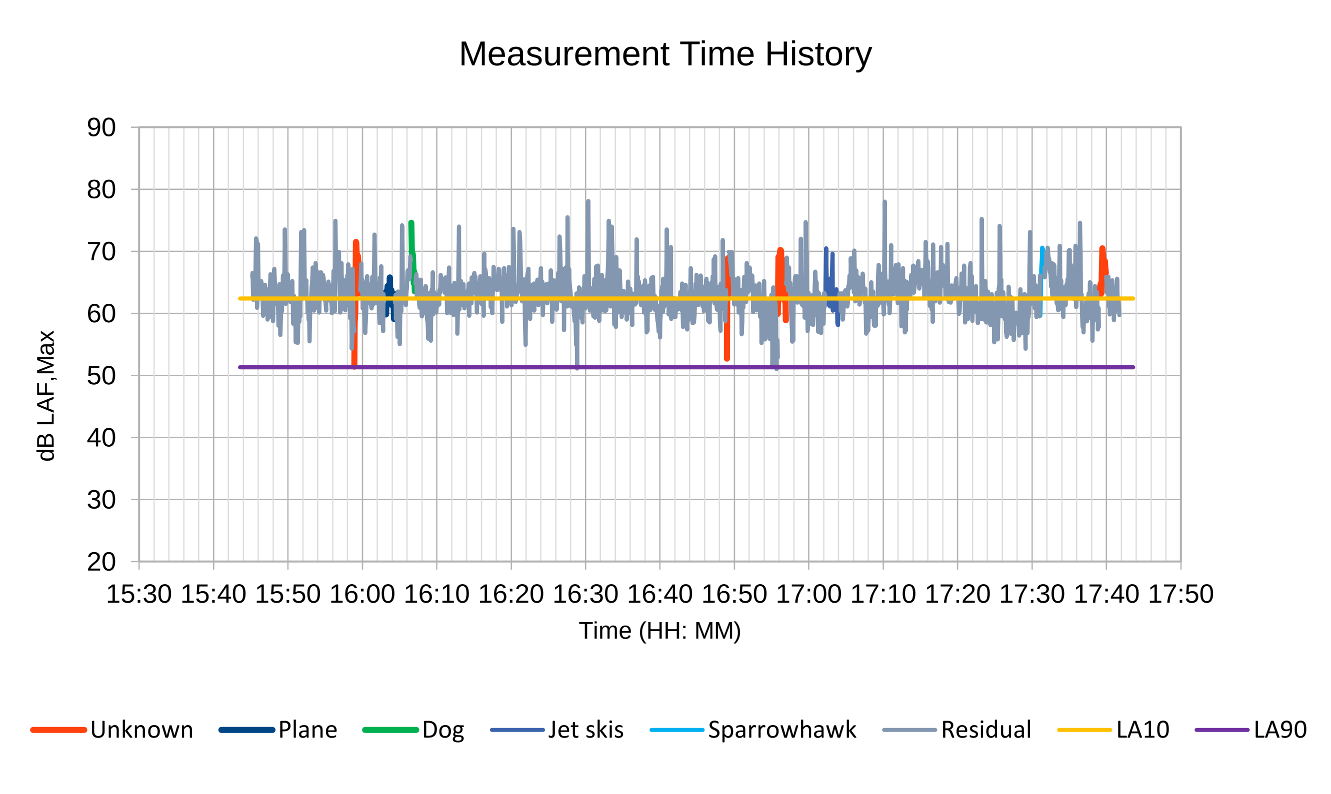
13.56 Unknown - All flew up to 5-8m and down
14.19 Large lorry - No reaction
15.01 Unknown - No disturbance type recorded
15.15 Aircraft - No reaction
15.16 RAF jet - No reaction
15.17 RAF Jet (x3) - No reaction
15.19 RAF Jet (x3) - No reaction pretty loud
15.21 Unknown - No disturbance type recorded

BMP01-0013

Noise Measurement Record

Measurement Number	**014**	Position	**BMP01**
Start Time	2//6/2017 15:43:35	Equipment	01dB Duo S/N: 10426
End Time	2//6/2017 17:43:37	Data File(s)	20170602_154335_174337_Modified.CMG
Duration (hh:mm:ss)	01:49:22		
Weather	Light breeze (Beaufort Force 2) from South West. 18°C		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	71.5	00:02:57
Plane	dB $L_{AF,max}$	65.8	00:01:27
Dog	dB $L_{AF,max}$	74.6	00:00:29
Jet skis	dB $L_{AF,max}$	70.5	00:01:47
Sparrowhawk	dB $L_{AF,max}$	70.6	00:00:29
Residual	dB $L_{AF,max}$	78.1	01:49:22
Ambient Noise Level	dB $L_{Aeq,T}$	59.4	01:49:22
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	62.4	01:49:22
Background Noise Level	**dB $L_{A90,T}$**	**51.3**	**01:49:22**



Notes

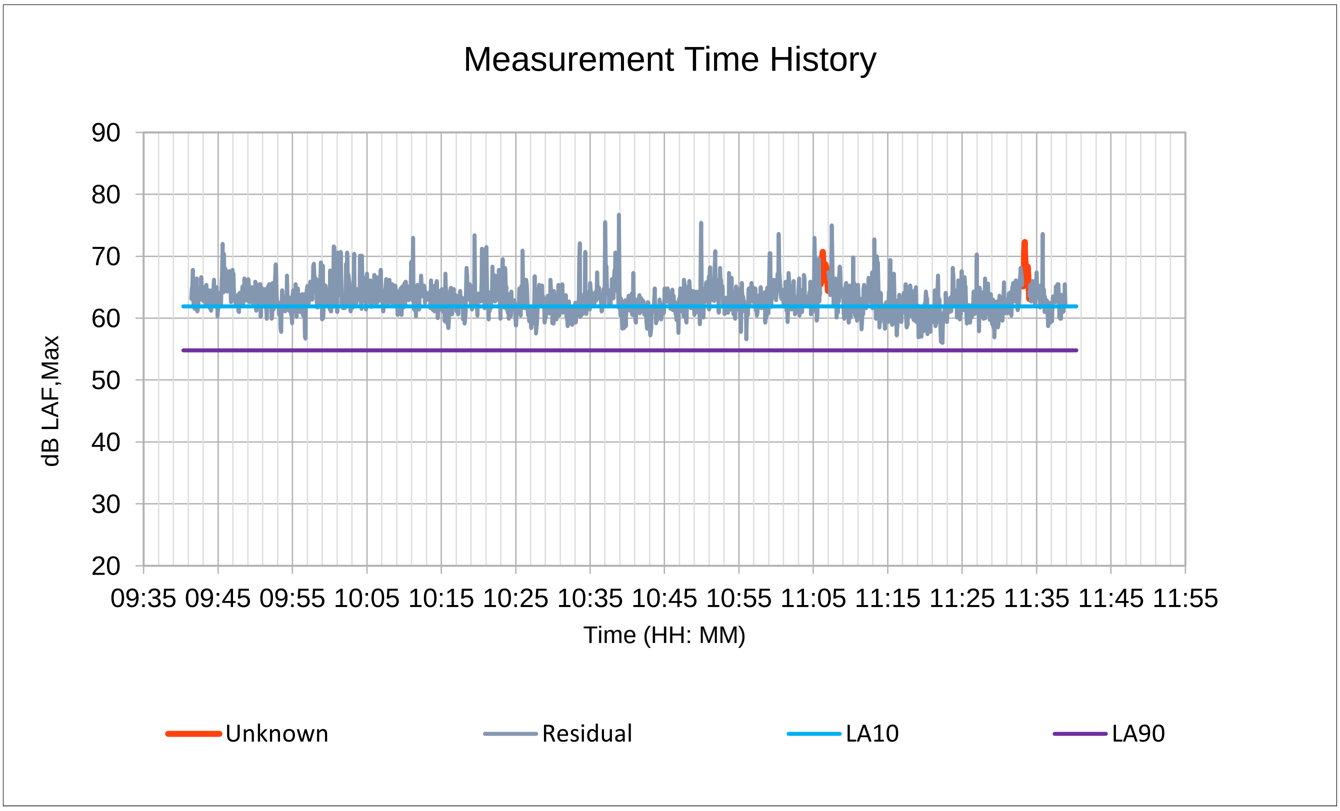
15.59 Unknown - No disturbance type noted
16.03 Passenger Plane - No reaction
16.07 Greyhound Dog - Flew up low and scattered for 60 seconds, before landing back down, small island first then large lisland
16.49 Unknown - No disturbance type noted
16.56 Unknown - No disturbance type noted
17.03 Jet Skis (x4) - No reaction- different sound
17.31 Female Sparrowhawk - About 30 terns fly-up
17.39 Unknown - No disturbance type noted

BMP01-0014

Noise Measurement Record

Measurement Number	**015**	Position	**BMP01**
Start Time	3//6/2017 09:41:12	Equipment	01dB Duo S/N: 10426
End Time	3//6/2017 11:41:14	Data File(s)	20170603_094112_114114_Modified.CMG
Duration (hh:mm:ss)	02:00:02		
Weather	Fresh breeze (Beaufort Force 5) from South South West. 17°C		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	72.3	00:01:55
Residual	dB $L_{AF,max}$	76.7	01:55:34
Ambient Noise Level	dB $L_{Aeq,T}$	59.5	02:00:02
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	61.9	02:00:02
Background Noise Level	**dB $L_{A90,T}$**	**54.8**	**02:00:02**



Notes

11.07 Unknown - No disturbance type noted

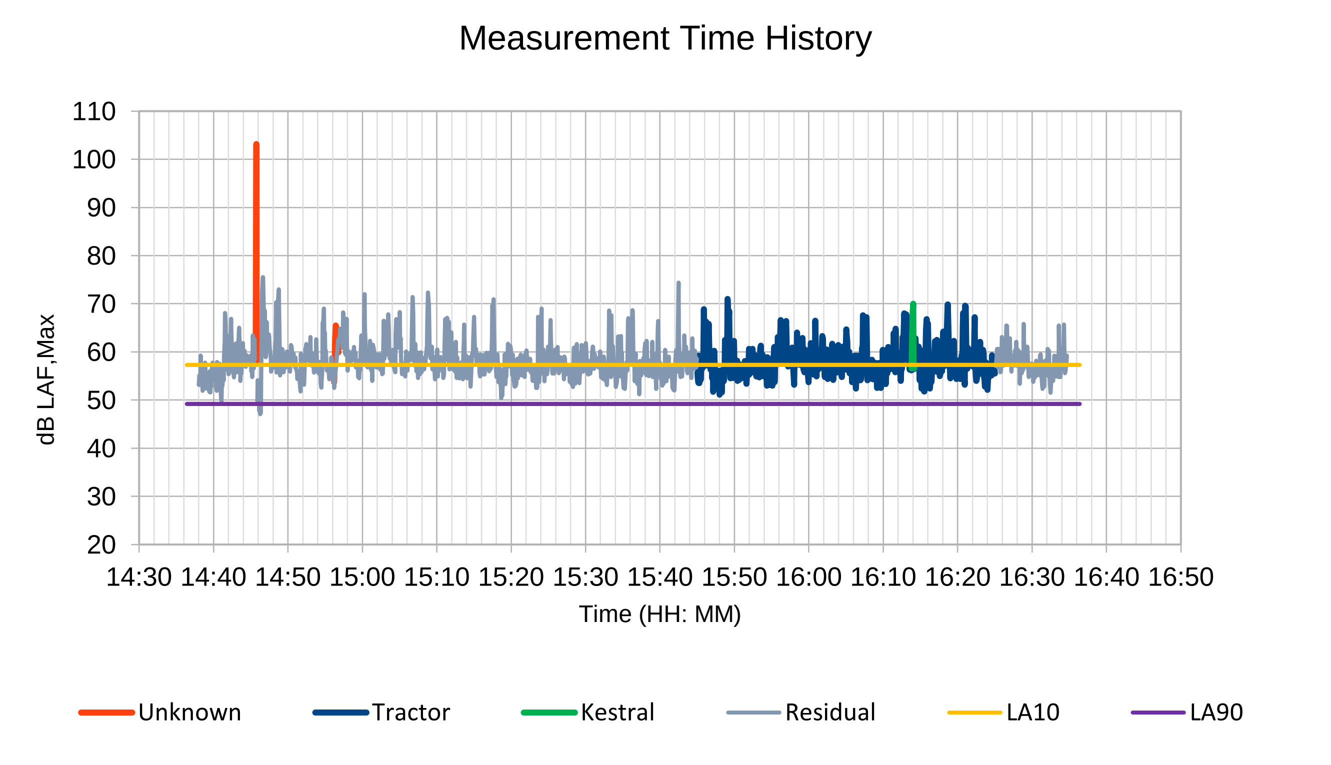
11.34 Unknown - No disturbance type noted

BMP01-0015

Noise Measurement Record

Measurement Number	**016**	Position	**BMP01**
Start Time	3//6/2017 14:36:25	Equipment	01dB Duo S/N: 10426
End Time	3//6/2017 16:36:27	Data File(s)	20170603_143625_163627_modified.CMG
Duration (hh:mm:ss)	02:00:02		
Weather	Fresh breeze (Beaufort force 5) to strong breeze (force 6). 19-20°C		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	65.5	00:00:32
Anthropogenic	dB $L_{AF,max}$	103.2	00:00:16
Kestral	dB $L_{AF,max}$	70.0	00:00:25
Residual	dB $L_{AF,max}$	75.5	01:55:28
Ambient Noise Level	dB $L_{Aeq,T}$	58.8	02:00:02
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	57.3	02:00:02
Background Noise Level	**dB $L_{A90,T}$**	**49.2**	**02:00:02**



Notes

14.56 Unknown - No disturbance type noted

15.45 Anthropogenic - Tractor cutting grass on opposite side of lagoon for 40 minutes, south east.

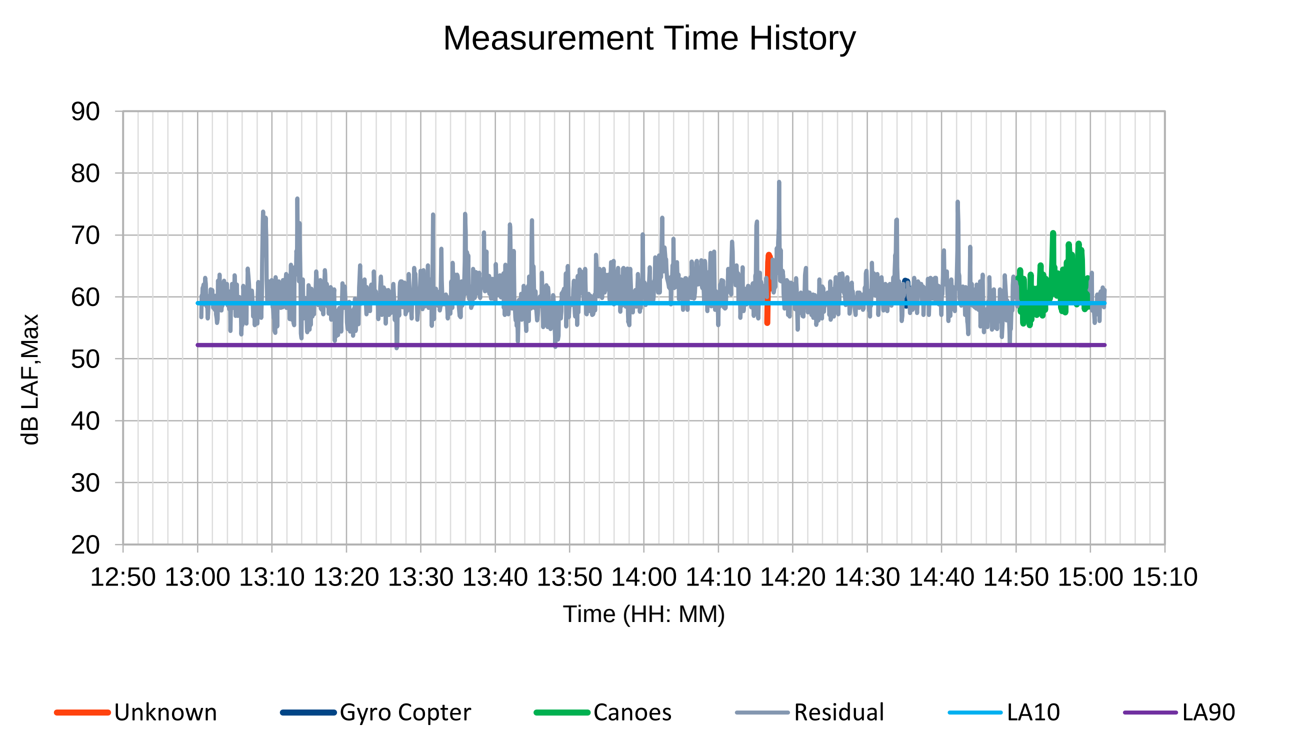
16.14 Kestrel - Kestrel flew low south west of lagoon to north east

BMP01-0016

Noise Measurement Record

Measurement Number	**017**	Position	**BMP01**
Start Time	4//6/2017 12:58:30	Equipment	01dB Duo S/N: 10426
End Time	4//6/2017 15:02:28	Data File(s)	20170604_125830_150228_Modified.CMG
Duration (hh:mm:ss)	02:03:58		
Weather	Strong breeze (Beaufort Force 6) from South West. 19°C.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	66.8	00:00:40
Gyro Copter	dB $L_{AF,max}$	62.6	00:00:27
Canoes	dB $L_{AF,max}$	70.3	00:09:39
Residual	dB $L_{AF,max}$	78.6	01:50:40
Ambient Noise Level	dB $L_{Aeq,T}$	56.8	02:03:58
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	59.0	02:03:58
Background Noise Level	**dB $L_{A90,T}$**	**52.2**	**02:03:58**



Notes

14.17 Unknown - No disturbance type noted

14.35 Gyro Copter - No reaction by birds

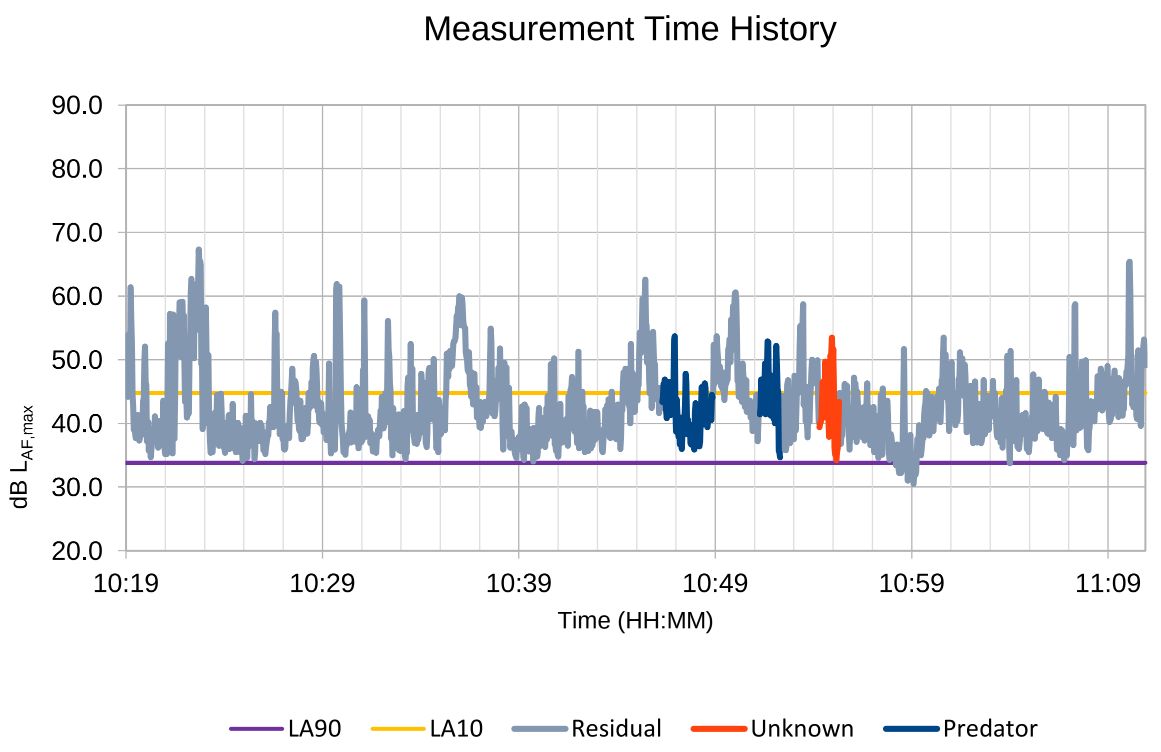
14.50 Canoes - No reaction by birds

BMP01-0017

Noise Measurement Record

Measurement Number	**019**	Position	**BMP02**
Start Time	07/06/17 10:19:41	Equipment	01dB Duo S/N: 10428
End Time	07/06/17 11:11:37	Data File(s)	20170607_101941_111137.cmg
Duration (hh:mm:ss)	00:51:56		
Weather	Fresh breeze from the west. Dry with high clouds and good visibility.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Predator	dB $L_{AF,max}$	53.7	00:03:40
Unknown	dB $L_{AF,max}$	53.5	00:01:02
Residual	dB $L_{AF,max}$	67.3	00:47:14
Ambient Noise Level	dB $L_{Aeq,T}$	43.2	00:51:56
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	44.8	00:51:56
Background Noise Level	**dB $L_{A90,T}$**	**33.8**	**00:51:56**



Notes

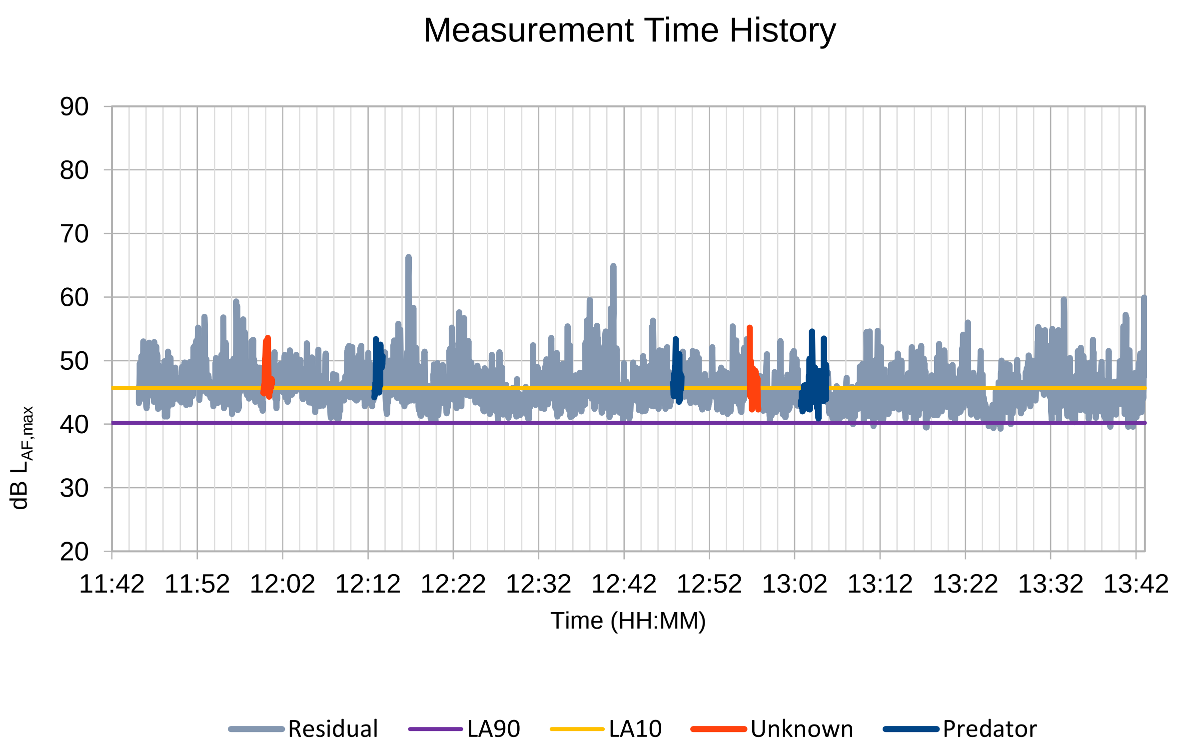
10:47 Man in high-visibility jacket walking east along ridge. Birds flew up to 5m for 30 seconds and landed. Fly up reaction.
10:52 Fulmar observed. Birds flew up to 10m for 60 seconds. Fly up reaction.
10:55 Birds flew up to 10m for 45 seconds. Fly up reaction.

