The Tecpro Building,
Clonshaugh Business & Technology Park,
Dublin 17, Ireland.

T: + 353 1 847 4220
F: + 353 1 847 4257
E: info@awnconsulting.com
W: www.awnconsulting.com

TECHNICAL NOTE

Project	**Hugh Lane Gallery**
Subject	**Noise Impact of Building Services Plant to Hugh Lane Gallery 1930's Wing**
Author	**Jennifer Harmon**
Date	**29 May 2019**
Ref.	**JH/18/10473NT01**

1.0 INTRODUCTION

AWN Consulting Limited has been requested to review the potential noise impact of new mechanical plant items located on the flat roof above the Francis Bacon Gallery, which lies to the rear (north) of the existing 1930's wing. The plant is required to provide environmental control to the 1930's wing and Frances Bacon suite of Galleries.

The development will involve removal and replacement of AHU plant items and the addition of a chiller unit and additional AHU's to the roof of the Frances Bacon Gallery.

The roof area under consideration is situated in close proximity to residential dwellings along Frederick Street to the north and Bethesda Place to the west. The following has been undertaken to determine the potential impact of the proposed development on the adjacent noise sensitive buildings:

- A baseline noise survey has been undertaken to characterise the prevailing noise environment representative of the nearest noise sensitive locations;
- A review of the relevant standards and guidelines has been undertaken to set appropriate noise levels;
- Operational plant noise levels have been calculated at the nearest noise sensitive locations;
- Calculated noise levels have been compared against the adopted criteria and noise control measures have been incorporated, where necessary to reduce operational noise levels.

This technical note provides a summary of the noise assessment undertaken.

2.0 ASSESSMENT CRITERIA

In the absence of statutory documents for control of environmental noise from fixed plant items, reference is made to the typical conditions that would be applied by DCC to the development of this nature:

> *"Noise levels from the proposed development should not be so loud, so continuous, so repeated, of such duration or pitch or occurring at such times as to give reasonable cause for annoyance to a person in any premises in the neighbourhood or to a person lawfully using any public space. In particular the rated noise levels from the proposed development shall not constitute reasonable grounds for complaint as provided for in B.S. 4142. Method for rating industrial noise affecting mixed residential and industrial area.*
>
> *Reason: In order to ensure a satisfactory standard of development, in the interests of residential amenity."*

Guidance from DCC on noise emissions from mechanical plant items makes reference to the British Standard BS 4142: 2014: *Methods for Rating and Assessing Industrial and Commercial Sound*. This document is the industry standard method for analysing building services plant noise emissions to residential receptors and is the document used by DCC in their standard planning conditions and also in complaint investigations.

BS 4142 describes methods for rating and assessing sound of an industrial and/or commercial nature. The methods described in this British Standard use outdoor sound levels to assess the likely effects of sound on people who might be inside or outside a dwelling or premises used for residential purposes upon which sound is incident.

For an appropriate BS 4142 assessment it is necessary to compare the measured external background noise level (i.e. the $L_{A90,T}$ level measured in the absence of plant items) to the rating level ($L_{Ar,T}$) of the various plant items, when operational. Where noise emissions are found to be tonal, impulsive in nature or irregular enough to attract attention, BS 4142 also advises that a penalty be applied to the specific level to arrive at the rating level.

The subjective method for applying a penalty for tonal noise characteristics outlined in BS 4142 recommends the application of a 2dB penalty for a tone which is just perceptible at the noise receptor, 4dB where it is clearly perceptible, and 6dB where it is highly perceptible.

The following definitions as discussed in BS 4142 as summarised below:

"ambient noise level, $L_{Aeq,T}$"	is the noise level produced by all sources including the sources of concern, i.e. the residual noise level plus the specific noise of mechanical plant, in terms of the equivalent continuous A-weighted sound pressure level over the reference time interval [T].
"residual noise level, $L_{Aeq,T}$"	is the noise level produced by all sources excluding the sources of concern, in terms of the equivalent continuous A-weighted sound pressure level over the reference time interval [T].
"specific noise level, $L_{Aeq,T}$"	is the sound level associated with the sources of concern, i.e. noise emissions solely from the

	mechanical plant, in terms of the equivalent continuous A-weighted sound pressure level over the reference time interval [T].
"rating level, $L_{Ar,T}$"	is the specific sound level plus any adjustments for the characteristic features of the sound (e.g. tonal, impulsive or irregular components);
"background noise level, $L_{A90,T}$"	is the sound pressure level of the residual noise that is exceeded for 90% of the time period T.