BMP02-0019

Noise Measurement Record

Measurement Number	**022**	Position	**BMP02**
Start Time	10/06/17 11:42:16	Equipment	01dB Duo S/N: 10428
End Time	10/06/17 13:43:20	Data File(s)	20170610_114216_134320_3m eliminated.cmg
Duration (hh:mm:ss)	02:01:04		
Weather	Fresh to strong breeze blowing from the southwest. Drizzle, mist with moderate to high clouds and moderate visibility. 14 deg. C.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Predator	dB $L_{AF,max}$	54.6	00:05:06
Unknown	dB $L_{AF,max}$	55.2	00:02:04
Residual	dB $L_{AF,max}$	66.3	01:50:46
Ambient Noise Level	dB $L_{Aeq,T}$	43.7	02:01:04
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	45.7	02:01:04
Background Noise Level	**dB $L_{A90,T}$**	**40.2**	**02:01:04**



Notes

12:00 Birds rose to 5m for 25 seconds and down. Fly up reaction.

12:13 Black-headed gull showing aggression. Fly up reaction.

12:48 Eating sea food on southern edge of lagoon. Fly up reaction.

12:57 Birds rose 5-8m for 30 seconds and down. Fly up reaction.

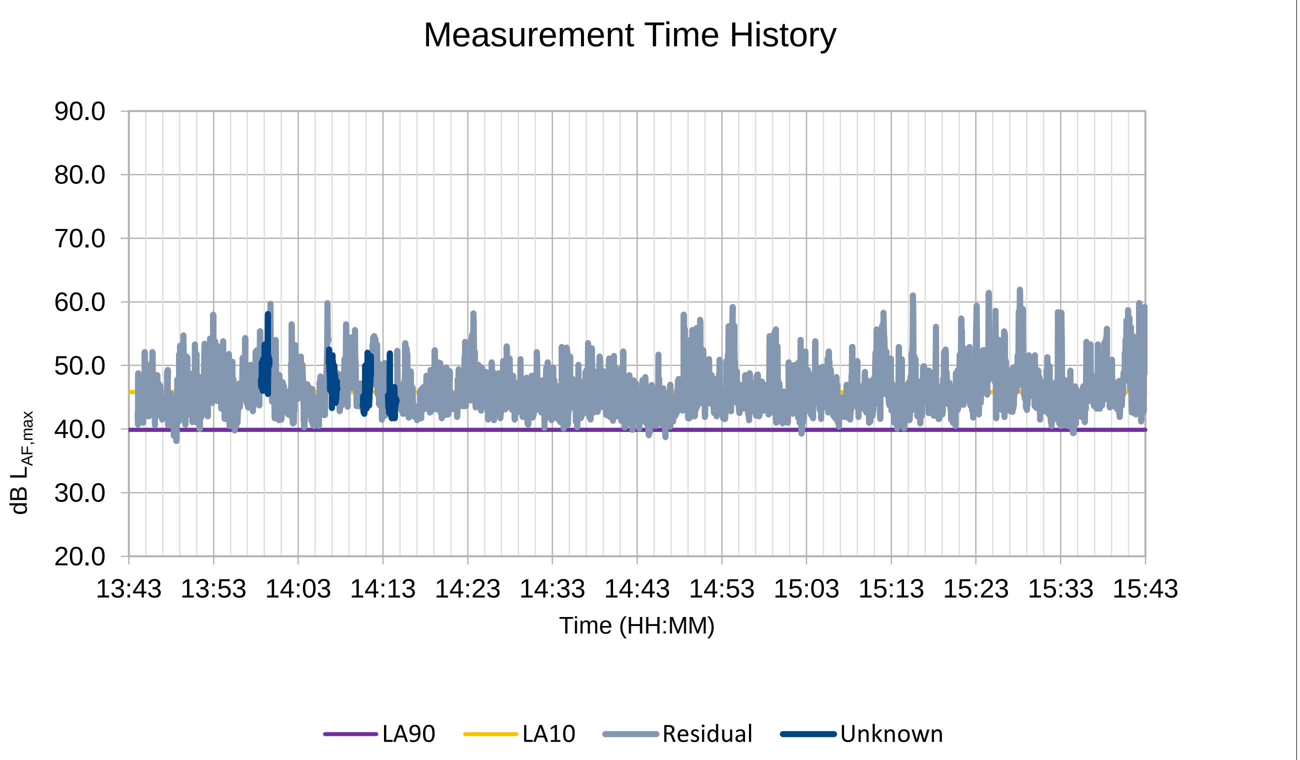
13:03 Walking along ridge pointing silver walking stick. Fly up reaction.

BMP02-0022

Noise Measurement Record

Measurement Number	**023**	Position	**BMP02**
Start Time	10/06/17 13:43:24	Equipment	01dB Duo S/N: 10428
End Time	10/06/17 15:43:26	Data File(s)	20170610_134324_154326_1m eliminated.cmg
Duration (hh:mm:ss)	02:00:02		
Weather	Moderate gale blowing from the southwest. Dry with high clouds and good visibility. 14 to 15 deg. C		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	58.1	00:04:08
Residual	dB $L_{AF,max}$	61.9	01:54:52
Ambient Noise Level	dB $L_{Aeq,T}$	43.8	02:00:02
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	45.8	02:00:02
Background Noise Level	**dB $L_{A90,T}$**	**39.9**	**02:00:02**



Notes

13:59 All birds rose 5-8m for 35 seconds and down. Fly up reaction.

14:07 All birds rose 5-8m for 30 seconds and down. Fly up reaction.

14:11 All birds rose 5-8m for 30 seconds and down. Fly up reaction.

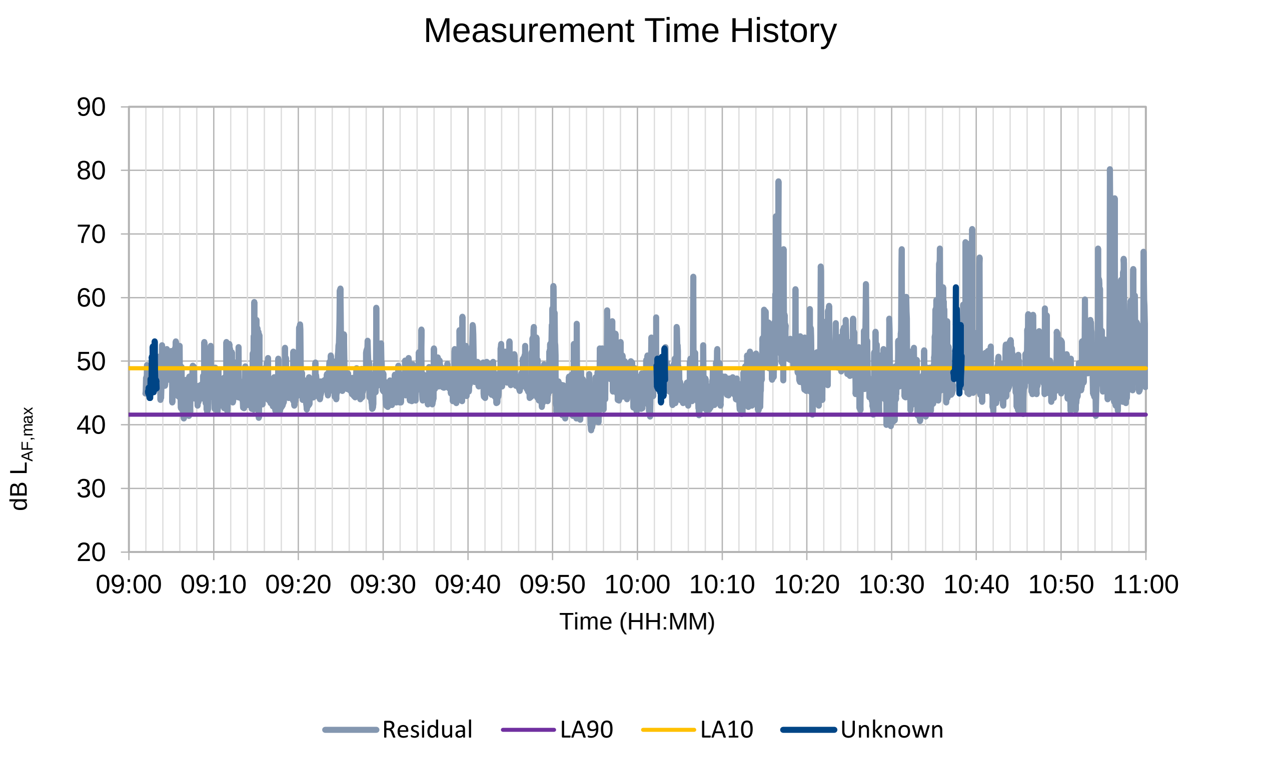
14:14 All birds rose 5-8m for 15 seconds and down. Fly up reaction.

BMP02-0023

Noise Measurement Record

Measurement Number	**024**	Position	**BMP02**
Start Time	11/06/17 09:00:44	Equipment	01dB Duo S/N: 10428
End Time	11/06/17 11:00:46	Data File(s)	20170611_090044_110046_2m eliminated.cmg
Duration (hh:mm:ss)	02:00:02		
Weather	Strong breeze to moderate gale blowing from the south southwest. Dry then light rain with high clouds and good visibility. 14 deg. C.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	61.6	00:03:06
Residual	dB $L_{AF,max}$	80.2	01:55:00
Ambient Noise Level	dB $L_{Aeq,T}$	47.6	02:00:02
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	48.9	02:00:02
Background Noise Level	**dB $L_{A90,T}$**	**41.6**	**02:00:02**



Notes

09:03 Birds rose to 5m for 30 seconds and down. Fly up reaction.

10:03 Birds rose to 5m for 20 seconds and down. Fly up reaction.

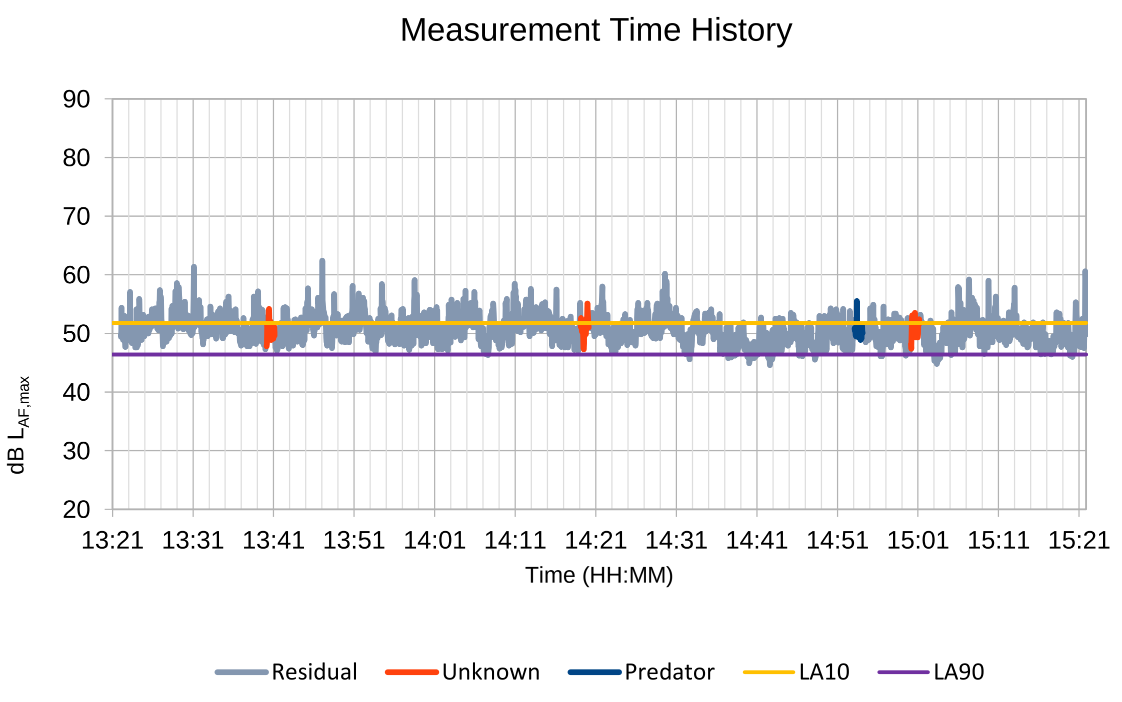
10:38 Birds rose to 5-8m for 50 seconds and down. Fly up reaction.

BMP02-0024

Noise Measurement Record

Measurement Number	**025**	Position	**BMP02**
Start Time	11/06/17 13:21:52	Equipment	01dB Duo S/N: 10428
End Time	11/06/17 15:22:46	Data File(s)	20170611_132152_152246_1m eliminated.cmg
Duration (hh:mm:ss)	02:00:54		
Weather	Moderate to fresh gale blowing from the south southwest. Dry with high clouds and good visibility. 17 deg. C.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Predator	dB $L_{AF,max}$	55.5	00:01:02
Unknown	dB $L_{AF,max}$	55.1	00:03:06
Residual	dB $L_{AF,max}$	62.4	01:55:44
Ambient Noise Level	dB $L_{Aeq,T}$	49.6	02:00:54
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	51.8	02:00:54
Background Noise Level	**dB $L_{A90,T}$**	**46.4**	**02:00:54**



Notes

13:41 Birds rose to 5m for 25 seconds and down. Fly up action.

14:20 Birds rose to 5m for 20 seconds and down. Fly up action.

14:54 Little Egret came over ridge, landed and took off. Fly up action.

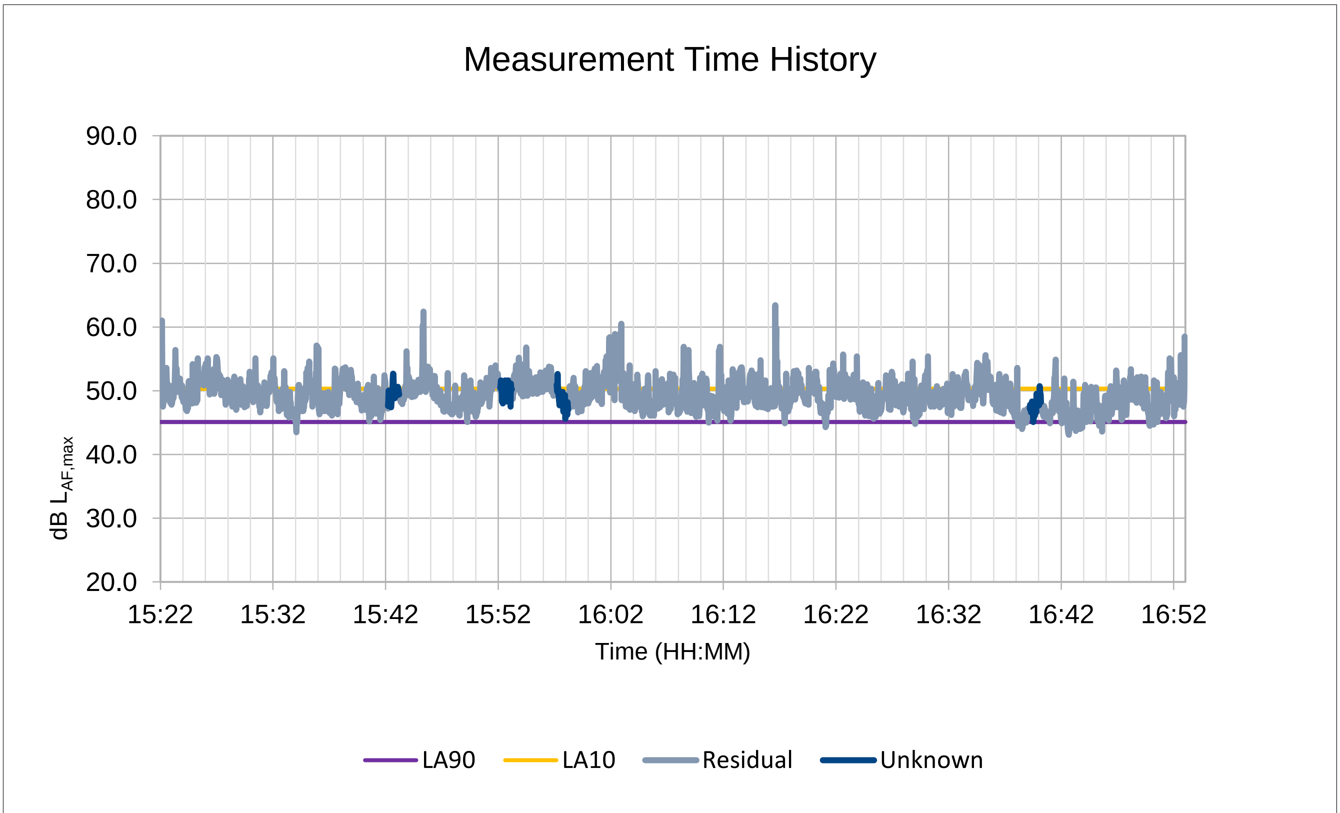
15:01 Birds rose 5-8m for 30s and down. Fly up action.

BMP02-0025

Noise Measurement Record

Measurement Number	**026**	Position	**BMP02**
Start Time	11/06/17 15:22:47	Equipment	01dB Duo S/N: 10428
End Time	11/06/17 16:53:51	Data File(s)	20170611_152247_165351.cmg
Duration (hh:mm:ss)	01:31:04		
Weather	Moderate gale (Beaufort scale 7) blowing from the southwest. Dry then heavy showers.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	52.7	00:04:05
Residual	dB $L_{AF,max}$	63.4	01:26:59
Ambient Noise Level	dB $L_{Aeq,T}$	63.4	01:31:04
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	50.3	01:31:04
Background Noise Level	**dB $L_{A90,T}$**	**45.1**	**01:31:04**



Notes

15:43 Birds rose to 3m for 15 second and back down. Fly up reaction.

15:53 Birds rose to 5m for 20 second and back down.Fly up reaction.

15:58 Birds rose to 5m for 30 second and back down. Fly up reaction.

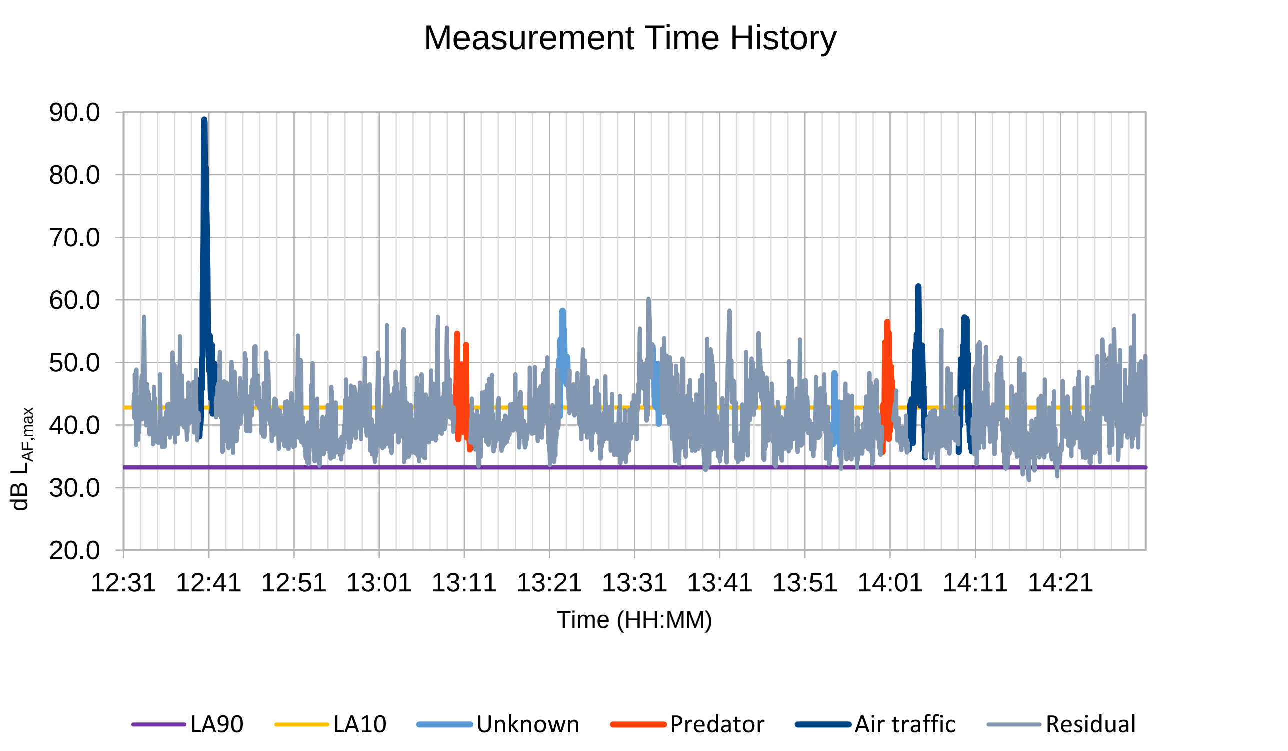
16:40 Birds rose to 5m for 30 second and back down. Fly up reaction.

BMP02-0026

Noise Measurement Record

Measurement Number	**027**	Position	**BMP02**
Start Time	12/06/17 12:31:52	Equipment	01dB Duo S/N: 10428
End Time	12/06/17 14:31:53	Data File(s)	20170612_123152_143153_1m eliminated.cmg
Duration (hh:mm:ss)	02:00:01		
Weather	Moderate to fresh breeze from the west-southwest. Dry with high clouds and good visibility.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Air traffic	dB $L_{AF,max}$	88.8	00:05:34
Predator	dB $L_{AF,max}$	56.5	00:03:08
Unknown	dB $L_{AF,max}$	58.3	00:03:06
Residual	dB $L_{AF,max}$	60.2	01:47:03
Ambient Noise Level	dB $L_{Aeq,T}$	54.7	02:00:01
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	42.8	02:00:01
Background Noise Level	**dB $L_{A90,T}$**	**33.2**	**02:00:01**



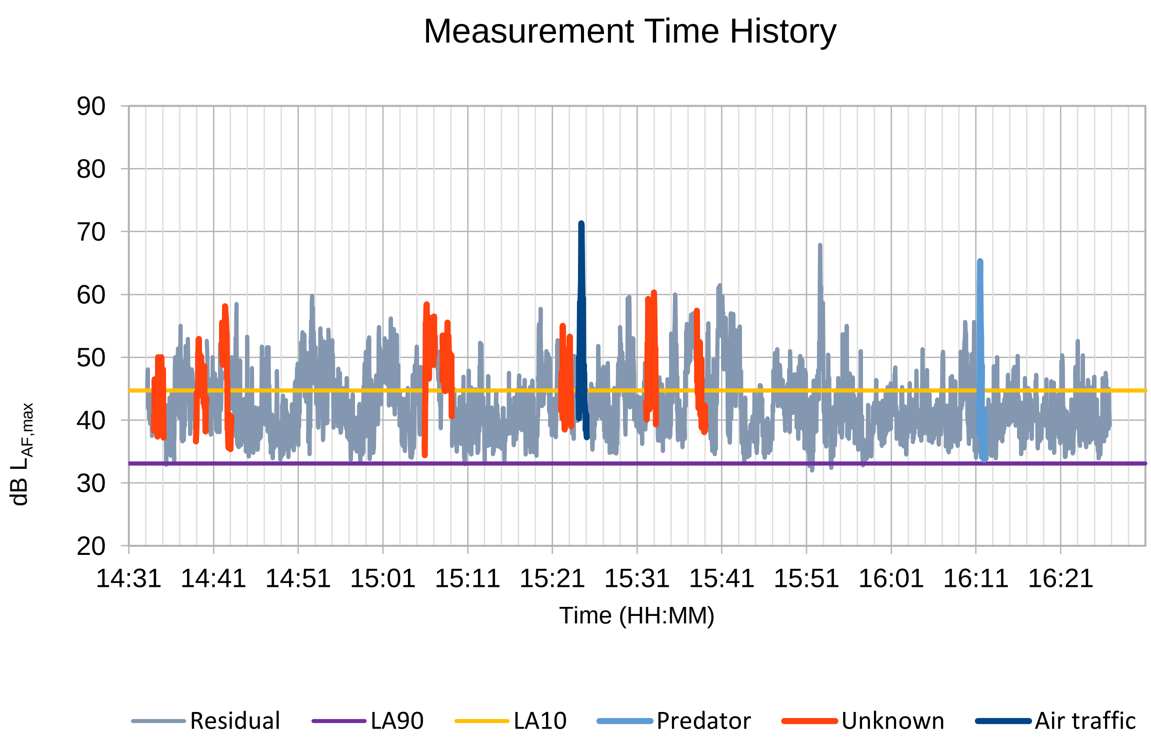
Notes

12:41 Loud jet over at 400m. Fly up reaction.
13:11 Little Egret flew along southern edge of lagoon. Fly up reaction.
13:23 Birds rose to 5m for 40 secs and back down. Fly up reaction.
13:34 Birds rose to 10m for 60 secs and back down. Fly up reaction.
13:55 Birds rose to 5-8m for 40 secs and back down. Fly up reaction.
14:01 Little egret came over ridge and landed. No reaction.
14:04 Jet flying south of lagoon to east at 500m. No reaction.
14:10 Jet flying southeast of lagoon at 600m. No reaction.

Noise Measurement Record

Measurement Number	**028**	Position	**BMP02**
Start Time	12/06/17 14:31:55	Equipment	01dB Duo S/N: 10428
End Time	12/06/17 16:31:56	Data File(s)	20170612_143155_163156_2m and 4m eliminated.cmg
Duration (hh:mm:ss)	02:00:01		
Weather	Gentle to moderate breeze from the west-southwest. Dry with high clouds and good visibility.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Air traffic	dB $L_{AF,max}$	71.3	00:01:02
Unknown	dB $L_{AF,max}$	60.3	00:09:18
Predator	dB $L_{AF,max}$	65.3	00:00:44
Residual	dB $L_{AF,max}$	67.9	01:42:38
Ambient Noise Level	dB $L_{Aeq,T}$	43.9	02:00:01
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	44.7	02:00:01
Background Noise Level	**dB $L_{A90,T}$**	**33.1**	**02:00:01**



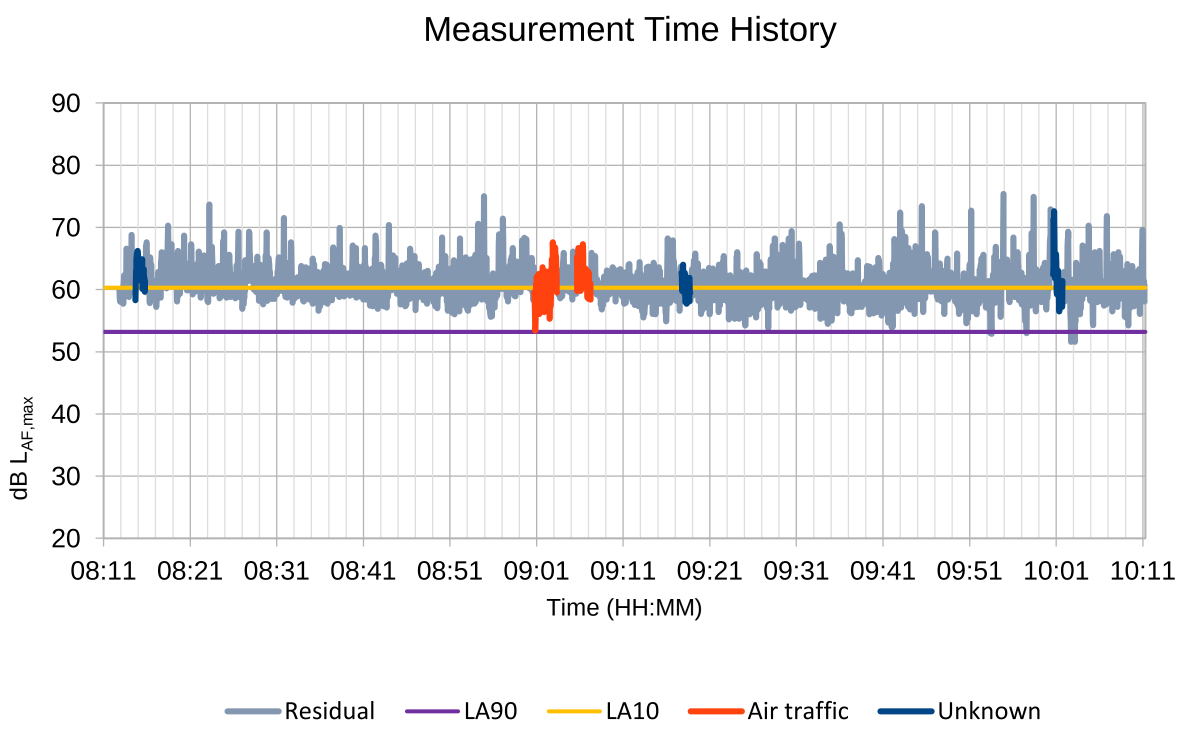
Notes

14:35 Birds rose to 20m for 1 minute and back down. Fly up reaction.
14:40 Birds rose to 6m for 30 seconds and back down. Fly up reaction.
14:43 Birds rose 3m for 30 seconds and back down. Fly up reaction.
15:07 Birds rose to 5-20m for 60 seconds and back down. Fly up reaction.
15:09 Birds rose to 5-30m for 60 seconds and back down. Fly up reaction.
15:23 Birds rose to 5-30m for 15 seconds and back down. Fly up reaction.
15:25 Jet from north west flying south at 500m. No reaction.
15:33 Birds rose 5m for 30 seconds and back down. Fly up reaction.
15:39 Birds rose to 5-10m for 25 seconds and back down. Fly up reaction.
16:13 Loud "tin" sound closing grain container at farm. No reaction.

Noise Measurement Record

Measurement Number	**029**	Position	**BMP01**
Start Time	13/06/17 08:11:15	Equipment	01dB Duo S/N: 10428
End Time	13/06/17 10:11:35	Data File(s)	20170613_081115_101135_1m eliminated.cmg
Duration (hh:mm:ss)	02:00:20		
Weather	Moderate breeze from the south/ south southwest. Dry with low to high clouds and good visibility.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	72.6	00:03:18
Air traffic	dB $L_{AF,max}$	67.6	00:04:16
Residual	dB $L_{AF,max}$	75.4	01:50:56
Ambient Noise Level	dB $L_{Aeq,T}$	58.0	02:00:20
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	60.3	02:00:20
Background Noise Level	**dB $L_{A90,T}$**	**53.2**	**02:00:20**



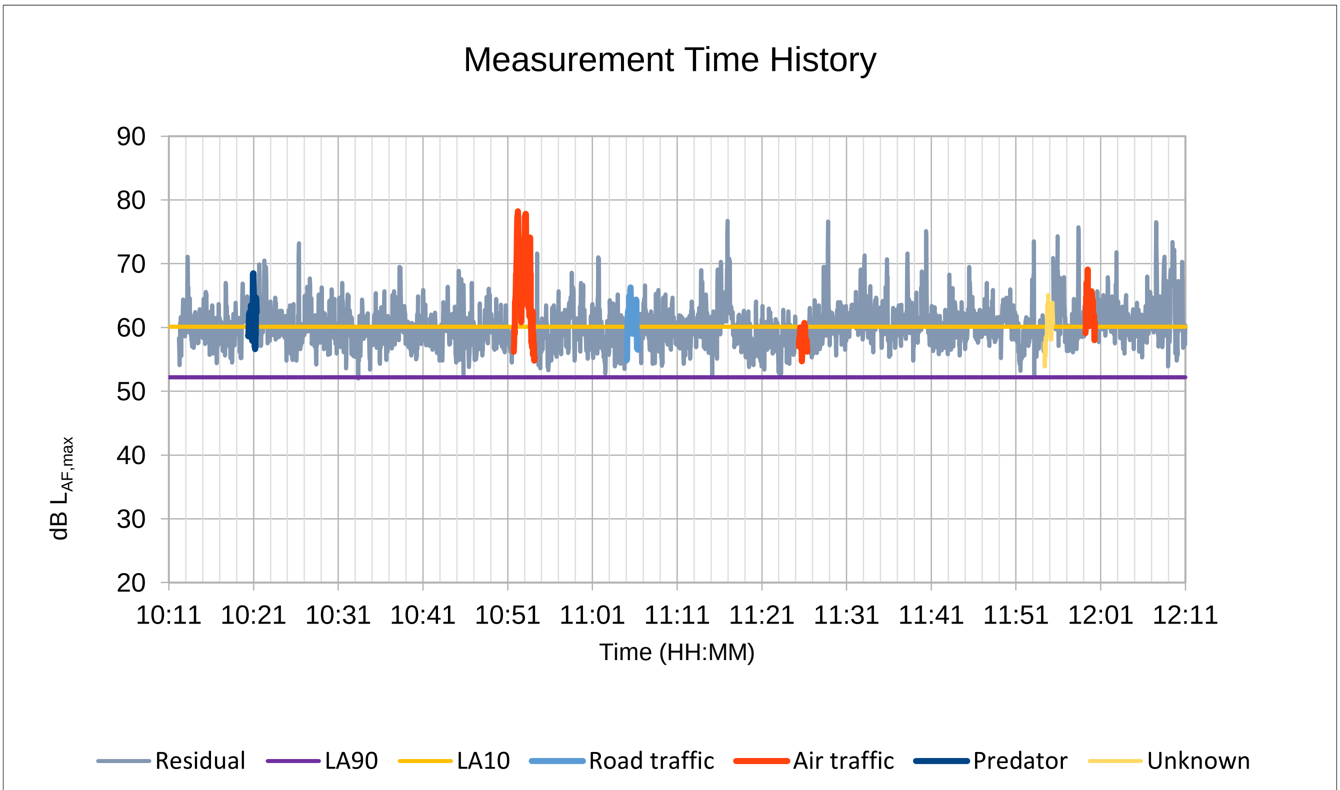
Notes

08:15 Birds rose to 5m for 20 seconds and back down. Fly up reaction.
09:01 Two jets to east of lagoon flying south east at 700m. No reaction.
09:06 Jet to east of lagoon flying south east at 500m. No reaction.
09:18 Birds rose to 5m for 30 seconds and back down. Fly up reaction.
10:01 Birds rose to 5-8m for 40 seconds and back down. Fly up reaction.

Noise Measurement Record

Measurement Number	**030**	Position	**BMP01**
Start Time	13/06/17 10:11:38	Equipment	01dB Duo S/N: 10428
End Time	13/06/17 12:11:39	Data File(s)	20170613_101138_121139_1m eliminated.cmg
Duration (hh:mm:ss)	02:00:01		
Weather	Moderate breeze from the south-southwest. Dry with high clouds and good visibility.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Predator	dB $L_{AF,max}$	68.5	00:01:02
Air traffic	dB $L_{AF,max}$	78.2	00:04:40
Road traffic	dB $L_{AF,max}$	66.3	00:01:20
Unknown	dB $L_{AF,max}$	65.1	00:01:02
Residual	dB $L_{AF,max}$	76.7	01:50:45
Ambient Noise Level	dB $L_{Aeq,T}$	58.2	02:00:01
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	60.1	02:00:01
Background Noise Level	**dB $L_{A90,T}$**	**52.2**	**02:00:01**



Notes

10:21 Herring gull flew through. Birds rose to 5m for 20 seconds and back down. Fly up and attack reaction.

10:52 Quite loud jet flying NW to SE at 500m. Birds rose to 5m for 30 seconds and down. Fly up and attack reaction.

10:53 Jet, not as loud as earlier jet flying NW to SE at 600m. No reaction.

11:06 Silver car driving along road sun reflecting brightly. Birds rose to 5m for 20 seconds and back down. Fly up and attack reaction.

11:26 Jet to east flying north at 700m. No reaction, jet not very loud

11:55 Birds rose to 5m for 20 seconds and back down. Fly up and attack reaction.

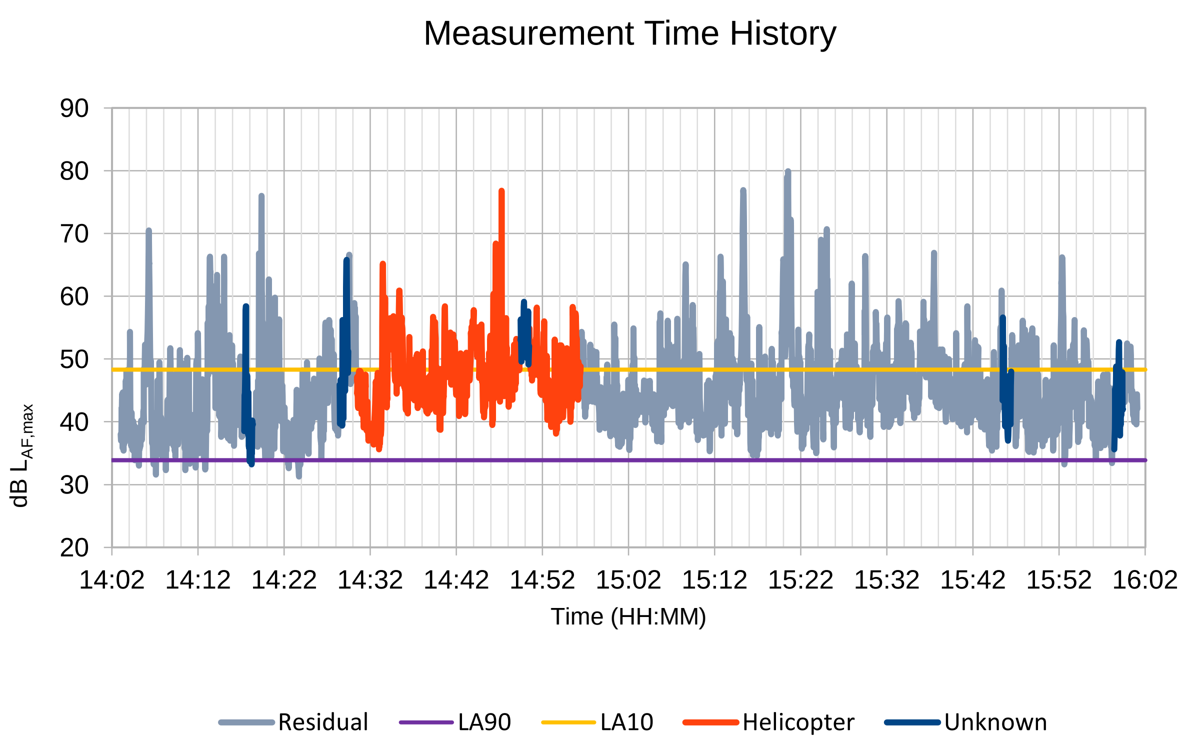
12:00 Jet to east flying south at 700m. No reaction.

BMP01-0030

Noise Measurement Record

Measurement Number	**031**	Position	**BMP01**
Start Time	19/06/17 14:02:33	Equipment	01dB Duo S/N: 10428
End Time	19/06/17 16:02:37	Data File(s)	20170619_140233_160237_1m and 1m eliminated.cmg
Duration (hh:mm:ss)	02:00:04		
Weather	Light air from the northeast. Dry with high clouds and good visibility. 22 to 23 deg. C		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Unknown	dB $L_{AF,max}$	65.8	00:05:10
Helicopter	dB $L_{AF,max}$	76.8	00:25:00
Residual	dB $L_{AF,max}$	79.9	01:27:58
Ambient Noise Level	dB $L_{Aeq,T}$	49.2	02:00:04
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	48.3	02:00:04
Background Noise Level	**dB $L_{A90,T}$**	**33.9**	**02:00:04**



Notes

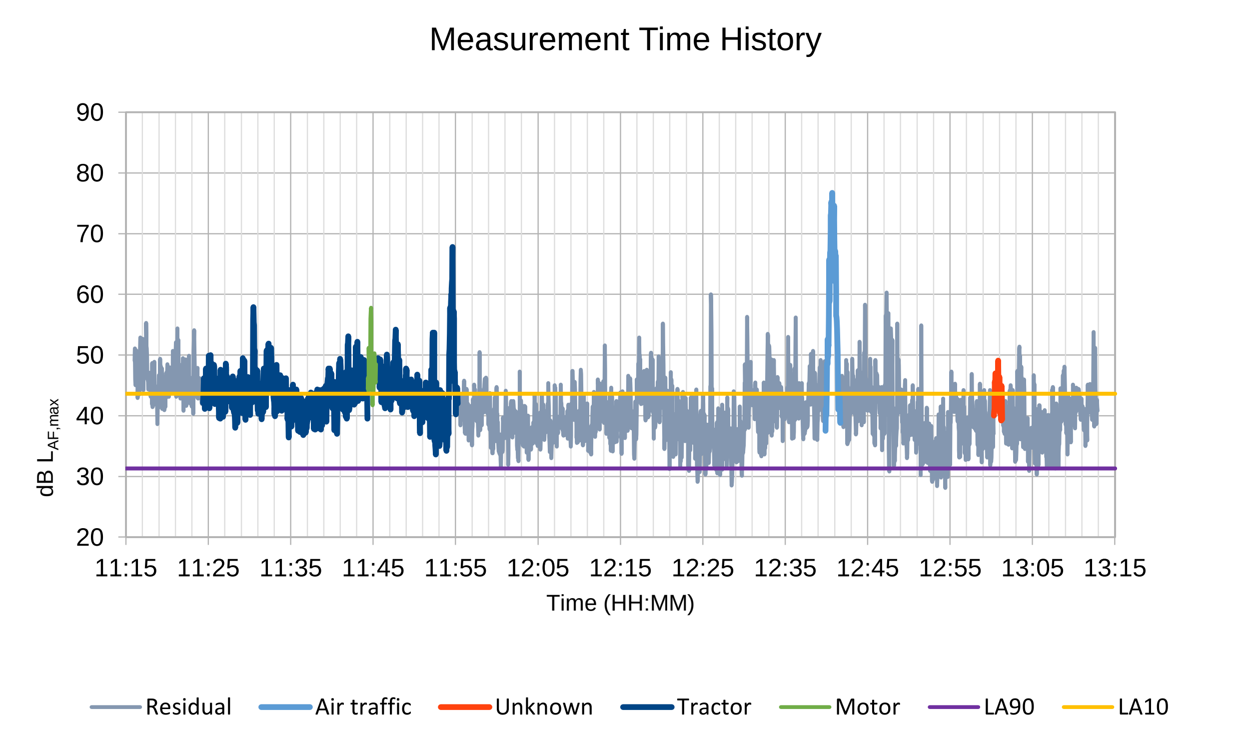
14:18 Birds rose to 5m for 20 secs and back down. No disturbance type noted.
14:29 Birds rose to 5m for 30 secs and back down. No disturbance type noted.
14:31 Helicoter To southwest of lagoon hovering. No reaction.
14:50 Birds rose to 5m for 20 secs and back down. No disturbance type noted.
15:46 Birds rose to 5-8m for 40 secs and back down. No disturbance type noted.
15:59 Birds rose to 5m for 30 secs and back down. No disturbance type noted.