If the rated plant noise level is +10dB or more above the pre-existing background noise level then this indicates that complaints are likely to occur and that there will be a significant adverse impact. A difference of around +5dB is likely to be an indication of an adverse impact, depending on the context.

The lower the rating level is relative to the measured background sound level, the less likely it is that the specific sound source will have an adverse impact or a significant adverse impact. Where the rating level does not exceed the background sound level, this is an indication of the specific sound source having a low impact.

Additional guidance on recommended internal noise levels for dwellings is contained within BS 8233:2014 *Guidance on Sound Insulation and Noise Reduction for Buildings*. This British Standard sets out recommended noise limits for indoor ambient noise levels in dwellings as presented in Table 2.

Typical situations	Design Range, $L_{Aeq,T}$ dB	
	Daytime $L_{Aeq,16hr}$ (07:00 to 23:00hrs)	Night-time $L_{Aeq,\ 8hr}$ (23:00 to 07:00hrs)
Living / Dining Rooms	35 - 40	n/a
Bedrooms	35	30

Table 1 Recommended Indoor Ambient Noise Levels from BS 8233:2014

In order to determine an external noise level based on the internal criteria noted in Table 1 above, a correction factor across a partially open window of 15dB is typical. The following external noise levels would, therefore, achieve the internal noise levels noted in Table 1 above.

- Daytime / Evening (07:00 to 23:00 hours) 50 - 55dB $L_{Aeq,1hr}$
- Night-time (23:00 to 07:00 hours) 45dB $L_{Aeq,15min}$

The absolute noise levels referred to above are a useful guide to assessing the overall potential noise impact in addition to the relative change assessment used in BS 4142. The overall noise impact from the plant area will therefore be assessed taking account of both standards.

3.0 BASELINE NOISE ENVIRONMENT

An unattended logging monitor was installed on the roof close to where the new plant area is proposed and directly opposite the nearest residents along Bethesda Place. Figure 1 below indicates the monitoring location, the nearest noise sensitive receivers indicated in orange, and the approximate proposed plant area indicated in red. The survey was carried out between the 21 March and 25 March 2019.

The noise survey was conducted in general accordance with ISO 1996-2: 2017: *Acoustics – Description, measurement and assessment of environmental noise Part 2: Determination of sound pressure levels.*