BMP01-0031

Noise Measurement Record

Measurement Number	**035**	Position	**BMP02**
Start Time	21/06/17 11:15:40	Equipment	01dB Duo S/N: 10428
End Time	21/06/17 13:15:44	Data File(s)	20170621_111540_131544_1m 2m eliminated.cmg
Duration (hh:mm:ss)	02:00:04		
Weather	Light breeze from the northeast/ north northwest at the start of the survey, switching to east southeast towards the end of the survey. Light showers then dry with moderate to high clouds and good visibility. 20 to 22 deg. C.		

Summary Levels	**Metric**	**Value**	**Duration (T) (hh:mm:ss)**
Tractor	dB $L_{AF,max}$	67.8	00:29:56
Unknown	dB $L_{AF,max}$	49.1	00:01:02
Air traffic	dB $L_{AF,max}$	76.7	00:01:50
Motor	dB $L_{AF,max}$	57.8	00:01:02
Residual	dB $L_{AF,max}$	60.3	01:23:04
Ambient Noise Level	dB $L_{Aeq,T}$	39.1	02:00:04
CRTN Road Traffic Noise Descriptor	dB $L_{A10,T}$	43.6	02:00:04
Background Noise Level	**dB $L_{A90,T}$**	**31.3**	**02:00:04**



Notes

11:25 Tractors cutting silage from field. No reaction from birds.

11:45 No disturbance type noted. Birds from small island flew at 2m height for 30 secs and dropped back down.

11:47 Motor starting up. No disturbance caused, sound not located.

12:41 3 jets flying over slow 400m altitude. No disturbance noted.

13:01 No disturbance type noted. Small island only - 3m altitude, flew around then back to colony.

BMP02-0035

Appendix C. BS5228-1 $L_{AF,max}$ sound power levels, dB

Ref.	Plant Description	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AFmax} dB at 10m	L_{AW} dB
C2.1	Dozer	79	77	76	74	68	67	60	59	75	103
C2.31	Dump truck (empty)	86	79	79	79	79	84	69	60	87	115
C2.33	Articulated dump truck	85	87	77	75	76	73	69	62	81	109
C2.34	Lorry	73	78	78	78	74	73	68	66	80	108
C2.37	Roller (rolling fill)	72	75	81	78	74	70	63	55	79	107
C2.38	Roller	80	75	77	72	67	62	54	46	73	101
C2.39	Vibratory roller	88	83	69	68	67	65	62	59	74	102
C2.40	Vibratory roller	82	78	67	71	67	64	60	57	73	101
C4.1	Articulated dump truck	90	87	77	79	75	73	67	63	81	109
C4.2	Articulated dump truck	85	80	77	72	74	70	65	58	78	106
C4.3	Dumper	84	81	74	73	72	68	61	53	76	104
C4.4	Dumper	82	76	75	74	68	68	64	55	76	104
C4.6	Dumper	89	86	77	74	72	72	66	62	79	107
C4.7	Dumper	90	86	72	71	71	71	66	59	78	106
C4.9	Dumper	82	82	78	77	69	67	61	53	77	105
C4.12	Wheeled excavator	84	82	77	75	72	68	60	52	77	105
C4.13	Wheeled loader	83	72	70	69	65	64	57	49	71	99
C4.15	Fuel tanker lorry	79	73	71	75	72	67	59	50	76	104
C4.74	Tractor (towing equipment)	79	71	78	75	78	70	61	55	80	108
C4.75	Tractor (towing trailer)	93	86	76	76	73	72	64	59	79	107
C5.14	Bulldozer	77	86	75	75	82	80	73	67	86	14
C5.15	Bulldozer	83	81	76	77	82	70	65	58	83	111
C5.16	Articulated dump truck	88	90	80	79	76	71	65	61	81	109
C5.17	Articulated dump truck	85	88	77	75	77	74	69	63	81	109
C5.19	Road roller	87	85	75	73	75	73	69	63	80	108

Ref.	Plant Description	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AFmax} dB at 10m	L_{AW} dB
C5.21	Vibratory roller	90	84	77	81	73	68	65	61	80	108
C5.22	Vibratory roller	92	83	75	79	77	70	67	61	81	109
C5.23	Vibratory roller (not vibrating)	83	77	75	84	76	72	66	61	83	111
C5.24	Vibratory roller	89	82	76	77	72	74	81	61	84	112
C5.32	Asphalt paver (+ tipper lorry)	87	84	81	80	79	76	74	65	84	112
C6.13	Dump truck	97	95	91	91	86	84	79	75	92	120
C6.14	Dump truck	89	94	89	85	83	81	76	71	89	117
C6.15	Dump truck	94	91	91	87	84	83	77	70	90	118
C6.16	Articulated dump truck (empty)	93	90	85	84	83	81	77	69	88	116
C6.17	Articulated dump truck	86	84	86	83	79	76	72	67	85	113
C6.18	Articulated dump truck	91	90	83	83	81	79	70	61	86	114
C6.19	Road lorry (empty)	81	79	75	70	70	70	68	65	76	104
C6.20	Road lorry (empty)	81	76	79	70	71	68	64	60	76	104
C6.21	Road lorry (full)	96	82	74	73	77	72	71	64	80	108
C6.22	Road lorry (empty)	97	85	81	83	76	71	69	64	83	111
C6.23	Rigid road lorry	88	86	80	78	75	73	76	68	82	110
C6.31	Grader	88	87	83	79	84	78	74	65	86	114
C6.36	Diesel bowser	80	81	84	81	84	85	76	66	89	117f
C6.38	Tractor (towing water bowser)	78	86	84	78	78	77	70	69	83	111
C8.13	Articulated dump truck	92	89	83	84	79	75	68	64	85	113
C8.14	Articulated dump truck	88	84	82	73	75	71	66	60	80	108
C8.15	Articulated dump truck	91	81	76	77	73	72	70	62	79	107
C8.16	Articulated dump truck	84	84	81	79	76	73	69	64	81	109
C8.18	Refuse wagon	82	79	78	75	71	72	66	62	78	106
C8.19	Refuse wagon	88	81	79	76	72	70	64	60	78	106

Ref.	Plant Description	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AFmax} dB at 10m	L_{AW} dB
C8.20	Tipper lorry	88	82	74	74	74	73	70	67	79	107
C8.21	Skip wagon	82	84	78	75	71	70	65	59	78	106
C9.16	Rigid dump truck	86	89	88	88	86	83	76	70	91	119
C9.17	Rigid dump truck	99	95	87	86	84	83	77	73	90	118
C9.18	Rigid dump truck	95	97	89	85	83	83	76	75	90	118
C9.19	Rigid dump truck	90	91	88	85	83	82	77	73	89	117
C9.20	Rigid dump truck	96	97	90	84	84	84	74	76	90	118
C9.21	Rigid dump truck	92	91	86	85	84	85	77	77	90	118
C9.22	Articulated dump truck	100	97	88	84	82	80	77	68	89	117
C10.16	Wheeled loader	83	89	92	80	71	69	64	58	85	113
C10.17	Wheeled loader	77	83	91	75	75	72	65	59	84	112
C10.18	Articulated dump truck	87	85	83	81	78	74	71	66	83	111
C10.19	Articulated dump truck	98	94	89	85	79	79	70	65	87	115
C11.4	Lorry	82	80	78	75	76	78	75	69	83	111
C11.5	Lorry	92	82	77	76	77	72	68	63	80	108
C11.6	Lorry	92	82	76	78	77	76	74	68	83	111
C11.7	Lorry	87	79	77	74	73	73	70	64	79	107
C11.8	Lorry	81	79	79	83	84	81	76	70	88	116
C11.9	Lorry	99	82	81	76	78	74	71	66	82	110
C11.10	Lorry	91	79	77	74	71	69	64	61	77	105
C11.11	Lorry	96	79	75	79	82	80	72	67	86	114
C11.12	Lorry	96	80	75	75	74	72	67	60	79	107
C11.13	Lorry	84	80	76	74	73	70	67	61	78	106
C11.14	Lorry	93	79	76	74	73	72	69	66	79	107
C11.15	Lorry	86	94	81	77	80	77	75	69	85	113
C11.16	Lorry	86	81	74	76	73	72	69	60	79	107
C11.17	Lorry	91	78	74	70	72	74	66	59	78	106
C11.18	Lorry	85	78	83	82	86	80	73	69	88	116
C11.19	Lorry	87	76	73	81	79	75	68	62	83	111
C11.20	Lorry	91	76	79	78	80	76	70	64	83	111

Ref.	Plant Description	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AFmax} dB at 10m	L_{AW} dB
Maximum of each frequency		100	97	92	91	86	85	81	77	93	121

Appendix D. Method for predicting short-term construction noise impacts at tern receptor locations

HORIZON
NUCLEAR POWER

Note on Appendix A13-4: Method for predicting short-term construction noise impacts at tern receptor locations

This report was produced as part of the application relating to Site Preparation and Clearance Proposals. It is provided here as a supporting appendix to *D13-13 Noise Modelling for Ecological Receptors* as it provides further detail on the methodology used for the modelling of short-term construction noise impacts at tern receptor locations. The results relating to the Wylfa Newydd Project Development Consent Order application are provided within the main appendix D13-13.

HORIZON NUCLEAR POWER

ENERGY WORKING FOR BRITAIN

SITE PREPARATION AND CLEARANCE NOISE IMPACTS - WYLFA NEWYDD PROJECT

Short-term construction noise impacts at tern receptor locations

DCRM Ref Number: WN034-JAC-PAC-REP-00161

Revision: 1.0

Additional Requirements or Controls			
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Approvals Table				
	Role	**Printed Name**	**Signed Name**	**Date**
Originated by	Document Author	Sam Williams	[redacted]	/11/2016
Reviewed by	Document Reviewer	Gail Hitchins		/11/2016
Checked by	Head of Section	Russell Cryer		/01/17

Revision History				
Date	**Rev No.**	**Summary of Changes**	**Ref Section**	**Purpose of Issue**
29/11/16	1.0	Initial draft for client review		

Contents

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List of Tables

1 About this report

Natural Resources Wales has requested further worst-case noise modelling be undertaken in support of the Site Preparation and Clearance (SPC) Habitats Regulations Assessment, due to concerns about disturbance to breeding terns.

The noise and vibration chapter of the SPC Environmental Statement includes predictions of construction noise levels based upon conservative plant placement assumptions and averaged over a one-hour basis, in accordance with *Minerals Technical Advice Note (Wales) 1: Aggregates* (Welsh Assembly Government, 2004). Natural Resources Wales' comments are interpreted as requiring further noise modelling of more extreme 'worst-case' conditions, with all heavy plant located as close to the tern habitat as possible, and over short durations so that the smoothing effects of averaging over time are minimised.

In response, additional noise modelling has been undertaken that considers more extreme worst-case conditions, over one-hour and five-minute timescales.

1.1 Glossary

Term	Definition
A-weighting	The human ear demonstrates increased sensitivity at some frequencies compared to others. The A-weighting network applies filters to the signal processing of a sound level meter to mimic the response of the human ear at each frequency.
Attenuation	Reduction in sound pressure level
Atmospheric absorption	The attenuation of sound as a result of its passage through the air. The mechanisms of atmospheric absorption are quite complex and include shear viscosity, thermal conductivity, mass diffusion, thermal diffusion, and relaxation of both rotational and vibrational energies within the air molecules.
BSI	British Standards Institution
Decibel (dB)	A scale for comparing the ratios of two quantities, including sound pressure and sound power. The difference in level between two sounds S_1 and S_2 is given by $20 \cdot \log10(S_1/S_2)$. The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20µPa.
dB(A)	A-weighted decibel. See: 'A-weighting' and 'dB'.
dB(Lin)	Sound pressure level expressed in dB with the application of a flat, linear frequency weighting network. In recent years, this has largely been replaced by the 'Zero' (dB(Z)) weighting network which implies no frequency weighting, although it is still common in older texts and guidance.
Equivalent continuous sound pressure level (L_{eq})	The notional steady sound level which, over a stated period of time, would contain the same amount of acoustic energy as the fluctuating sound measured over that period. The period of time over which this quantity is evaluated is normally added to the sub-

Term	Definition
	script notation, as shown in the following examples: $L_{eq,5min}$, $L_{eq,1-hour}$, $L_{eq,8-hours}$.
Free field	An environment in which there are no vertical reflective surfaces within the frequency region of interest.
Frequency	Sound consists of vibrations transmitted to the ear as rapid variations in air pressure. The more rapid the variations in air pressure, the higher the frequency of the sound. Frequency is defined as the number of pressure fluctuations per second and is expressed in Hertz (Hz).
L_{Aeq}	A-weighted equivalent continuous sound pressure level. See 'A-weighting' and 'equivalent continuous sound pressure level'.
Noise emissions	Used to describe noise levels generated by, and other characteristics of, a noise source
Site Preparation and Clearance (SPC)	Project proposed for some enabling works for the construction of the Wylfa Newydd Power Station.
Wylfa Newydd Development Area	The indicative area of land including the Power Station Site and the surrounding areas that would be used for the construction and operation of the Wylfa Newydd Power Station. This area will be refined through the consultation process as Horizon develops a better understanding of the size and location of the areas that would be needed for construction activities and as the setting and features of the Wylfa Newydd Power Station are finalised.

Table 1 Terms and definitions

2 Receptor locations

The terns are known to nest on an island in Cemlyn Bay, within the Special Protection Area and Site of Special Scientific Interest, and therefore Receptor 1 has been placed in the noise model at this location, at a height of one metre above ground. Receptor 2 has been placed at the edge of the Special Protection Area / Site of Special Scientific Interest closest to the SPC Application Site, at a height of five metres above ground, as the terns will be in flight at this location.

The terns leave the nest site to forage, and often pass around the headland between Cemlyn Bay and Cemaes Bay. Receptors 3, 5, 6 and 8 are located along this flight path, at heights of five metres above the sea level at the time of the LiDAR survey that provided the ground model.

Occasionally, terns will forage within Porth-y-pistyll and Porth y Wylfa, and therefore receptors have been included in these locations at heights of five metres above sea level at the time of the LiDAR survey that provided the ground model (Receptor 4 is at Porth-y-pistyll and Receptor 7 is at Porth y Wylfa). Figure 1 below shows the location of the noise sensitive receptor points i.e. where the terns will possibly be sensitive to disturbance.

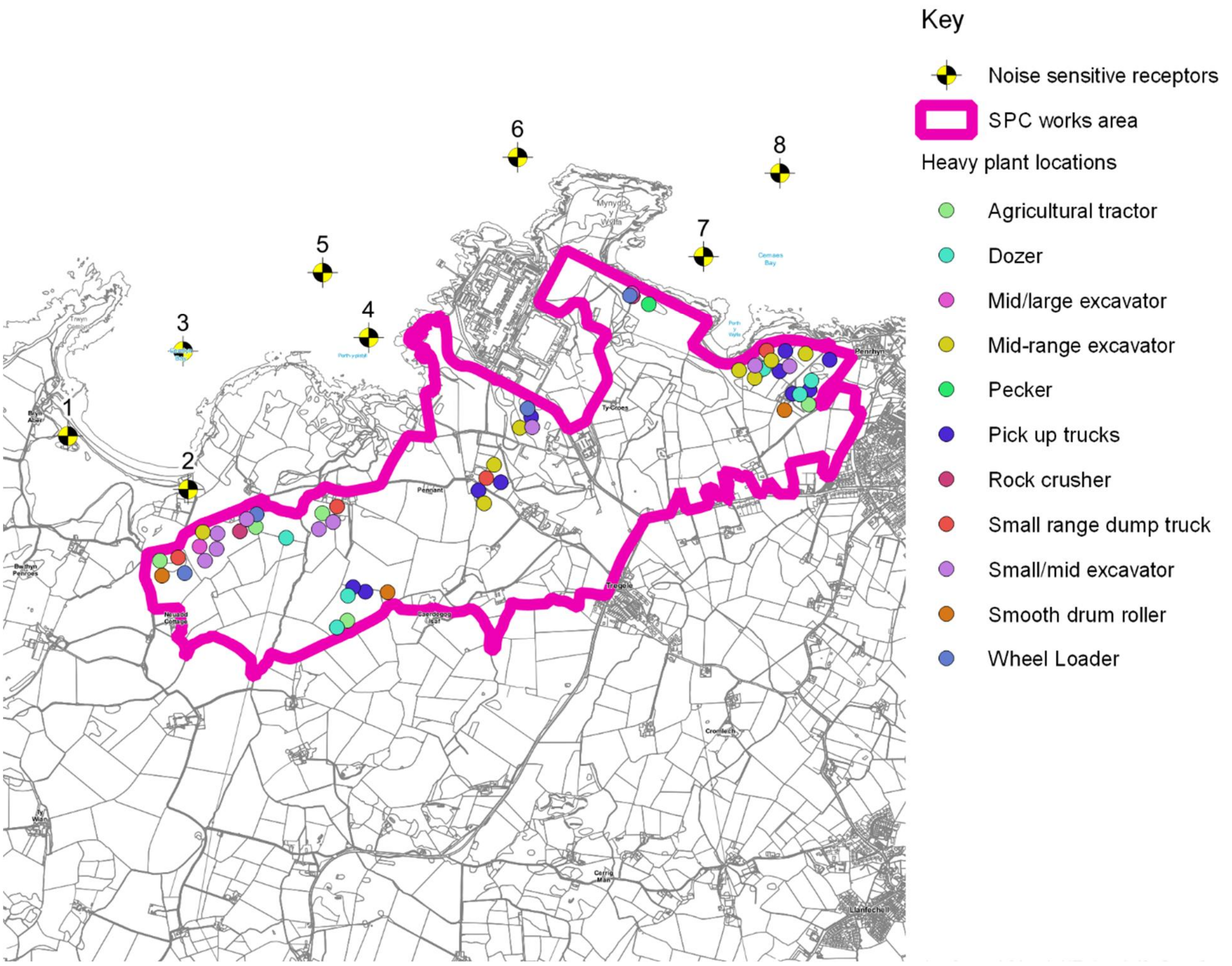

Figure 1 Noise-sensitive receptors and phase 3 and 4 heavy plant locations

3 Modelling methodology

The construction noise prediction method set out in BS5228-1:2009+A1:2014 (BSI, 2014a) has been used to calculate noise levels at the tern receptor locations. The sources of noise emissions within the model are identical to those used for the SPC Environmental Statement (Jacobs, 2016) construction noise models, except the input data have been modified to represent a more extreme worst-case scenario as follows.

- The on-times associated with heavy plant, which represent the proportion of the assessment period during which the machine will operate at, or near, full load have been increased.
- The heavy plant in the model have been relocated close to the closest boundary of each working area to the tern receptor locations. This spatial distribution of heavy plant is considered exceedingly unlikely and will result in the highest possible contributions at Receptors 1 to 8 shown in figure 1 above.
- A backhoe-mounted pecker has been included at the rock winning area, as blasting would not be undertaken during the tern breeding season.
- The crawler drill used to drill boreholes for blasting has been excluded, as blasting would not be undertaken during the tern breeding season.

This will result in predictions that represent the highest continuous equivalent noise levels that could theoretically occur for short periods of time, rather than the noise level over a day, which is more often predicted. Although theoretically possible, it is considered very unlikely that all of the heavy plant would be situated along the SPC Application Site boundaries closest to Receptors 1 to 8 in figure 1 simultaneously.

In summary, the modified inputs to the BS5228-1:2009+A1:2014 methodology to calculate a short duration are as follows.

Input	One-hour noise model	Five-minute noise model
On-time corrections	Pickup trucks 70% Agricultural tractors 70% Dozers 70% Wheel loaders 90% Smooth drum rollers 90% Small range dump trucks 70% Mid-range excavators 90% Small/mid excavators 90% Rock crushers 90% Mid/large excavators 90% Pecker 70%	100% on-time assumed for all plant
Traverse length corrections for mobile plant	None	None
All plant operating continuously	Yes	Yes

Input	One-hour noise model	Five-minute noise model
All plant located close to the SPC Application Site boundary closest to receptors	Yes	Yes
Proportion of soft ground	Land: 50%; Water: 0%	Land: 50%; Water: 0%

Table 2 Model input data

With respect to other factors which can affect noise propagation, BS 5228-1 (BSI, 2014a) states that:

"Other factors such as meteorological conditions (particularly wind speed and direction) and atmospheric absorption can also influence the level of noise received. The estimation of the effects of these factors is complicated, not least because of interaction between these factors, and is beyond the scope of this standard. In general, at short distances (say less than 50 m), the size of any effects arising from these factors will be small, whereas at longer distances there will be a tendency towards an increase in sound attenuation. Meteorological conditions can result in increased noise levels due to focusing of the sound and this can be important, for example, where screening is present".

Therefore, consideration has been given to the need to account for downwind propagation conditions, for example by applying a correction of +2dB to the results in accordance with BS8233-1:2014 (BSI, 2014b). However, as in the quoted section above, the BS5228-1 (BSI, 2014a) prediction method does not account for attenuation from atmospheric absorption, which can be significant over larger distances. The effects of atmospheric attenuation have been explored in the noise model by undertaking equivalent calculations with the ISO 9613 (ISO, 1996) methodology, which does include atmospheric absorption, the results of which show that the BS5228-1 (BSI, 2014a) predictions are in the order of 3-4dB higher at receptors; therefore, it is considered overly pessimistic to apply an additional downwind correction factor to the modelled results. It is also noted, as demonstrated by figure 2 below, that the prevailing winds are from the south-west, and therefore the Special Protection Area / Site of Special Scientific Interest will not often be downwind of the SPC works.

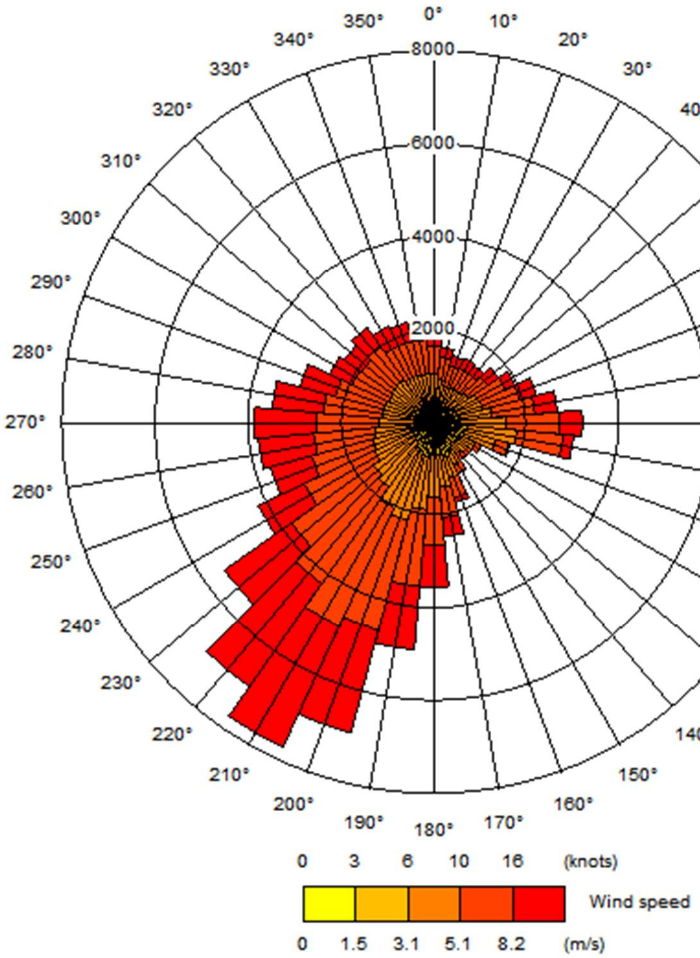

Figure 2 Wind rose for 2003–2014

4 Results

The predicted short-term noise levels at the receptors are set out in table 2 and as noise plots (calculated at five metres above the ground/water surface) in figures 3 and 4, below. For the short-term noise models, the results correspond to the phases of work (1 and 2 or 3 and 4) that result in the highest noise level at that receptor; this is generally phases 3 and 4, apart from at Receptors 4 and 5.

Input	SPC Environmental Statement		Short-term noise models	
	Phase 1 and 2, dB $L_{Aeq,1h}$	Phase 3 and 4, dB $L_{Aeq,1h}$	One-hour dB $L_{Aeq,1h}$	Five-minute dB $L_{Aeq,5min}$
1	40.2	46.7	46.9	47.4
2	39.5	53.4	56.4	56.8
3	43.8	46.9	48.6	49.2
4	51.8	49.3	52.7	53.3
5	49.9	48.2	50.4	51.1
6	44.6	45.3	44.9	45.7
7	60.9	60.8	60.9	62.2
8	53.9	53.8	53.9	55.2

Table 3 Predicted free field short-term worst-case construction noise levels

It can be seen that there is relatively little difference (in the order 0.4–1.3 dB) between the one-hour and five-minute results. This is due to the conservative on-times that have been used in the one-hour model. Such small differences would be considered below the threshold of audibility by humans, who can generally only detect a minimum change of 3dB in fluctuating environmental noise.

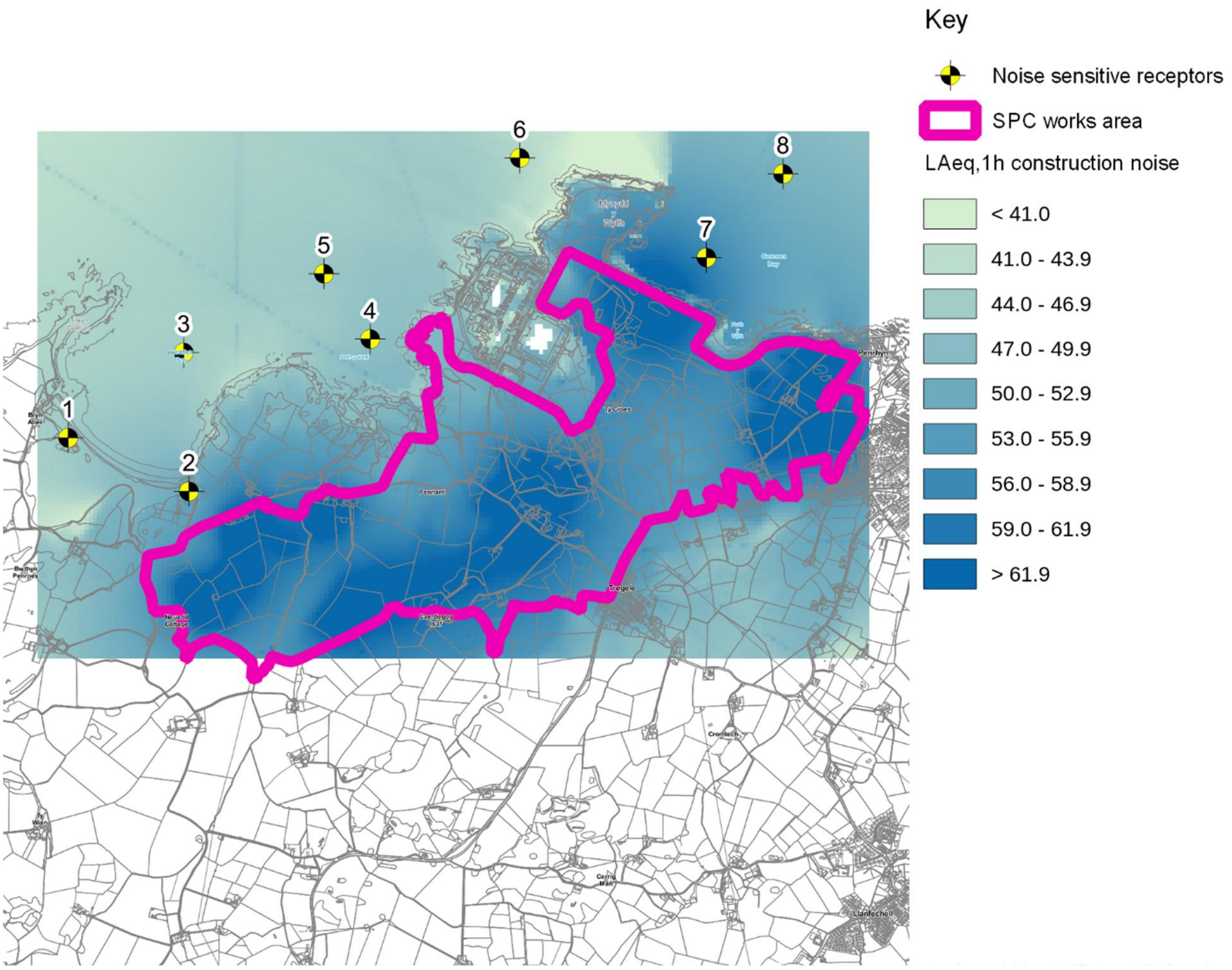

Figure 3 Predicted free field $L_{Aeq,1h}$ worst-case construction noise levels

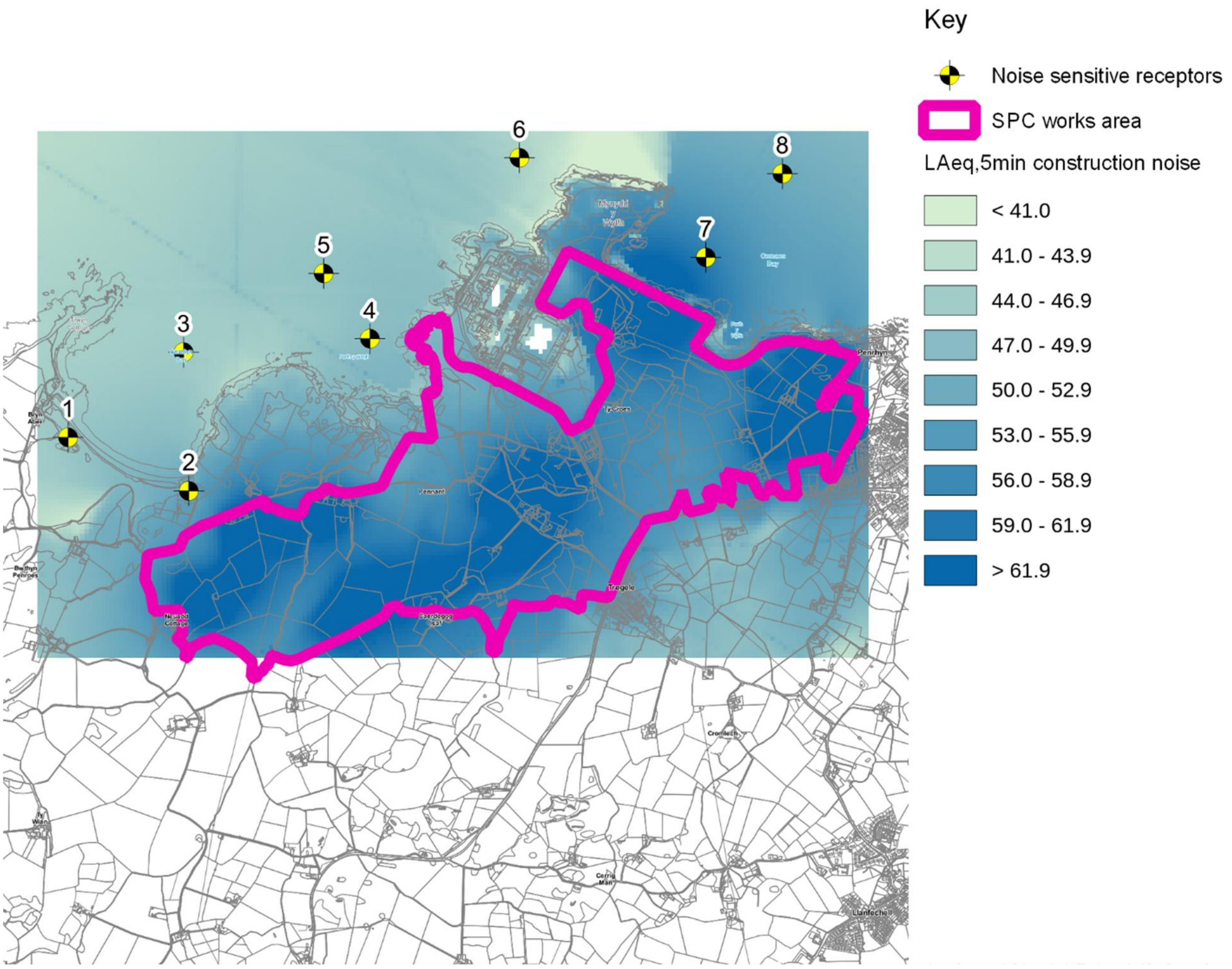

Figure 4 Predicted free field $L_{Aeq, 5min}$ worst-case construction noise levels

5 References

British Standards Institution (BSI), 2014a. *BS 5228-1:2009+A1:2014 'Code of practice for noise and vibration control on construction and open sites. Noise',* London: British Standards Institution.

BSI, 2014b. *BS 8233:2014 'Guidance on sound insulation and noise reduction for buildings'.* London: British Standards Institution.

ISO, 1996. *ISO 9613-2:1996 'Acoustics - Attenuation of sound propagation outdoors - Part 2: General method of calculation',* Geneva: International Organisation for Standardization.

Jacobs, 2016. *Site Preparation and Clearance Environmental Statement,* Glasgow: Jacobs.

Welsh Assembly Government, 2004. *Minerals Technical Advice Note (Wales) 1: Aggregates*.

Appendix E. Method for predicting impulsive construction noise effects at tern receptor locations

HORIZON NUCLEAR POWER

ENERGY WORKING FOR BRITAIN

SITE PREPARATION AND CLEARANCE NOISE EFFECTS - WYLFA NEWYDD PROJECT

Impulsive construction noise effects at tern receptor locations

DCRM Ref Number: WN034-JAC-PAC-REP-00165

Revision: 1.0

Additional Requirements or Controls			
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Originated by	Document Author	Sam Williams	[redacted]	24/01/2017
Reviewed by	Document Reviewer			
Checked by	Head of Section			
Approved by	EMT Representative			

Revision History				
Date	**Rev No.**	**Summary of Changes**	**Ref Section**	**Purpose of Issue**
24/01/17	1.0	Initial draft for client review		

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1 About this report

It has been agreed with the IACC EHO that predictions of construction noise levels for human receptors should be calculated in accordance with British Standard 5228-1:2009+A1:2014 *Code of practice for noise and vibration control on construction and open sites. Noise* (British Standards Institution, 2014). The predicted noise levels assume conservative plant placement and are averaged over a one-hour basis, in accordance with *Minerals Technical Advice Note (Wales) 1: Aggregates* (Welsh Assembly Government, 2004).

During consultation on Habitats Regulations Assessment however, concerns have been raised by Natural Resources Wales (NRW) and the Isle of Anglesey County Council's (IACC) technical advisors (Amec Foster Wheeler) that noise modelling and assessment agreed for human receptors does not fully explore potential disturbance to breeding terns, as it does not consider short term impulsive noise events. These concerns are summarised in an email from Mike Frost (Amec Foster Wheeler) to IACC on 3 October 2016:

"*My colleagues and I have had a quick look at this, and the modelling scenario appears to be valid in capturing a worst case $L_{Aeq,\ 5mins}$. However, this is still a 5 minute average noise level that may not reflect the L_{Amax} (the maximum noise level generated by the plant), which I think would be more useful re. disturbance of nesting terns, as sudden loud noises are potentially more disturbing than continuous background noise. However, I'm mindful that this is potentially complex – whilst standard sound power levels for various plant are available, the L_{Amax} in reality will depend on a wide range of variables and sampling data for these may not be readily available. For example, the first load into the back of a dumptruck tends to produce higher L_{Amax} levels as the material hits the bottom of the truck body; sometimes an excavator driver will sound his horn when the truck is full and ready to move out of the fill area; or there can be a difference between the L_{Amax} for a fully loaded dumptruck on the haul road and an empty one due to "body slap" when the empty truck passes over uneven surfaces. I guess if one needed to model L_{Amax} levels, for example, then you would need to have L_{Amax} based 'sound power levels' to input into the model and not L_{Aeq} based sound power levels. It would be possible to model L_{Amax} but it would need specific input data to be collected from the type of plant and activities proposed – which may be a limiting factor in this instance. Haul roads would need to be modelled as mobile point sources so that the highest L_{Amax} could be determined, etc., etc.*"

In response to these comments, preliminary estimates of the L_{AFmax} noise levels that could occur as a result of the SPC works have been undertaken, and a more detailed methodology that could be used to calculate L_{AFmax} noise levels with higher levels of accuracy has been proposed. This report sets out the preliminary estimates of the L_{AFmax} noise levels and the proposals for a more detailed methodology.

1.1 Glossary

Term	Definition
A-weighting	The human ear demonstrates increased sensitivity at some frequencies compared to others. The A-weighting network applies filters to the signal processing of a sound level meter to mimic the response of the human ear at each frequency.

Term	Definition
Acoustic impedance	The resistance of a porous material to induced flow through it, as a result of a pressure gradient (e.g. a sound pressure wave).
Attenuation	Reduction in sound pressure level
Atmospheric absorption	The attenuation of sound as a result of its passage through the air. The mechanisms of atmospheric absorption are quite complex and include shear viscosity, thermal conductivity, mass diffusion, thermal diffusion, and relaxation of both rotational and vibrational energies within the air molecules.
Broadband	Sound energy distributed over a wide frequency range.
BSI	British Standards Institution
Decibel (dB)	A scale for comparing the ratios of two quantities, including sound pressure and sound power. The difference in level between two sounds S_1 and S_2 is given by $20 \bullet \log10(S_1/S_2)$. The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20µPa.
dB(A)	A-weighted decibel. See: ‘A-weighting’ and ‘decibel’.
Equivalent continuous sound pressure level (L_{eq})	The notional steady sound level which, over a stated period of time, would contain the same amount of acoustic energy as the fluctuating sound measured over that period. The period of time over which this quantity is evaluated is normally added to the sub-script notation, as shown in the following examples: $L_{eq,5min}$, $L_{eq,1-hour}$, $L_{eq,8-hours}$.
Excess attenuation	Any sound attenuation not due to geometric divergence, atmospheric absorption of sound waves and attenuation due to screens and/or barriers.
Frequency	Sound consists of vibrations transmitted to the ear as rapid variations in air pressure. The more rapid the variations in air pressure, the higher the frequency of the sound. Frequency is defined as the number of pressure fluctuations per second and is expressed in Hertz (Hz).
Ground surface roughness	The roughness of the ground surface across which sound is propagating, which affects how sound waves are reflected by the ground and how wind speeds vary with height above ground.
Impulse	The sudden onset of sound is defined as an impulse.
Impulsive noise	Noise that starts suddenly is referred to as impulsive noise.
ISO	International Organization for Standardization
L_{Aeq}	A-weighted equivalent continuous sound pressure level. See ‘A-weighting’ and ‘equivalent continuous sound pressure level’.
L_{Amax}	A-weighted maximum sound level. See ‘A-weighting’ and ‘maximum sound level’.

Term	Definition
L_{AFmax}	A-weighted maximum sound level. See 'A-weighting' and 'maximum sound level'.
L_{AW}	A-weighted sound power level. See 'A-weighting' and 'sound power level'.
Maximum sound level	The maximum sound level (L_{Amax}) is the highest time-weighted sound level measured during a short period. The time constant of the measure is usually either **F**ast (125 ms) or **S**low (1 s), and it is usual to identify the time constant in the notation – e.g. L_{AFmax} indicates the A-weighted maximum sound level was measured with the fast time-weighting. Where no time weighting is provided, normal convention is to assume a fast time weighting (i.e. L_{Amax} implies L_{AFmax}).
Noise emission	Used to describe the noise levels generated by, and other characteristics of, a noise source.
Noise immission	The all-encompassing sound field at a position; composed of sound from near and distant emitters.
Site Preparation and Clearance (SPC)	Project proposed for some enabling works for the construction of the Wylfa Newydd Power Station.
Sound power level	Sound Power Level (L_W) is a Logarithmic measure of the sound power as a relation to the threshold of hearing which is intended to make the range of sound powers encountered in environmental acoustics into a more manageable range of values (i.e. 0 to 160 dB). The sound power level expresses the Sound Power relative to a reference value (W_0) of 1 Pico Watt (10^{-12} Watts) according to the following formula: $Lw = 10 \bullet lg (W/W_0)$ dB

Table 1 Terms and definitions

2 Receptor locations

The terns are known to nest on an island in Cemlyn Bay, within the Special Protection Area and Site of Special Scientific Interest, and therefore Receptor 1 has been placed at this location, at a height of one metre above ground. Receptor 2 has been placed at the edge of the Special Protection Area / Site of Special Scientific Interest closest to the SPC works area, at a height of five metres above ground, as the terns will be in flight at this location.

The terns leave the nest site to forage, and often pass around the headland between Cemlyn Bay and Cemaes Bay. Receptors 3, 5, 6 and 8 are located along this flight path, at heights of five metres above the sea level at the time of the LiDAR survey that provided the ground model.

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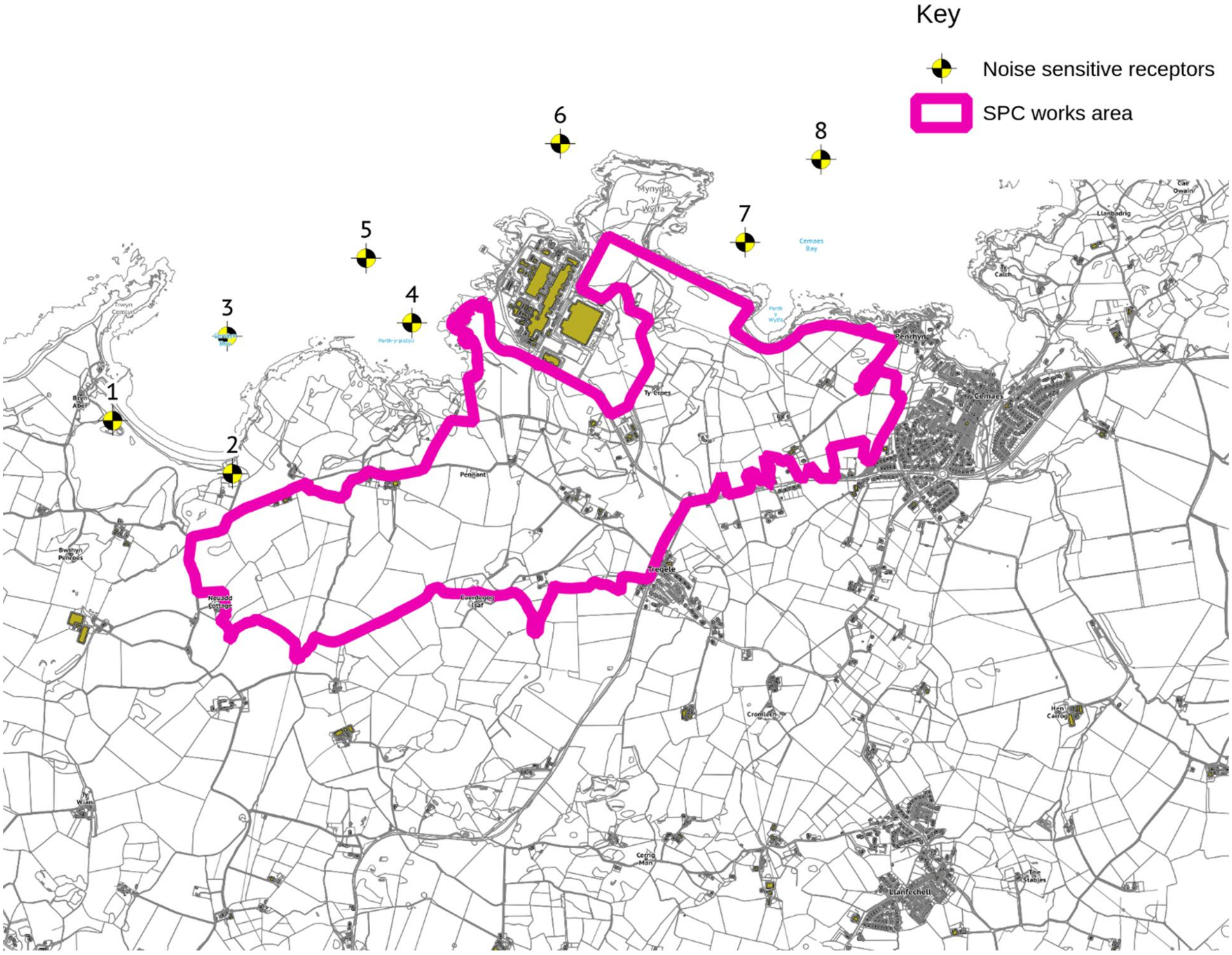

Figure 1 Noise-sensitive receptor points

3 Background

Construction noise levels fluctuate rapidly over time. As the instantaneous construction noise level is not very often a useful quantity, it is more common to express construction noise levels as a statistical quantity based on the distribution of fluctuating noise levels over the period of interest. The most common statistical noise descriptor for describing construction noise is the equivalent continuous sound pressure level over the time period of interest ($L_{Aeq,T}$). This is the notional continuous constant noise that contains the same sound energy over the period of interest as the actual fluctuating noise. The L_{Aeq} is not an arithmetic average (or mean) sound level over a period, but the concept has some similarities and provides a single figure quantity that can be used to compare two or more sets of noise levels which fluctuate with time.