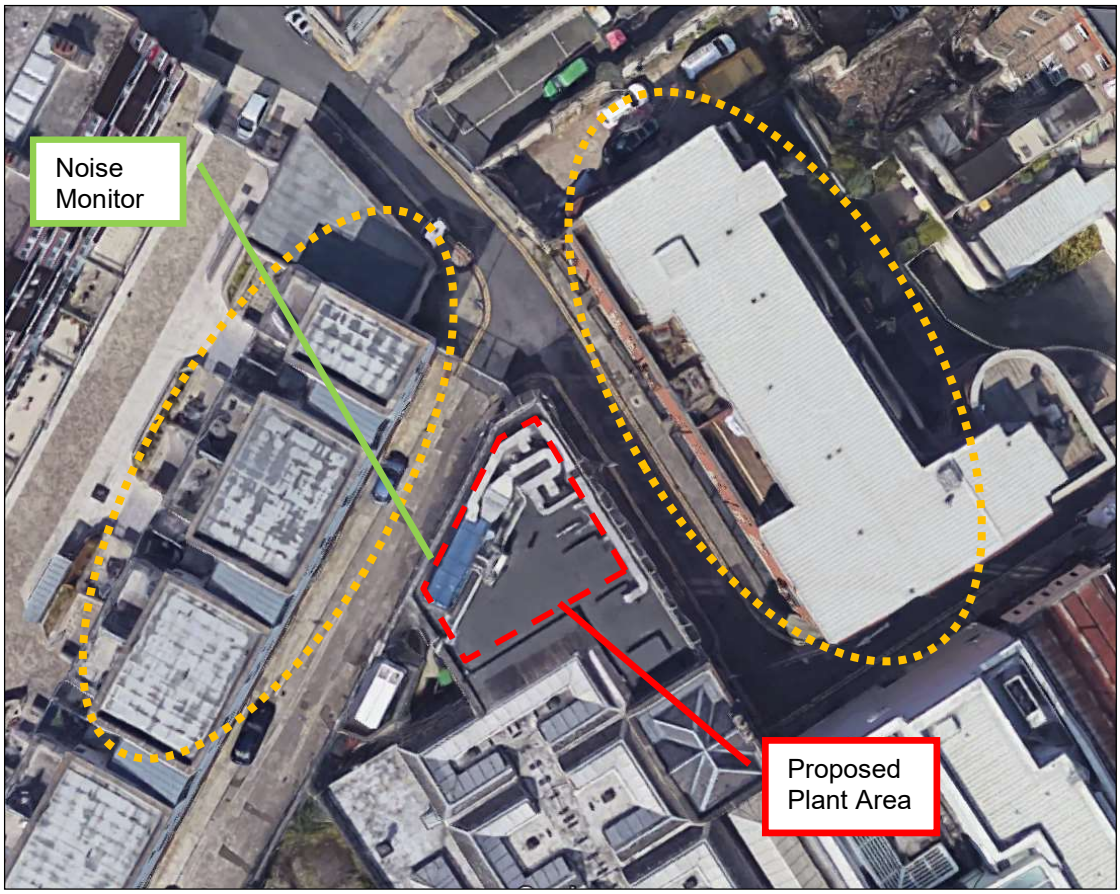

Figure 1 Site Location and Context

The main sources of noise noted in the vicinity of the monitoring position was from existing plant items serving the Hugh Lane Gallery and traffic on the surrounding local road network.

3.1 Survey Results

Following analysis of the baseline noise monitoring data the average noise levels surrounding the site have been determined. For the assessment of plant noise, the most important parameter is the L_{A90} which represents the steady background noise.

Table 1 presents the measured average ambient and background noise levels for daytime (07:00 – 19:00hrs), evening (19:00 – 23:00hrs) and night-time (23:00 – 07:00hrs)

Date	Period	Measured Noise Levels (dB re. $2x10^{-5}$ Pa)	
		L_{Aeq}	L_{A90}
21st March 2019	Day	53	58
	Evening	59	58
22nd March 2019	Day	59	59
	Evening	61	58
	Night	59	58
23rd March 2019	Day	59	58
	Evening	59	58
	Night	59	58
24th March 2019	Day	60	59
	Evening	59	58
	Night	59	58
25th March 2019	Day	59	58
	Night	59	58
Average	Day	59	58
	Evening	58	58
	Night	59	58

Table 2 Summary of Measured Baseline Noise Levels

Noise levels throughout the survey period were steady over day, evening and night time period. As can be seen in the table above the ambient and background noise levels are almost identical indicating that measured noise levels are dominated by a continuous non-varying source, i.e. the AHU on this roof. This was also observed while the monitor was being installed and collected on site.

The average ambient noise level was 59dB $L_{Aeq,1hr}$ for both the day and night time period which relates to the boundary of the plant area, opposite the residential apartments. The average background noise level was 58dB $L_{Aeq,1hr}$ for both the day and night time period.

Correcting for distance attenuation, the calculated noise level at the nearest noise sensitive properties along Bethesda Place based on the data captured in the baseline noise survey is 44 to 45dB L_{A90} which remains constant over day and night-time periods.

4.0 PREDICTED IMPACT FROM PROPOSED BUILDING SERVICES

4.1 Plant Items and Layout

4.1.1 Site Layout

Figure 2 illustrates the preliminary roof plant layout for the development that has been adopted for the assessment.

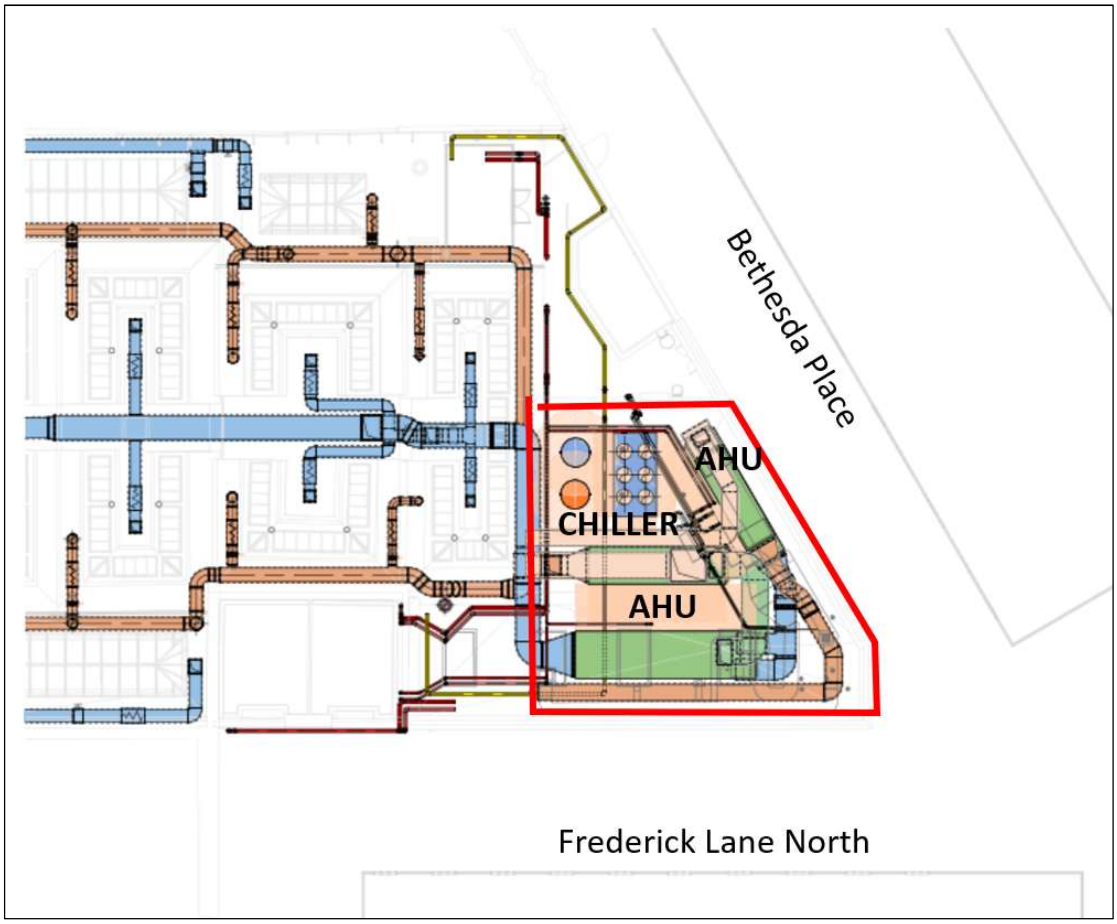

Figure 2 Roof Plant Layout and Context

4.1.2. Source Data

Table 3 lists the rooftop plant items required to serve the new development and the associated overall sound power noise level from each item.

Item	Description	Sound Power Level dB(A)
Chiller Unit	Heating Mode Operation	91
	Cooling Mode Operation	85
AHU – 01	AHU Supply	68
	AHU extract	62
AHU - 02	AHU Supply	61
	AHU extract	56

Table 3 Summary of Plant Noise Levels

The existing AHU along the west of the roof area along Bethesda Place will be removed and replaced with the AHU's listed above. As the existing AHU was the dominant contributor to prevailing background noise levels along this boundary, once this is

removed and replaced, there are no expected cumulative noise impacts from existing and proposed plant items.

Using the data from Table 3 that has been provided by the design team and manufacturers technical datasheets, calculations have been applied in line with appropriate guidance to predict the noise level of the proposed mechanical plant at the façade of the nearest NSL's.