In the United Kingdom, the authoritative method of calculating noise levels at receptor locations due to construction and demolition activities is set out in BS 5228-1:2009+A1:2014 (BSI, 2014a). This methodology calculates the equivalent continuous sound pressure level over the assessment period, which is often taken to be the working day, but which can be any other period. The method logarithmically summates the noise contributions from all of the individual items of plant and machinery operating during the assessment period, based on the propagation path between each receptor and each item of equipment. The contributions of plant are modified by applying corrections for factors such as the proportion of the assessment period that the equipment will be working at or near full load, the traverse distance (for mobile plant operating in a defined area) and the number of vehicles and the speed they are travelling (for haul routes). The result is an estimation of the equivalent continuous noise levels at each receptor for the assessment period, but there is no indication of the potential A-weighted maximum sound level (the noise over a short duration, usually 125ms, which is given the notation L_{AFmax}) during the assessment period. Indeed, the standard states that "*There are no general empirical relationships between L_{AFmax} and $L_{Aeq,T}$*".

The estimation of impulsive noise levels at receptors is more challenging than the estimation of continuous noise levels, because impulsive noise levels are influenced greatly by a large number of variables for which 'typical' time-averaged values cannot be determined. The propagation of sound through the atmosphere modifies the amplitude and phase characteristics of sound waves as they travel between the source and receptor. The modifications to sound waves that occur as they propagate through the atmosphere are due to the following factors:

- geometric attenuation;
- atmospheric absorption of sound;
- obstructions such as buildings and barriers;
- terrain type and contours; and
- wind direction/speed variations, temperature variations, and atmospheric turbulence.

Many of these factors can be considered to be continuously varying, and will change from moment to moment.

The impulsive noise generated by heavy plant may vary based on factors such as driver behaviour, and whether the plant is fully loaded, partially loaded or unloaded. For most plant and equipment the position and directivity of the noise source will also vary as the equipment goes about its task. Therefore, for most impulsive noise events due to construction activities, the location, orientation and height above ground of the source will be unique, as will the path between the source and receptor along which the sound wave travels. The shape of the terrain (e.g. focussing in valleys), ground surface roughness and the acoustic impedance of the ground surface are factors which affect noise propagation.

The propagation of impulsive sound through the atmosphere to the receptor is also highly influenced by the weather conditions at the time of propagation; wind direction/speed gradients, atmospheric turbulence, air temperature and relative humidity all affect the propagation of sound. It is difficult to accurately describe weather conditions which will vary with height within the volume of atmosphere represented in the model.

In summary, the impulsive noise level at a receptor due to two noise events caused by the same item of equipment or plant, a short time apart, may well differ due to differences in the noise emitted, differing terrain and obstructions along the path to the receptor, and different atmospheric conditions.

Whilst detailed numerical models can be developed to determine the propagation of impulsive noise from source to receptor, they are limited to calculating a result for one particular scenario, and are not suitable for a construction noise assessment.

Nonetheless, two potential approaches for predicting the impulsive noise levels from a limited number of construction activities are presented below; the first is a modification of the BS 5228:2009+A1:2014 (BSI, 2014a) method, which has been used to provide initial estimates of impulsive noise at the tern habitat, and the second is a more complex method which may yield more accurate results if further study is required.

4 Preliminary modelling methodology

For the preliminary calculations, a modified version of the BS 5228-1:2009+A1:2014 (BSI, 2014a) methodology is used. The modifications applied are as follows.

- Sound power levels for equipment relate to measured L_{AFmax} levels rather that L_{Aeq} levels.
- No corrections are applied for plant on-time, shift duration or traverse lengths.
- All sources are considered to be static point sources.
- No barrier/screening attenuations are applied.
- A downwind propagation correction of +2dB is applied in accordance with BS 8233-1:2014 (BSI, 2014b) to account for potential atmospheric refraction effects.
- The contributions of multiple sources are not summated; L_{AFmax} noise levels are assessed over a 125ms (1/8th of a second) timeframe, and it is considered very unlikely that more than one impulsive noise event will occur within such a short timeframe.
- All plant are assumed to be located at the closest point in the SPC work area to the receptor(s).

The BS 5228-1:2009+A1:2014 (BSI, 2014a) methodology does not account for the following attenuation effects.

- Source directivity (the standard assumes that the noise emission of source initially occurs uniformly in all directions from the point of origin).

- Reflection of sound waves due to turbulence (scattering) which reduces noise levels at the receptor.
- Terrain effects due to surface roughness, terrain profiles or vegetation, which can reduce noise levels at the receptor.
- Atmospheric absorption effects which reduce noise levels at the receptor.

As the preliminary methodology does not include the above sound attenuation mechanisms, which can significantly reduce sound propagation, it is anticipated that it will provide a conservative estimate of impulsive noise levels at receptors from the activities considered.

4.1 Sound power levels

Appendix C of BS 5228-1:2009+A1:2014 (BSI, 2014a) provides current sound level data on site equipment and site activities. Whilst the majority of the data are based on L_{Aeq} measurements, there are a number of L_{AFmax} noise levels that are of interest. These are presented in table 2 below. It should be noted that the equipment listed does not represent that which will be used for the SPC works; the list is provided to give an indication of typical L_{Amax} noise levels that may be generated on site.

Ref.	Plant Description	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AFmax} dB at 10m	L_{AW} dB
C2.1	Dozer	79	77	76	74	68	67	60	59	75	103
C2.31	Dump truck (empty)	86	79	79	79	79	84	69	60	87	115
C2.33	Articulated dump truck	85	87	77	75	76	73	69	62	81	109
C2.34	Lorry	73	78	78	78	74	73	68	66	80	108
C2.37	Roller (rolling fill)	72	75	81	78	74	70	63	55	79	107
C2.38	Roller	80	75	77	72	67	62	54	46	73	101
C2.39	Vibratory roller	88	83	69	68	67	65	62	59	74	102
C2.40	Vibratory roller	82	78	67	71	67	64	60	57	73	101
C4.1	Articulated dump truck	90	87	77	79	75	73	67	63	81	109
C4.2	Articulated dump truck	85	80	77	72	74	70	65	58	78	106
C4.3	Dumper	84	81	74	73	72	68	61	53	76	104
C4.4	Dumper	82	76	75	74	68	68	64	55	76	104
C4.6	Dumper	89	86	77	74	72	72	66	62	79	107
C4.7	Dumper	90	86	72	71	71	71	66	59	78	106
C4.9	Dumper	82	82	78	77	69	67	61	53	77	105
C4.12	Wheeled excavator	84	82	77	75	72	68	60	52	77	105
C4.13	Wheeled loader	83	72	70	69	65	64	57	49	71	99
C4.15	Fuel tanker lorry	79	73	71	75	72	67	59	50	76	104
C4.74	Tractor (towing equipment)	79	71	78	75	78	70	61	55	80	108

Ref.	Plant Description	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AFmax} dB at 10m	L_{AW} dB
C4.75	Tractor (towing trailer)	93	86	76	76	73	72	64	59	79	107
C5.14	Bulldozer	77	86	75	75	82	80	73	67	86	14
C5.15	Bulldozer	83	81	76	77	82	70	65	58	83	111
C5.16	Articulated dump truck	88	90	80	79	76	71	65	61	81	109
C5.17	Articulated dump truck	85	88	77	75	77	74	69	63	81	109
C5.19	Road roller	87	85	75	73	75	73	69	63	80	108
C5.21	Vibratory roller	90	84	77	81	73	68	65	61	80	108
C5.22	Vibratory roller	92	83	75	79	77	70	67	61	81	109
C5.23	Vibratory roller (not vibrating)	83	77	75	84	76	72	66	61	83	111
C5.24	Vibratory roller	89	82	76	77	72	74	81	61	84	112
C5.32	Asphalt paver (+ tipper lorry)	87	84	81	80	79	76	74	65	84	112
C6.13	Dump truck	97	95	91	91	86	84	79	75	92	120
C6.14	Dump truck	89	94	89	85	83	81	76	71	89	117
C6.15	Dump truck	94	91	91	87	84	83	77	70	90	118
C6.16	Articulated dump truck (empty)	93	90	85	84	83	81	77	69	88	116
C6.17	Articulated dump truck	86	84	86	83	79	76	72	67	85	113
C6.18	Articulated dump truck	91	90	83	83	81	79	70	61	86	114
C6.19	Road lorry (empty)	81	79	75	70	70	70	68	65	76	104
C6.20	Road lorry (empty)	81	76	79	70	71	68	64	60	76	104
C6.21	Road lorry (full)	96	82	74	73	77	72	71	64	80	108
C6.22	Road lorry (empty)	97	85	81	83	76	71	69	64	83	111
C6.23	Rigid road lorry	88	86	80	78	75	73	76	68	82	110
C6.31	Grader	88	87	83	79	84	78	74	65	86	114
C6.36	Diesel bowser	80	81	84	81	84	85	76	66	89	117f
C6.38	Tractor (towing water bowser)	78	86	84	78	78	77	70	69	83	111
C8.13	Articulated dump truck	92	89	83	84	79	75	68	64	85	113
C8.14	Articulated dump truck	88	84	82	73	75	71	66	60	80	108
C8.15	Articulated dump truck	91	81	76	77	73	72	70	62	79	107
C8.16	Articulated dump truck	84	84	81	79	76	73	69	64	81	109
C8.18	Refuse wagon	82	79	78	75	71	72	66	62	78	106
C8.19	Refuse wagon	88	81	79	76	72	70	64	60	78	106
C8.20	Tipper lorry	88	82	74	74	74	73	70	67	79	107

Ref.	Plant Description	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	L_{AFmax} dB at 10m	L_{AW} dB
C8.21	Skip wagon	82	84	78	75	71	70	65	59	78	106
C9.16	Rigid dump truck	86	89	88	88	86	83	76	70	91	119
C9.17	Rigid dump truck	99	95	87	86	84	83	77	73	90	118
C9.18	Rigid dump truck	95	97	89	85	83	83	76	75	90	118
C9.19	Rigid dump truck	90	91	88	85	83	82	77	73	89	117
C9.20	Rigid dump truck	96	97	90	84	84	84	74	76	90	118
C9.21	Rigid dump truck	92	91	86	85	84	85	77	77	90	118
C9.22	Articulated dump truck	100	97	88	84	82	80	77	68	89	117
C10.16	Wheeled loader	83	89	92	80	71	69	64	58	85	113
C10.17	Wheeled loader	77	83	91	75	75	72	65	59	84	112
C10.18	Articulated dump truck	87	85	83	81	78	74	71	66	83	111
C10.19	Articulated dump truck	98	94	89	85	79	79	70	65	87	115
C11.4	Lorry	82	80	78	75	76	78	75	69	83	111
C11.5	Lorry	92	82	77	76	77	72	68	63	80	108
C11.6	Lorry	92	82	76	78	77	76	74	68	83	111
C11.7	Lorry	87	79	77	74	73	73	70	64	79	107
C11.8	Lorry	81	79	79	83	84	81	76	70	88	116
C11.9	Lorry	99	82	81	76	78	74	71	66	82	110
C11.10	Lorry	91	79	77	74	71	69	64	61	77	105
C11.11	Lorry	96	79	75	79	82	80	72	67	86	114
C11.12	Lorry	96	80	75	75	74	72	67	60	79	107
C11.13	Lorry	84	80	76	74	73	70	67	61	78	106
C11.14	Lorry	93	79	76	74	73	72	69	66	79	107
C11.15	Lorry	86	94	81	77	80	77	75	69	85	113
C11.16	Lorry	86	81	74	76	73	72	69	60	79	107
C11.17	Lorry	91	78	74	70	72	74	66	59	78	106
C11.18	Lorry	85	78	83	82	86	80	73	69	88	116
C11.19	Lorry	87	76	73	81	79	75	68	62	83	111
C11.20	Lorry	91	76	79	78	80	76	70	64	83	111
Maximum of each frequency		**100**	**97**	**92**	**91**	**86**	**85**	**81**	**77**	**93**	**121**

Table 2 BS 5228-1:2009+A1:2014 Measured drive-by L_{Amax} Noise Levels, dB

The item for which the highest impulsive noise level was recorded was a dump truck (reference C6.13) with a broadband value of 92dB L_{AFmax} at 10m, which equates to a sound power level of 120dB L_{AW}. However, if the maximum value from each frequency band is considered, a spectrum that equates to a sound power level of 121dB L_{AW} is obtained. This value is used as a source sound power level for the preliminary calculations of vehicle movements on the site, and represents an unrealistic worst case.

It is noted that there is no L_{AFmax} data in Appendix C of BS 5228-1:2009+A1:2014 (BSI, 2014a) that relates to piling, or using a breaker attachment on an excavator to break rock (commonly referred to as ‘peckering’). Although neither of these activities are currently proposed as part of the SPC works, they are often associated with creating the highest levels of impulsive noise on sites and have been considered to provide a worst-case assessment. Data for peckering is not available, but limited L_{AFmax} noise monitoring data for impact piling undertaken for the Crossrail project (RSK, 2016) at a distance of 42m from the pile is available. When corrected for distance, and converted to a sound power level, a value of 126 dB L_{AW} is obtained.

5 Preliminary results

The distances between the closest point of the area within which the SPC works will be undertaken and each receptor has been calculated in a Geographic Information System, and resultant maximum noise levels have been calculated at each receptor. Where the receptor is located over water, the percentage of soft (acoustically absorbent) ground has been set to 0%. For receptors 1 and 2 where the propagation path is over natural ground, a conservative value of 50% soft ground has been used. The results are set out in table 3 below.

Receptor	Minimum distance to the SPC works, m	Percentage soft ground	Vehicle L_{AFmax} dB	Piling L_{AFmax} dB
1	664	50%	55.0	60.0
2	174	50%	68.1	73.1
3	779	0% (propagation over water)	57.2	62.2
4	187	0% (propagation over water)	69.5	74.5
5	502	0% (propagation over water)	61.0	66.0
6	488	0% (propagation over water)	61.2	66.2
7	259	0% (propagation over water)	66.7	71.7
8	768	0% (propagation over water)	57.3	62.3

Table 3 Predicted maximum noise levels, dB L_{AFmax}

It can be seen from table 3 that the predicted maximum sound levels from heavy vehicle movements on site are all below 70dB L_{AFmax}, albeit in the case of Receptors 2 and 4 by only small margins.

The predicted piling maximum sound levels exceed 70dB L_{AFmax}, at Receptors 2 and 7. It should be noted that these predictions are based on the piling occurring at the closest point of the SPC works area, which is unlikely; however, further details on the precise locations of piling activities are not available at this time.

6 Detailed modelling methodology

To conduct more detailed modelling of impulsive noise events, including from piling and peckering activities, it is proposed to utilise parts of the methodology set out in BS ISO

13474:2009 Acoustics — Framework for calculating a distribution of sound exposure levels for impulsive sound events for the purposes of environmental noise assessment (BSI, 2009).

This method is primarily intended to estimate long-term averaged immission levels from a sequence of impulsive noise events given a likely statistical distribution of wind velocity, wind direction, temperature, humidity and atmospheric stability, but it can also be used to calculate immission levels as a result of one particular atmospheric situation (i.e. a worst-case scenario). The method is applicable to impulsive noise propagating over large distances (quoted as 0.5km to 30km).

This method is largely based on the attenuation terms set out in ISO 9613 Parts 1 (ISO, 1993) and 2 (ISO, 1996) (with some modifications), but also includes atmospheric refraction effects and an impedance model based ground correction. The standard notes that various methods exist for calculating the excess attenuation spectra for atmospheric refraction and atmospheric turbulence effects, and that a parabolic equation method was selected in the so-called Harmonoise reference model. However, parabolic equation algorithms only return accurate results in a region limited by a maximum elevation angle, have a high computing time (particularly at frequencies above 600Hz) and scattering in the direction back towards the sound source caused by wind speed gradients (i.e. turbulence) is neglected. Given that a worst-case scenario is to be modelled, it is proposed to omit the excess attenuation from atmospheric refraction and atmospheric turbulence effects altogether.

It will be necessary to gather representative L_{AFmax} noise levels from similar activities and equipment that would be used on the Wylfa Newydd Project to provide more accurate inputs to the detailed modelling, which will be conducted using spreadsheets.

7 References

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Appendix F. Outline methodology for predicting audible noise and infrasound from construction blasting

HORIZON NUCLEAR POWER

ENERGY WORKING FOR BRITAIN

PREDICTING AIR OVERPRESSURE - WYLFA NEWYDD PROJECT

Appendix A13-6 Outline methodology for predicting audible noise and infrasound from construction blasting

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1 About this Report

This report proposes a methodology by which estimates of the A-weighted maximum sound pressure level (dBL_{Amax}) can be estimated from the maximum instantaneous charge weight, and distance from various types of blast.

The purpose of this method is to estimate the magnitude of the A-weighted maximum sound level at tern nesting sites, so that Horizon may form an initial view as to whether the 70 dBL_{Amax} threshold, above which adverse responses in the terns may be observed, is likely to pose a significant constraint to construction blasting.

This proposed method has not been validated by any field testing, and therefore should be used with extreme caution.

1.1 Glossary

Term	Definition
Air overpressure	A pressure wave in the atmosphere produced by a detonation of explosives. Air overpressure consists of both audible and infrasound energy, is measured in pascals and is normally reported in dB(lin).
Air pressure pulse (APP)	A component of air overpressure caused by the direct displacement of rock at the face (a piston like movement of the rock mass which causes an air pressure wave).
Airblast	Alternative term for air overpressure, primarily used in U.S. literature.
A-weighting	The human ear demonstrates increased sensitivity at some frequencies compared to others. The A-weighting network applies filters to the signal processing of a sound level meter to mimic the response of the human ear at each frequency.
Blast	The action of breaking and displacing rock by means of explosives, also known as a ‘shot’.
Blasthole	A hole drilled into rock and/or other materials within which explosives are placed. The explosives may be 'decked' at different levels within the blast hole, and the blasthole is backfilled with stemming material after the placement of the explosives.
Confinement	Constraining effect of the environment on the explosive charge. The confinement of a charge depends on the characteristics of the surrounding rock and free faces, the distance from the blasthole to the free face, the amount of rock being broken and other factors. No general system has been devised for quantifying confinement.
Decibel (dB)	A scale for comparing the ratios of two quantities, including sound pressure and sound power. The difference in level between two sounds s_1 and s_2 is given by $20\bullet\log10(s_1/s_2)$. The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20 µPa.

Term	Definition
Deck (or Decking)	Vertically positioning an explosive charge within a blasthole so as to separate it from other explosive charges in the same borehole, using stemming material or an air cushion.
Delay	The predetermined interval of time between the sequential detonation of explosive charges.
MTAN1	Minerals Technical Advice Note (Wales) 1: Aggregates sets out detailed advice on the mechanisms for delivering Welsh policy for aggregates extraction by mineral planning authorities and the aggregates industry. The document sets out acceptable times for blasting, and maximum acceptable levels of ground vibration at receptors.
DCO	Development consent order
DMP	Disturbance mitigation plan
EIA	Environmental Impact Assessment
Free-field	An environment in which there are no vertical reflective surfaces within the frequency region of interest
Frequency	Sound consists of vibrations transmitted to the ear as rapid variations in air pressure. The more rapid the variations in air pressure, the higher the frequency of the sound. Frequency is defined as the number of pressure fluctuations per second and is expressed in Hertz (Hz).
Gas release pulse (GRP)	A component of air overpressure which results from blast gases escaping through rock fractures and venting at the face.
Highwall	A near vertical face at the edge of a bench, bluff or ledge on a surface excavation.
ISEE	International Society of Explosives Engineers
Maximum instantaneous charge (MIC) weight	The maximum weight of explosive detonated in any delay, measured in kg.
Parting blast (or parting shot)	A blast where the explosive charge is decked within a parting (a rock mass) located between two seams of coal. A parting is usually relatively thin and this type of blast often creates a high gas release pulse caused by blast gases escaping to the face through the softer coal strata.
Rock pressure pulse (RPP)	A component of air overpressure caused by vibrating ground close to the receptor.
Stemming release pulse (SRP)	The stemming release pulse is the component of air overpressure which results from blast gases escaping up the blasthole through the stemming material.

Table 1 Terms and definitions

2 Air overpressure

Air overpressure is a pressure wave that is formed in the atmosphere by the detonation of explosives. This consists of energy manifested as audible (noise) and largely inaudible ('infrasound', which is also known as 'concussion'). Air overpressure differs from noise from other construction activities which do not normally contain the low-frequency pressure-wave components associated with explosive sources (Dowding, 2000).

Infrasound is often described as sound that is lower in frequency than 20Hz. The frequency of 20 Hz used to be regarded as the lower threshold of hearing, however, more recent research has demonstrated that the threshold of hearing may be as low as 4Hz in special listening conditions if the level is sufficient (Watanabe & Møller, 1990). Infrasound is primarily sensed by the ear, the sensitivity of which decreases with frequency. To be perceived, the sound pressure level of the infrasound must exceed the threshold of hearing. At higher intensities, infrasound may also be felt as vibrations in other parts of the body.