For the purposes of this assessment we have assumed that all plant items are operational simultaneously, at full load and on a 24/7 basis.

4.1.3 Plant Screening

The base model has included the provision of a solid screen to the perimeter of the roof plant area at a height of 4.4m above the roof level. The screen is located around the north, west and south of the roof plant area. The screen will be lined on the internal plant side with an absorbent facing to reduce reverberant noise build up in this space.

4.1.4 Noise Model

A 3D computer-based prediction model has been prepared in order to quantify the noise level associated with the proposed plant items in accordance with *ISO 9613: Acoustics – Attenuation of sound during propagation outdoors, Part 2: General method of calculation, 1996*. Details of the model development area included in Appendix A.

Noise levels have been calculated at the apartments to the north along Frederick Street (R1 – R4) at heights of first to third floor level and along Bethesda Place (R5 – R11) at heights of first and second floor level representative of the most exposed windows of the apartment buildings.

Figure 3 illustrates the noise assessment locations.

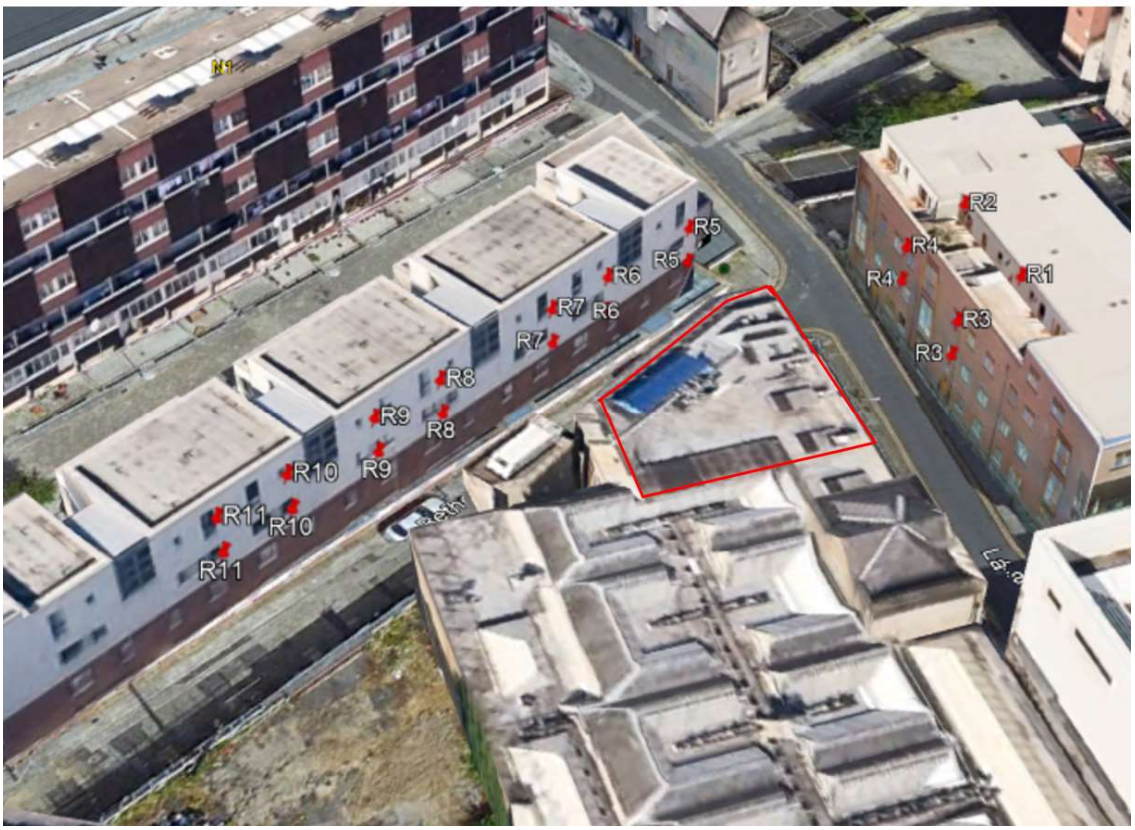

Figure 3 Noise assessment Locations

Operational Scenario - Chiller Unit Heating Mode

Table 4 details the highest calculated noise level at each NSL representative of the upper floors of the apartment buildings. The calculations assume the AHU's are operating at full load and the Chiller unit in heating mode. The relevant assessment level in accordance with the methodology outlined in BS4142:2014 is also included through comparison against the background noise level.