2.1 Components of air overpressure

There are four component parts to air overpressure, as detailed below.

- Air pressure pulse (APP): Direct rock displacement at the face or mounding at the blasthole collar creates a low-frequency air pressure wave. The effects of the individual blastholes can be seen on the time histories from measurements made close-in or in front of the face, but at distance or behind the face the individual pulses become less distinct and a single, low-frequency pulse is observed. For a well-designed and well-confined blast, the APP is of greater magnitude than the other air overpressure components.
- Rock pressure pulse (RPP): ground vibrations caused by the detonation travel through the ground to the receptor, where the movement of the ground surface causes an air wave. As ground vibration travels faster than the speed of sound in air, the RPP is the first component of air overpressure to arrive at the receptor, though it is usually quite small in magnitude compared to the airborne pressure wave caused by the other components. The dominant frequency of the RPP is the same as the frequency of the vertical ground vibration, which is normally higher than for the APP.
- Gas release pulse (GRP): Gases arising from the detonation escape from the blasthole to the surface of the face through cracks and fissures in the rock, where they cause higher frequency air pressure waves than the APP.
- Stemming release pulse (SRP): Gases arising from the detonation also escape along the blasthole through the stemming material to the surface. The SRP also causes higher frequency air pressure waves than the APP.

2.2 Frequency characteristics

The RPP has relatively little influence on the overall magnitude of the air overpressure at the receptor, contributing just a small proportion of the energy.

The low-frequency pressure wave from the APP contains most of the energy in a well-confined blast, but is low in frequency. Higher frequencies are contributed by the GRP and SRP, which in theory are the most easily controlled aspects of air overpressure.

The two greatest contributors to higher frequency air overpressure are the direction of the face (towards the receptor results in greater high frequency components) and insufficient confinement of the blast.

The predominant frequency spectra for mining and construction blasts is in the range 0.5 – 25Hz (Siskind, et al., 1987), which explains why the A-weighting network is not normally used when describing air overpressure; at 10Hz the A-weighting network applied a response correction of -70.4dB reducing to -44.8dB at 25Hz. This would effectively filter much of the important low-frequency components from the total air overpressure level.

2.3 Propagation of air overpressure

Air overpressure is transmitted through the atmosphere, and so the prevailing meteorological conditions at the time of the blast are important. Wind speed, wind direction, the amount of cloud cover and humidity levels will all affect the intensity and phase of the pressure wave at the receptor. Some of these factors can vary rapidly with time, with height above ground and with horizontal distance from the blast site. Unlike predicting equivalent continuous sound levels, it is not possible to determine 'average' atmospheric propagation conditions for a given moment in time.

2.4 Difficulties for predictions

The relative energies of the GRP and the SRP depend on factors such as the type of blast, the location, number and geometry of fissures in the rock and how the blasthole has been stemmed; these variables are complex and difficult to account for in a model.

The propagation of the air overpressure through the atmosphere to the receptor is also highly influenced by the weather conditions at the time of propagation; wind direction/speed gradients, atmospheric turbulence, air temperature and relative humidity all affect the propagation of sound. The shape of the terrain (e.g. focussing in valleys), ground roughness and the acoustic impedance of the ground surface are also factors.

Both the weather conditions and the terrain/ground conditions vary continuously from source to receptor. While it is possible to describe the terrain/ground conditions accurately, as these are generally static, is difficult to accurately describe the variable weather conditions within the volume of atmosphere represented in the model.

3 Approaches to propagation models

There are three basic approaches to sound propagation models:

1. Engineering methods which mainly establish an empirical mathematical model of the relationship between the system input and output, based on adding the separate contributions that each sound attenuation factor has on noise propagation.
2. Semi-analytical modelling based on simplified analytical solutions of the acoustic wave equation, which follow the same basic structure as the engineering methods.

3. Numerical modelling of the physical mechanisms which modify the amplitude and phase characteristics of the sound waves.

For the first method, the model must provide a good fit between the outputs and inputs of the entire system, but does not necessarily have to incorporate each of the physical parameters as separate terms in the model. Practical engineering methods are simple and easy to use, but are only capable of taking into account averaged meteorological effects. The methods described in BS5228-1:2009+A1:2014 and ISO9613-2:1996 fall within this category of model. For instance, BS5228-1:2009+A1:2014 does not consider the effects of meteorological conditions, and combines the attenuations due to geometric divergence and ground effects into a single term which is sensitive only to the proportion of acoustically porous ground between the source and receptor (not to factors such as roughness of terrain). ISO9613-2:1996 uses a slightly more advanced model which calculates noise immission levels under a so-called 'downwind' condition where the long-term average level is estimated using a correction factor C_{met}. However, ISO9613-2:1996 specifically excludes the prediction of impulsive noise from its scope, and holds only for A-weighted noise levels.

Of the semi-analytical methods, the most popular is simple ray tracing. These methods allow better tracking of the influence of specific meteorological conditions on noise levels, such as upwind or downwind conditions. Ray tracing is computationally fast and provides a better level of accuracy than the engineering methods, but is not well suited to modelling low-frequency noise due to the wavelengths involved. As a significant proportion of the energy associated with impulsive sound events is expected to be in the lower frequency bands, this method would not appear to be a good fit to this application.

Methods belonging to the numerical modelling group include the Fast Field Program method, the Parabolic Equation method and the Boundary Element Method. The success of the numerical modelling methods depends on identifying and quantifying the effects of physical parameters (such as wind velocity/direction gradients, atmospheric temperature and relative humidity) on the propagation of sound, and the limitations of the particular modelling technique.

In respect of quantifying the effects of physical parameters, Andrew Bullmore (Bastasch, et al., 2012) states: "*A sound wave will propagate across a distance of 1km in approximately 3 seconds. It thus follows that, in order to precisely model the effects of changes in meteorological parameters, the values of all significant controlling parameters must be known at every point and moment in time as the sound wave travels from source to receiver. Based on current, or even foreseeable, measurement technology such detailed information is unlikely to be available*".

In addition to the difficulties in stipulating the physical parameters for the model, each numerical method has its own limitation, as follows.

- Fast Field Program is restricted to situations with a layered atmosphere and a homogeneous ground surface, and cannot model terrain which changes in shape or acoustic impedance, or changing atmospheric conditions within the modelled volume. The technique is also computationally expensive. Together these limitations make this technique inappropriate for use over long distances or mixed ground conditions.
- Parabolic Equation algorithms only return accurate results in a region limited by a maximum elevation angle, have a high computing time (particularly at frequencies above

600Hz) and scattering in the direction back towards the sound source caused by wind speed gradients (i.e. turbulence) is neglected.

- Boundary Element Method models require surfaces to be discretised at a resolution of 5-10 elements per wavelength, which at a frequency of 1,000Hz results in a memory requirement of around 1.5GB per $50m^2$ area within the model. As the frequency of interest increases, the memory requirement increases rapidly, which generally limits this method to small scale models.

In summary, whilst numerical methods have strengths in terms of accuracy, they also have many weaknesses, mainly in their practical application.

Given the difficulties in modelling the individual effects of the physical parameters, it is not surprising that the only prediction methods for air overpressure which have been adopted by countries outside the UK are empirical engineering methods. The following sections consider the three most common methods, which all predict the total air overpressure in physical units (pascals or millibars) which are easily converted to decibels, but do not give an indication of the frequency distribution of the sound pressure.

3.1 ISEE method

The ISEE Blaster's Handbook (International Society of Explosives Engineers, 2011) ('the handbook') advises that for scaling air overpressure, using the cube root of the maximum instantaneous charge weight (within any 8ms delay) shows less scatter than the more common square root scaled distance used for scaling ground vibration. The cube root scaled distance (SD_3) is given by the following formula.

$$SD_3 = \left(\frac{R}{W^{\frac{1}{3}}}\right)$$ Equation 1

Where

SD_3	=	cube root scaled distance factor
R	=	distance from the blast to a point (m)
W	=	maximum weight of explosives per delay (kg)

Following from this, the best fit line to calculate the air overpressure from scaled distance is calculated in accordance with the following formula.

$$P = A \times (SD_3)^{-B}$$ Equation 2

Where:

P	=	air overpressure (millibar)
SD_3	=	cube root scaled distance ($m^{-1}\ kg^{1/3}$)
A	=	intercept of the line at a SD_3 value of 1
B	=	slope of the line (negative)

The following constants for A and B for different types of blasts are set out in the handbook.

Blasting	A	B	Source
Open air (no confinement)	3589	-1.38	Perkins
Coal mines (parting)	2596	-1.62	USBM RI 8485
Coal mines (highwall)	5.37	-0.79	USBM RI 8485
Quarry face	37.1	-0.97	USBM RI 8485
Metal mine	14.3	-0.71	USBM RI 8485
Construction (average)	24.8	-1.1	Oriard (2005)
Construction (highly confined)	2.48	-1.1	Oriard (2005)
Buried (total confinement)	1.73	-0.96	USBM RI 8485

Table 2 ISEE Blaster's Handbook site constants and site exponents for types of blasts

When the air overpressure is converted from millibars to dB(Lin) the cube root scaled distance regression lines shown in figure 1 below are obtained.

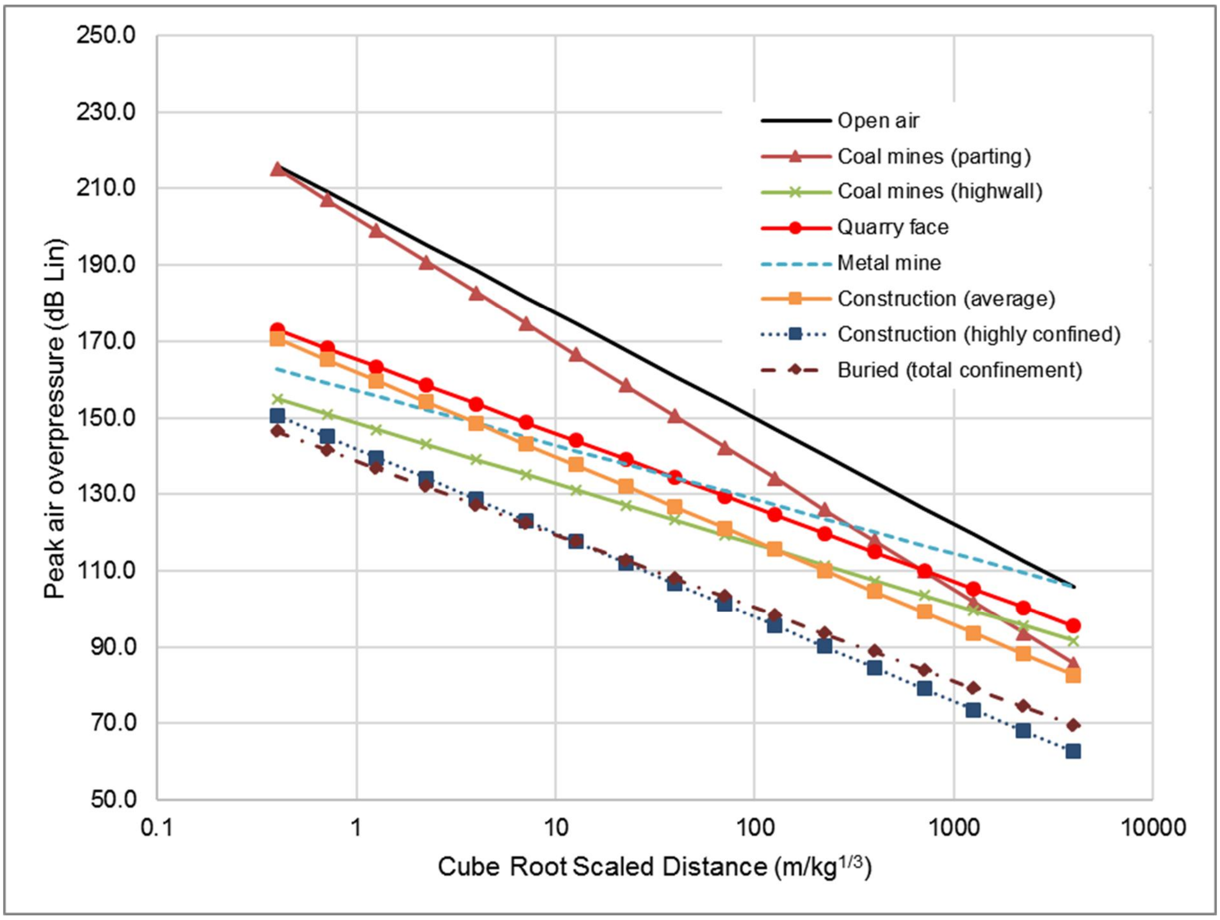

Figure 1 Cube root scaled distance for different types of blasts using ISEE constants

From the above it can be calculated that an unconfined charge of 50kg (MIC) at a distance of 1,000m (SD_3 = 271) would be expected to result an air overpressure of 138dB(Lin) with neutral weather conditions. Conversely under the same environmental conditions, a totally confined blast with the same charge weight would yield an air overpressure of just 92 dB(Lin).

The handbook notes that wind direction will cause air overpressures to be enhanced downwind: *"For a 32 kilometer/hour (20mph) wind, an additional 10 to 20 decibels may be received downwind, or a lower 10 to 20 decibels upwind compared to a no wind situation. Mild crosswinds do not have a significant effect, but strong turbulent winds may mask the sound as well as disrupt the continuity of the air overpressures.*"

3.2 Australian method

Australian Standard AS 2187.2-2006 (Standards Australia Committee CE-005, 2006) ('the standard') presents the same formula as the ISEE Blaster's Handbook (International Society of Explosives Engineers, 2011), except that the SD_3 term expanded into its constituent parts.

$$P = K_a \left(\frac{R}{\sqrt[3]{Q}}\right)^a$$ Equation 3

Where:

P = pressure (kPa)

Q = explosives charge mass (kg)

R = distance from charge (m)

K_a = site constant

a = site exponent

Although it is not explicit in the standard, it is assumed that the explosives charge mass relates to the MIC of the blast, which is consistent with the ISEE method. However, the range of recommended constants differ.

- For unconfined surface charges, in situations which are not affected by meteorological conditions, a good estimate may be obtained by using a site exponent (a) of -1.45, and a site constant (K_a) of 516.
- For confined blasthole charges, when using a site exponent (a) of -1.45, the site constant (K_a) is commonly in the range 10 to 100.

Using the constants for an unconfined surface charge, a charge weight of 50kg and a propagation distance of 1000m, a value of 138dB(Lin) is calculated; for these inputs Formula 3 yields the same result (when rounded to the nearest integer) as is obtained using the ISEE method in Section 3.1 above.

Using the constants for a confined blast results in levels between 103dB(Lin) for K_a=10, and 123dB(Lin) for K_a=100. These values are higher than those yielded by the ISEE constants for total confinement. Since AS 2187.2-2006 provides no commentary on the studies from which this range of constants was derived, what type of blasting they relate to is not clear. Therefore the cube root scaled distance lines resulting from the AS 2187.2-2006 constants are shown along those based on selected ISEE constants in figure 2 below; it can be seen that there is very little difference for unconfined charges, the K_a=100 confinement is quite similar to that recommended by ISEE for coal mine parting blasts, and the K_a=10 confinement does not match any of the ISEE constants particularly well.

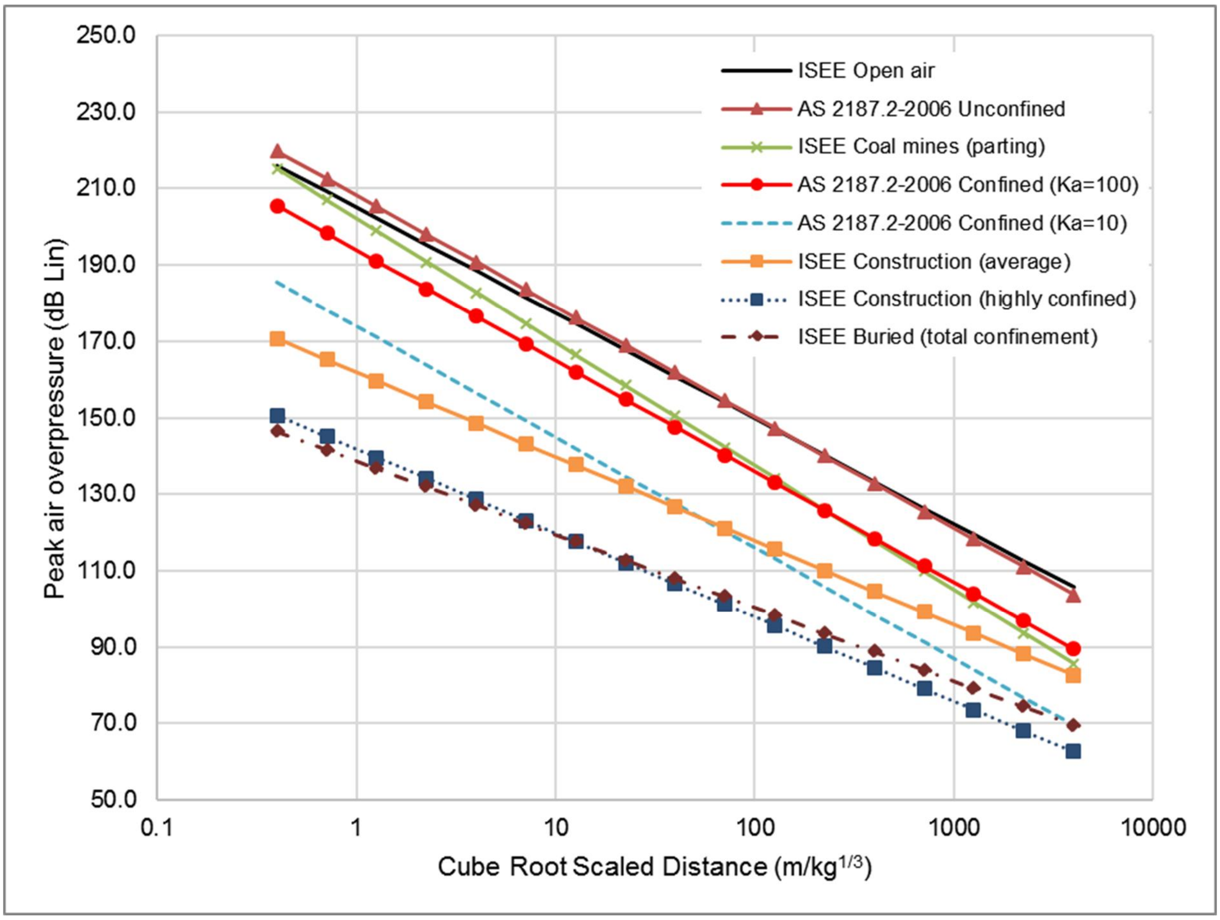

Figure 2 Cube root scaled distance for different types of blasts using AS 2187.2-2006 and selected ISEE constants

With respect to the effects of meteorological conditions, the Australian method states that "*it is common for airblast levels to be increased by up to 20 dB(Lin) due to the combined effects of an increase with altitude of temperature (an inversion) and/or wind velocity*".

3.3 ICI Handbook of Blasting Tables

The *ICI Handbook of Blasting Tables* (ICI Australia Operations. ICI Explosives., 1990) presents the same basic formula as the ISEE Blaster's Handbook (International Society of Explosives Engineers, 2011) and AS 2187.2-2006 (Standards Australia Committee CE-005, 2006), but suggests that a site exponent (a) of -1.2 and a site constant (K_a) of 185 may be used to estimate air overpressure for unconfined surface charges. For the example situation (a 50kg MIC blast at 1000m), this results in an estimated air overpressure of 141dB(Lin) which is 3dB higher than the other methods.

For fully-confined blasts, ICI recommend a site exponent (a) of -1.2 and a site constant (K_a) of 3.3. The cube root scaled distance lines resulting from the ICI constants are shown on figure 3.

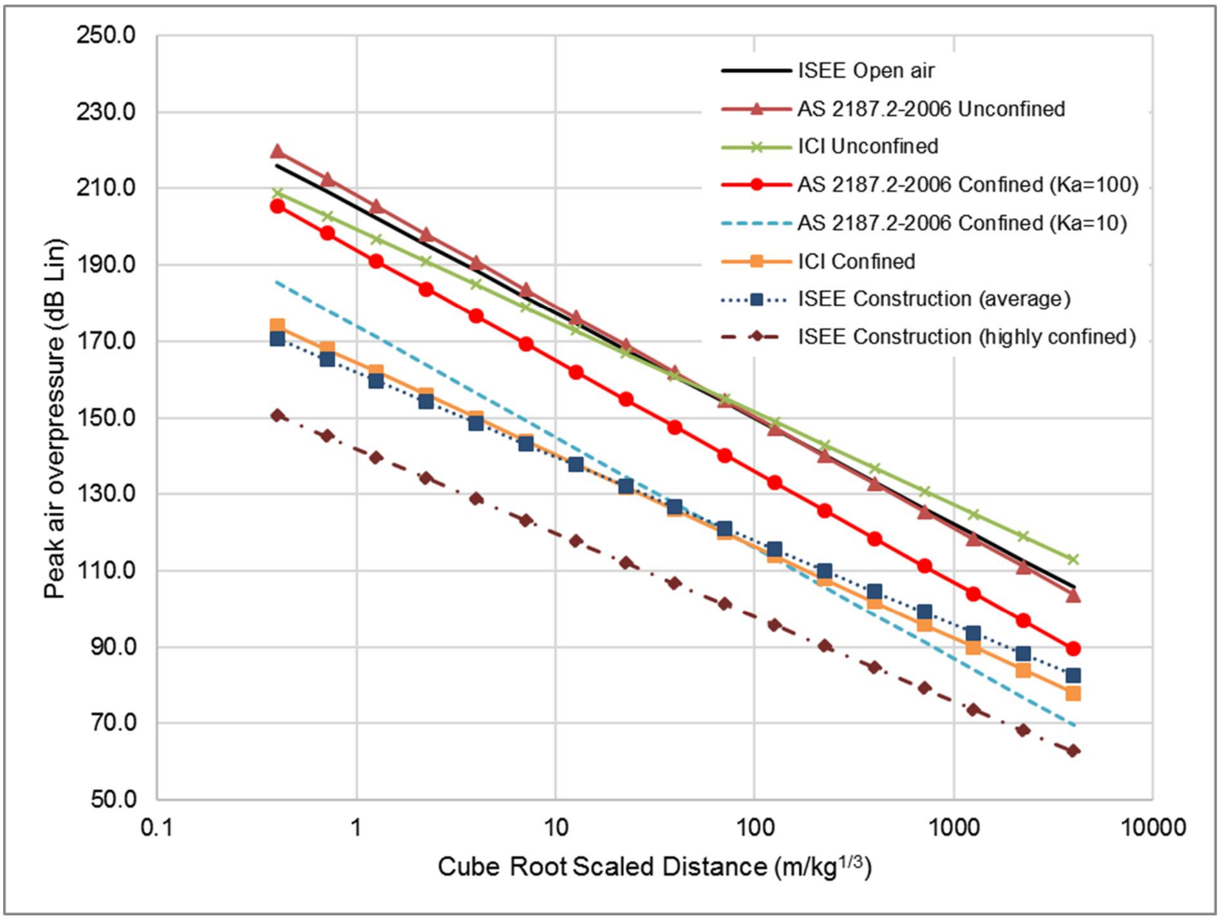

Figure 3 Cube root scaled distance for different types of blasts using ICI, AS 2187.2-2006 and selected ISEE constants

3.4 Comparison of prediction methods

Figures 1-3 above show that the range of predicted air overpressures for any given MIC and distance vary by between 41-69dB, depending on the choice of site constant and site exponent.

From the ISEE Blaster's Handbook (International Society of Explosives Engineers, 2011) the constants for unconfined blasts and coal mine parting blasts result in the highest air overpressures.

AS 2187.2-2006 (Standards Australia Committee CE-005, 2006) is generally consistent with the ISEE Blaster's Handbook, but provides little detail on how to select an appropriate site constant (K_a) in the recommended range 10-100. As this variable has a significant effect on the predicted noise level, selection of an appropriate site constant (K_a) is of great importance.

The ICI method also produces results to the ISEE Blaster's Handbook and AS 2187.2-2006, but is relatively inflexible, offering just a choice of unconfined or confined blasts, with no discussion as to the origin of the site constant or exponent.

Following this review, it is recommended that the method and constants set out in the ISEE Blaster's Handbook be used for the predictions, together with the application of a 10 – 20 dB wind direction/temperature inversion propagation correction.

All of the methods predict the peak air overpressure, but none yield a dominant frequency or frequency spectrum which can be used to estimate the audible proportion of the sound pressure wave.

4 Frequency Spectra

The United States Department of the Interior, Bureau of Mines (USMB) has published much research into the effects of ground vibration and air overpressure from blasting for minerals extraction. Of note is the USBM Report of Investigations RI 8485: Structure Response and Damage Produced by Airblast from Surface Mining (Siskind, et al., 1987), which summarises research by the Bureau of Mines into air overpressure effects on residential structures. The research includes the generation, propagation, and frequency content of air overpressures.

USBM RI 8485 reviews the different frequency spectra associated with different types of airblast previously classified by Siskind (Siskind, 1977):

- Type 1
- Type 2
- Poorly constrained

The frequency characteristics of each are considered below in turn.

4.1 Type 1

Figure 4 below shows the frequency spectra of a type 1 airblast which is characterised by prominent and distinct air pressure pulses, which result from line of sight (or near line of sight) propagation conditions between the free face and the receptor. Often a spike occurs at around 15Hz which corresponds to a 60ms separation between successive blasthole detonations.

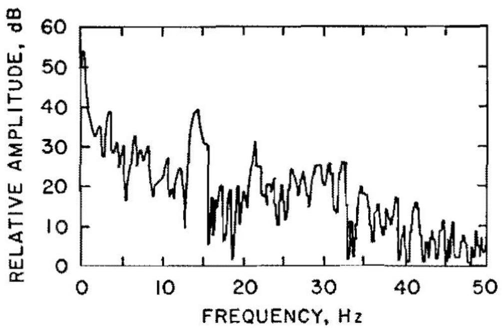

Figure 4 Frequency spectra of a type 1 airblast

4.2 Type 2

Figure 5 below shows the frequency spectra of a type 2 airblast, in which it can be seen that the air pressure pulses are spread out into a single, very-low-frequency overpressure. This type of airblast is typically observed at large distances and behind the rock face, as the rock face acts as a barrier to the higher frequencies. An exception to this is where there is a high wall opposite the free face, which reflects the higher frequencies back towards the free face.

As higher frequency noise is attenuated at a higher rate with distance than low frequencies, all airblasts become similar to type 2 at large distances.

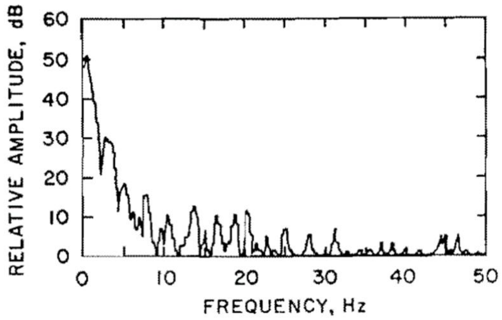

Figure 5 Frequency spectra of a type 2 airblast

4.3 Poorly confined

Figure 6 below shows the air overpressure frequency spectra from a coal mine highwall blast, which produced a blowout and significant stemming release pulse. It should be noted that the horizontal axis of this graph extends to 100Hz, in contrast to the graphs for type 1 and type 2 airblasts which extend only to 50Hz.

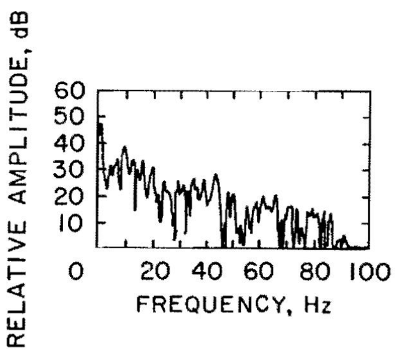

Figure 6 Frequency spectra of a poorly confined airblast

A well-designed blast should prevent the generation of stemming release and gas release pulses, but RI 8485 notes that the natural variability of the blasted material makes it impossible to control SRP at all times.

RI 8485 goes on to note that "*Small blasts such as those used in construction and coal-mine-parting shots are particularly troublesome, not only for the high levels of airblast they can produce, but also because they are of high frequency (as much as 5-25 Hz compared with the usual 0.5-1.5 Hz). Obtaining sufficient confinement is the usual problem with these shots*".

4.4 Report of Investigations 8892

Earlier work published in USBM RI 8892 *Airblast and ground vibration generation and propagation from contour mine blasting* (Stachura, et al., 1984) contains the frequency analysis from a large number of airblasts measured at different types of mines.

Appendix A to USBM RI 8892 presents two sets of histograms; the first being the number of occurrences of frequencies where the measured blast air overpressure had a magnitude that was within 3dB of the peak spectra for the blast, and the second being where the measured blast air overpressure had a magnitude that was within 20dB of the peak spectra for the blast.

Those blasts with the greatest number of occurrences at higher (audible frequencies) are from coal mine parting blasts and steep slope contour coal mines (figure 7 and figure 8 below), which are both difficult to properly confine. These data agree with the spectra presented in USBM RI 8485.

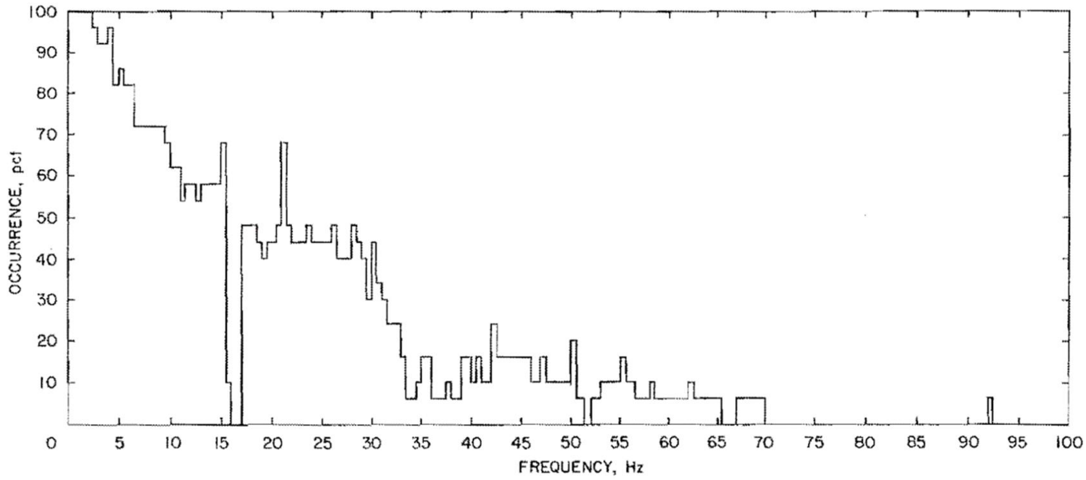

Figure 7 Flat-area coal mine parting airblast, frequencies within 20 dB of peak spectra [USMB RI 8892 Figure A-11]

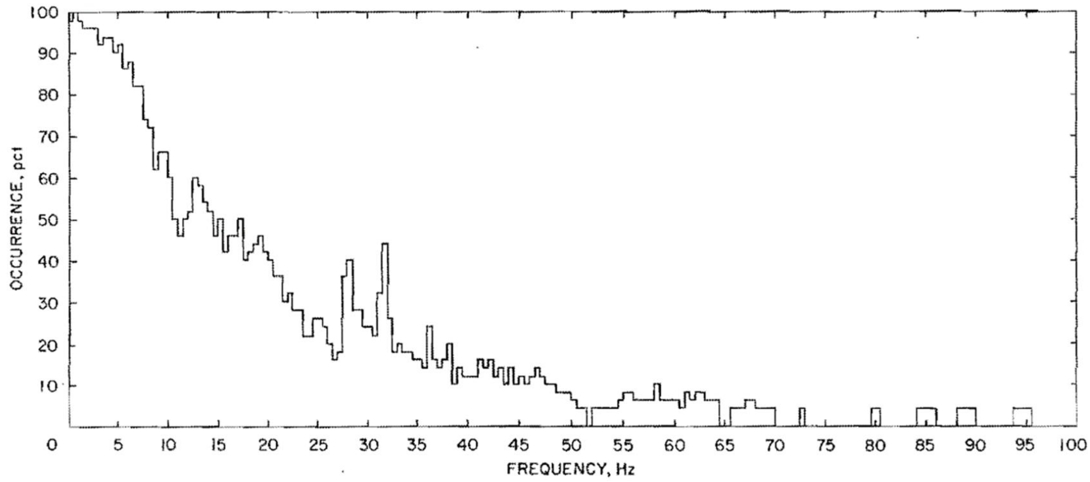

Figure 8 Steep-slope contour coal mine airblast, frequencies within 20 dB of peak spectra [USMB RI 8892 Figure A-8]

5 Proposed methodology

It is proposed to adopt the example blast spectra from figures 4, 5 and 6 as templates of 'typical' air overpressure frequency distribution to determine the A-weighted maximum sound pressure level at environmental receptors.

5.1 Type 1 blasts

The diminishing amplitude of the peak spectra with increased frequency associated with a type 1 airblast can be approximated with a straight regression line, as shown in figure 9 below.

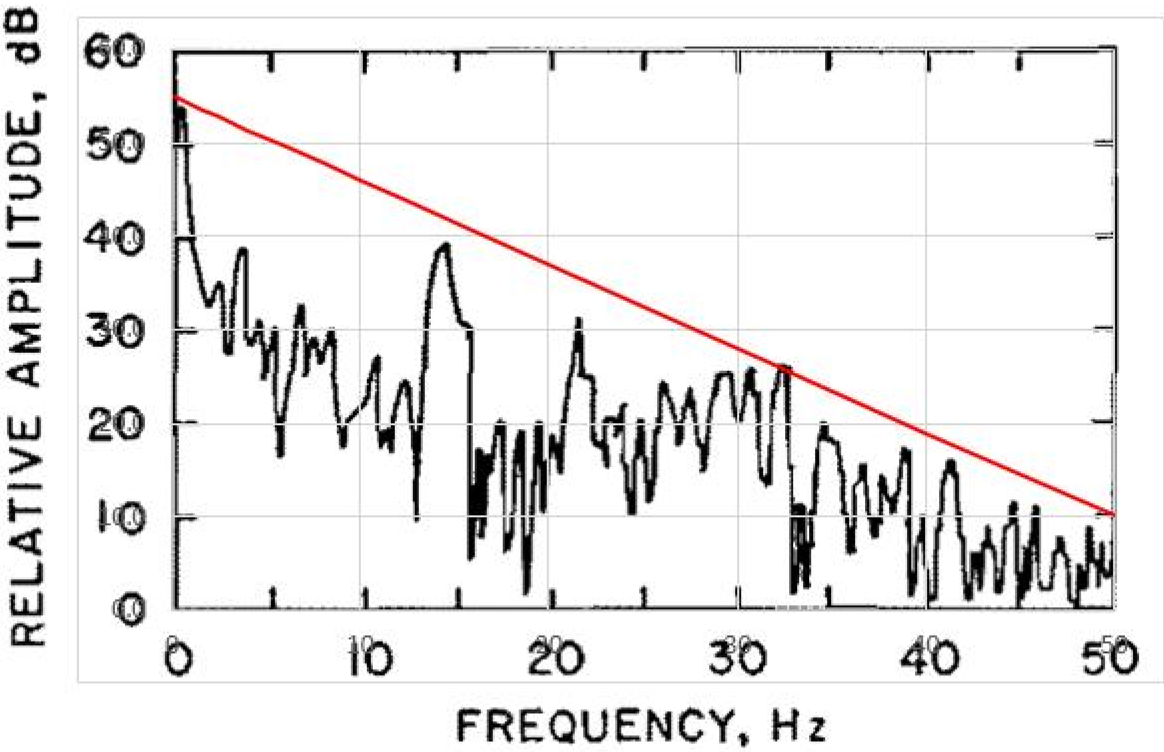

Figure 9 Reducing amplitude of air overpressure peak spectra with increasing frequency for a type 1 blast

The equation of the line is:

$$y = m\,x + b$$ Equation 4

Where

m = -0.897959184

b = 55

At 50Hz the value of y is 10.1dB, and this value is assigned to all higher frequencies (i.e. in the absence of further data, it is assumed that there is no further attenuation of the peaks with increased frequency). This yields a spectrum which reduces in magnitude in a linear manner between 0.1-50Hz (by 44.8 dB) and then remains constant to 20kHz.

The y-values shown on figure 9 are relative amplitudes, and therefore this spectrum can be shifted up or down to give a dB(Lin) spectrum with the same total sound energy over the range 0.1-20kHz as the broadband air overpressure value predicted using the ISEE method.

It now only remains to apply the A-weighting network to the dB(Lin) spectrum, and energetically summate the result, to arrive at an estimate of the dB(A) L_{max} resulting from the blast at the receptor point, which can then be compared directly with the thresholds for protected bird species.

As the shape of the dB(Lin) spectrum, and the A-weighting values applied at each frequency remain constant, the difference between the dB(Lin) value and the dB(A) value is always the same. For a typical type 2 blast, the A-weighted maximum sound level is 40dB(A) less than the broadband dB(Lin) air overpressure level.

5.2 Type 2 blasts

The diminishing amplitude of the peak spectra with increased frequency associated with a type 2 airblast is better approximated by a power curve regression than a straight line, as shown in figure 10 below.

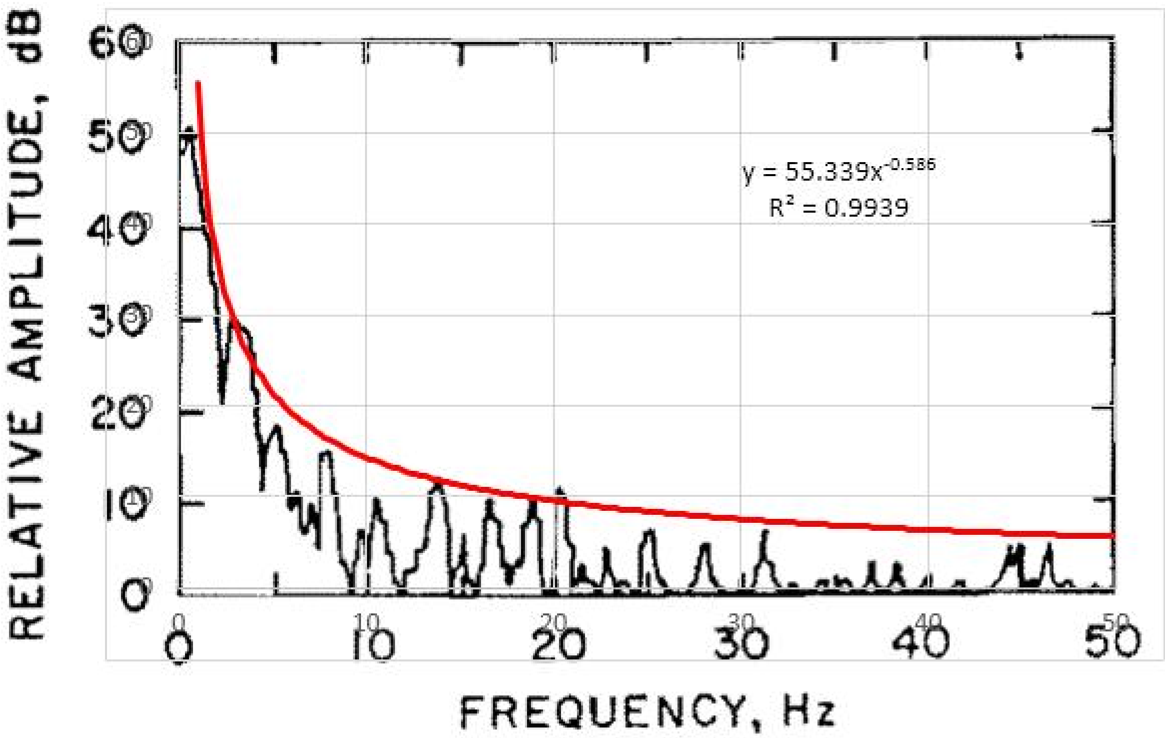

Figure 10 Reducing amplitude of air overpressure peak spectra with increasing frequency for a type 2 blast

The equation of the line is:

$$y = \alpha x^{\beta}$$ Equation 5

Where

α = 55.339

β = -0.558

As with the type 2 blast spectrum, this can be shifted up or down until the total sound energy across the spectrum matches the predicted broadband air overpressure level. Applying the A-weighting network to the resulting values, and then calculating the broadband A-weighted value reveals that for a typical type 1 blast, the A-weighted maximum sound level is 43dB(A) less than the broadband dB(Lin) air overpressure level.

5.3 Poorly confined blasts

As with a type 2 blast, the diminishing amplitude of the peak spectra with increased frequency associated with a poorly confined airblast can be approximated with a straight regression line, as shown in figure 11 below.

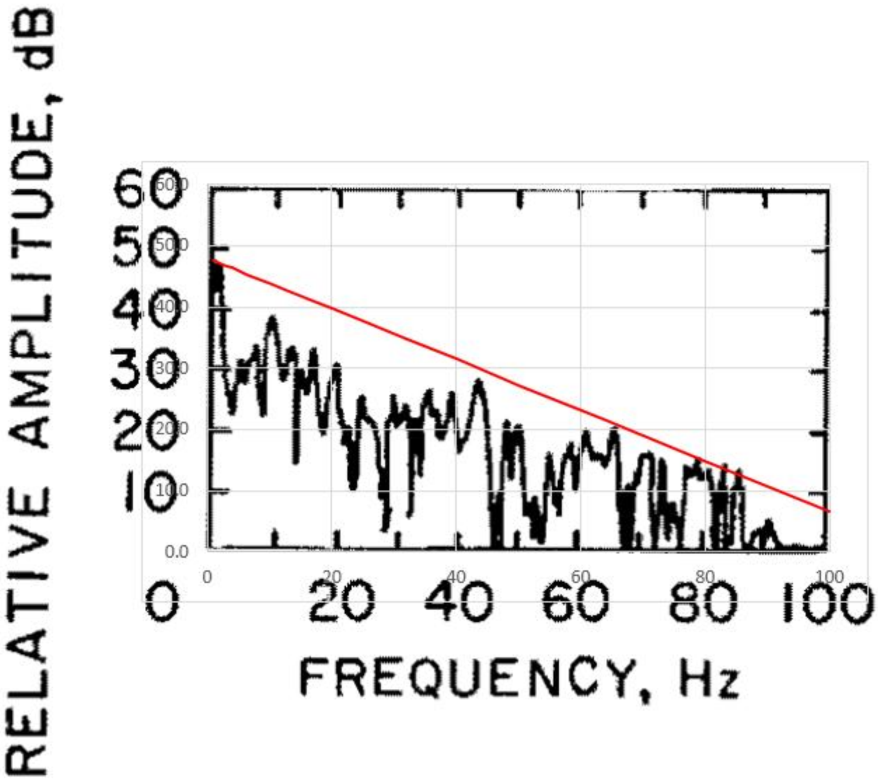

Figure 11 Reducing amplitude of air overpressure peak spectra with increasing frequency for a poorly confined blast

The equation of the line is:

$$y = m\,x + b$$ Equation 4

Where

m = -0.414141414

b = 48

Applying the same process described above for the type 2 and type 1 blasts reveals that for a typical poorly confined blast, the A-weighted maximum sound level is 38dB(A) less than the broadband dB(Lin) air overpressure level.

6 Limitations

The type 1 and unconfined blast spectra presented in USBM RI 8485 are intended as typical examples, and do not represent the limit of potential frequency distributions which could occur, which are essentially impossible to define.

The cube root scaled distance model presented in the ISEE is based on best fit regression lines, and so it can be expected that around 50% of the blasts will be above these levels.

In USBM RI 8485 (Siskind, et al., 1987) it is noted that the direction of the receptor relative to the orientation of the free face can make a 5-10dB difference in the magnitude of the air overpressure at the receptor. None of the prediction methodologies reviewed in this report take this potential increase in noise into consideration.

The proposed dB(A) L_{max} prediction method does account for the effects of atmospheric absorption or turbulent scattering that will offer additional attenuation of the high frequency components over long distances.

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