Reference	Location	Background Level (dB L_{A90})	Rating Noise Level from New Plant dB $L_{Ar,T}$	BS 4142 Assessment Level, dB	BS 4142 Potential Impact
R1	Frederick St	44 - 45	52	+7 - 8	Adverse - high
R2	Frederick St		52	+7 -8	Adverse – high
R3	Frederick St		48	+3 - 4	Adverse - moderate
R4	Frederick St		48	+3 - 4	Adverse - moderate
R5	Bethesda Place		50	+5 - 6	Adverse – moderate
R6	Bethesda Place		52	+7 - 8	Adverse – high
R7	Bethesda Place		51	+6 - 7	Adverse – high
R8	Bethesda Place		48	+3- 4	Adverse - moderate
R9	Bethesda Place		46	+1 - 2	Adverse - low
R10	Bethesda Place		44	0	Low
R11	Bethesda Place		43	-1	Low

Table 4 Summary of Predicted Noise Levels and BS4142 assessment level

The assessment has been conducted in accordance with BS4142:2014 under a scenario where the chiller is operating in 'heating mode' the predicted noise from mechanical plant at the nearest noise sensitive locations would result in a low to high adverse noise impacts at the upper floors of residential apartments along Frederick Street and at apartments along Bethesda Place, directly opposite the chiller unit. A low noise impact is calculated at apartments south west of the plant area along Bethesda Place.

Operational Scenario - Chiller Unit Cooling Mode

Table 5 details the highest calculated noise level at each NSL representative of the upper floors of the apartment buildings. The calculations assume the AHU's are operating at full load and the Chiller unit in cooling mode. The relevant assessment level in accordance with the methodology outlined in BS4142:2014 is also included.

Reference	Location	Background Level (dB L_{A90})	Rating Noise Level from New Plant dB $L_{Ar,T}$	BS 4142 Assessment Level, dB	BS 4142 Potential Impact
R1	Frederick St	44 - 45	46	+1 - 2	Adverse - low
R2	Frederick St		46	+1 – 2	Adverse - low
R3	Frederick St		44	-0.2	Low
R4	Frederick St		44	0	Low
R5	Bethesda Place		46	+1 - 2	Adverse - low
R6	Bethesda Place		47	+ 2 - 3	Adverse – low
R7	Bethesda Place		47	+ 2 - 3	Adverse - low
R8	Bethesda Place		43	-1	Low

Reference	Location	Background Level (dB L_{A90})	Rating Noise Level from New Plant dB $L_{Ar,T}$	BS 4142 Assessment Level, dB	BS 4142 Potential Impact
R9	Bethesda Place		42	-2	Low
R10	Bethesda Place		40	-4	Low
R11	Bethesda Place		38	-6	Low

Table 5 Summary of Predicted Noise Levels and BS4142 assessment level

The assessment has concluded that with the chiller operating in 'cooling mode' the predicted noise from mechanical plant at the nearest noise sensitive locations would result in low-adverse noise impact at the upper floors of residential apartments along Frederick Street and at apartments along Bethesda Place, directly opposite the chiller unit. A low noise impact is calculated at apartments south west of the plant area.

Assessment Summary

The results of the assessment had determined that with a 4.4m solid screen to the perimeter of the roof plant area, operational noise levels have the potential to generate an adverse noise impact when the chiller is operating under heating mode conditions at full load. The overall range of noise levels calculated at the nearest apartment facades are 43 to 52dB L_{Aeq} under this scenario.

During daytime periods, an operational noise level of up to 52dB L_{Aeq} would result in an increase to the background noise environment. An external noise level of this magnitude is, however, within the design range of absolute noise levels for daytime periods of 50 to 55dB L_{Aeq} in order to achieve acceptable internal noise level within living spaces and bedrooms in accordance with BS 8233 2014.

During night-time periods, with the chiller unit in heating mode, the calculated noise level of up to 52dB L_{Aeq} would result in an increase to the background noise environment, and would not achieve acceptable night-time internal noise level within bedrooms at the nearest noise sensitive buildings.

With the chiller in cooling mode, the calculated noise levels are considered to be acceptable during daytime periods, but have the potential to generate a low-adverse noise impact at properties directly opposite the chiller unit during night-time periods. The overall noise level just exceeds the recommended absolute noise level of 45dB L_{Aeq} at the most exposed properties.

It is important to note, the noise levels calculated are considered a worst case analysis, assuming all plant items are operating at full load, particularly during night-time periods. In reality, the pumps serving the chiller units are not expected to require full loading during night-time periods under either heating or cooling mode and will therefore result in lower noise emissions. The specific operational noise level for part load conditions is not available for the units assessed, therefore the conservative assessment assuming full load has been included only.

5.0 MITIGATION MEASURES

As noted in Section 4, noise mitigation measures over and above the inclusion of a solid perimeter to the plant area boundary are required to reduce operational noise levels, particularly during night-time periods. Consideration of further noise mitigation measures are therefore required to the plant area to achieve acceptable operational noise levels.

The options for mitigation measures to reduce operational plant noise will require further noise control at source from the chiller unit to achieve acceptable noise levels.

The system will therefore be designed such that the following maximum operational noise levels will not be exceeded at the nearest noise sensitive locations:

- The maximum noise level during daytime periods will be limited to 50dB L_{Aeq} at the façade of the nearest noise sensitive location to the roof plant area;
- The maximum noise level during night-time periods will be limited to 45dB L_{Aeq} at the façade of the nearest noise sensitive location to the roof plant area.

Achievement of these operational noise limits will include one of the following mitigation measures:

- Selection of chiller unit with lower operational noise levels, up to 7dB quieter during heating mode and up to 2dB quieter during cooling mode, or;
- Installation of noise attenuation to chiller fans to achieve an overall noise level reduction of 7dB, or;
- Operation of chiller unit at half load during night-time periods such that operational noise levels from this unit achieve 45dB L_{Aeq} at the nearest NSL under this scenario, or;
- In the event that the operational noise levels from the chiller unit cannot be further attenuated to achieve the noise level reductions set out above, the system will revert to gas boiler heating during night-time hours which will remove the requirement for the chiller unit to operate during these hours.

It is acknowledged that the selection of the specific plant items and their final location is subject to change during the detailed design stage. However, noise from any new plant items should be designed and/or controlled so as not to give rise to adverse noise impacts at the nearest noise sensitive locations.

Furthermore, it is confirmed that any new plant items will not emit significant tonal or impulsive characteristics which may increase the potential for annoyance at the nearest noise sensitive locations. Note that the new plant should be selected to avoid tonal or impulsive sources and therefore no rating penalties have been applied.

6.0 CONCLUSION

A preliminary review of plant noise emissions has been carried out for the proposed development to assess the potential noise impact and the requirement for noise mitigation measures.

The calculated noise levels have been assessed against the relevant noise criteria within BS4142 and BS 8233 in order to ensure noise impact are controlled to avoid significant adverse noise impacts and to not give rise to reasonable grounds for complaint as provided for in BS 4142.

The assessment has been based on review of the information that has been provided to date for plant layout, plant screening and noise emission data. The findings indicate that once operational noise levels from plant noise emissions are controlled to the absolute noise limits in Section 5, the noise impact will be acceptable.

Mitigation measures to the plant area will include the 4.4m high perimeter screen to plant area and reduced noise emissions from the chiller unit through either selection of quieter plant, attenuation to chiller fans or restricting operational modes at night. The specifics of the final options will be determined during the detail design stage of the plant area.

APPENDIX A

NOISE MODEL INFORMATION

Noise Model

A 3D computer-based prediction model has been prepared in order to quantify the noise level associated with the proposed plant area This section discusses the methodology behind the noise modelling process.

Brüel & Kjær Type 7810 Predictor

Proprietary noise calculation software has been used for the purposes of this modelling exercise. The selected software, *Predictor,* calculates noise levels in accordance with *ISO 9613: Acoustics – Attenuation of sound during propagation outdoors, Part 2: General method of calculation, 1996*.

Predictor is a proprietary noise calculation package for computing noise levels in the vicinity of noise sources. The model calculates noise levels in different ways depending on the selected prediction standard. In general, however, the resultant noise level is calculated taking into account a range of factors affecting the propagation of sound, including:

- the magnitude of the noise source in terms of A weighted sound power levels (L_{WA});
- the distance between the source and receiver;
- the presence of obstacles such as screens or barriers in the propagation path;
- the presence of reflecting surfaces;
- the hardness of the ground between the source and receiver;
- Attenuation due to atmospheric absorption; and
- Meteorological effects such as wind gradient, temperature gradient and humidity (these have significant impact at distances greater than approximately 400m).

Brief Description of ISO9613-2: 1996

ISO9613-2:1996 calculates the noise level based on each of the factors discussed previously. However, the effect of meteorological conditions is significantly simplified by calculating the average downwind sound pressure level

The basic formula for calculating $L_{AT}(DW)$ from any point source at any receiver location is given by:

$$L_{fT}(DW) = LW + Dc - A \qquad \textbf{Eqn. A}$$

Where:
$L_{fT}(DW)$ is an octave band centre frequency component of $L_{AT}(DW)$ in dB relative to $2x10^{-5}$Pa;
L_W is the octave band sound power of the point source;
D_c is the directivity correction for the point source;
A is the octave band attenuation that occurs during propagation, namely attenuation due to geometric divergence, atmospheric absorption, ground effect, barriers and miscellaneous other effects.

The estimated accuracy associated with this methodology is shown in Table A1 below:

Height, h*	Distance, d†	
	0 < d < 100m	100m < d < 1,000m
0<h<5m	±3dB	±3dB
5m<h<30m	±1dB	±3dB

Table A1 Estimated Accuracy for Broadband Noise of L_{AT}(DW)

* h is the mean height of the source and receiver. † d is the mean distance between the source and receiver.
N.B. These estimates have been made from situations where there are no effects due to reflections or attenuation due to screening.

Input Data and Assumptions

The noise model has been constructed using data from various source as follows:

Site Layout The general site layout has been obtained from the drawings forwarded by Shaffrey Architects and plant layout drawings from Arup Consulting Engineers.

Local Area The location of noise sensitive locations has been obtained from a combination of site drawings provided by the design team and reference to Google earth.

Heights The heights of buildings on site have been obtained from site drawings forwarded by the design team

Source Sound Power Data

The following noise source data was used for the key noise emission.

Source	L_{wA} - Octave Band Centre Frequency								dB (A)
	63	125	250	500	1k	2k	4k	8k	
Chiller Unit – cooling mode	99	82	79	76	72	63	57	99	85
Chiller Unit – heating mode	102	89	86	85	79	71.5	65	102	91
AHU 01 - Extract	64	71	64	61	51	53	47	34	62
AHU 01 - Supply	73	78	71	66	56	56	50	41	68
AHU 02 - Extract	74	68	55	51	46	42	39	31	56
AHU 02 - Supply	61	64	59	55	58	53	48	40	61

Table A.2 L_{wA} levels Utilised in Noise Model

Modelling Calculation Parameters

Prediction calculations for plant noise have been conducted in accordance with *ISO 9613: Acoustics – Attenuation of sound during propagation outdoors, Part 2: General method of calculation, 1996*.

Ground attenuation factors of 0 have been assumed for hard ground. No metrological corrections were assumed for the calculations. The atmospheric attenuation outlined in Table A.3 has been assumed for all calculations.

Temp (ºC)	% Humidity	Octave Band Centre Frequencies (Hz)							
		63	125	250	500	1k	2k	4k	8k
10	70	0.12	0.41	1.04	1.92	3.66	9.70	33.06	118.4

Table A.3 Atmospheric Attenuation Assumed for Noise Calculations (dB per km)