1 Sound Level or Noise Level

The terms 'sound' and 'noise' are almost interchangeable, except that in common usage 'noise' is often used to refer to unwanted sound.

Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or Lp are commonly used to represent Sound Pressure Level. The symbol Lp represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Level. The symbol LA represents A-weighted Sound Pressure Level. The symbol LSW or LW, or the reference unit 10^{-12} W.

2 ‘A’ Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an ‘A-weighting’ filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing.

People’s hearing is most sensitive to sounds at mid frequencies (500 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dBA or 2 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness. The table below lists examples of typical noise levels.

<table>
<thead>
<tr>
<th>Sound Pressure Level (dBA)</th>
<th>Typical Source</th>
<th>Subjective Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>130</td>
<td>Threshold of pain</td>
<td>Intolerable</td>
</tr>
<tr>
<td>120</td>
<td>Heavy rock concert</td>
<td>Extremely noisy</td>
</tr>
<tr>
<td>110</td>
<td>Grind on steel</td>
<td>Very noisy</td>
</tr>
<tr>
<td>100</td>
<td>Loud car horn at 3 m</td>
<td>Very noisy</td>
</tr>
<tr>
<td>90</td>
<td>Construction site with pneumatic hammering</td>
<td>Loud</td>
</tr>
<tr>
<td>80</td>
<td>Kerbside of busy street</td>
<td>Loud</td>
</tr>
<tr>
<td>70</td>
<td>Loud radio or television</td>
<td>Moderate to quiet</td>
</tr>
<tr>
<td>60</td>
<td>Department store</td>
<td>Quiet to very quiet</td>
</tr>
<tr>
<td>50</td>
<td>General Office</td>
<td>Very quiet</td>
</tr>
<tr>
<td>40</td>
<td>Inside private office</td>
<td>Quiet to very quiet</td>
</tr>
<tr>
<td>30</td>
<td>Inside bedroom</td>
<td>Almost silent</td>
</tr>
<tr>
<td>20</td>
<td>Recording studio</td>
<td>Almost silent</td>
</tr>
</tbody>
</table>

Other weightings (eg B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting are referred to as ‘linear’, and the units are expressed as dB(lin) or dB.

3 Sound Power Level

The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or Lw, or by the reference unit 10^{-15} W.

The relationship between Sound Power and Sound Pressure may be likened to an electric radiator, which is characterised by a power rating, but has an effect on the surrounding environment that can be measured in terms of a different parameter, temperature.

4 Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels LAN, where LAN is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the LA1 is the noise level exceeded for 1% of the time, LA10 the noise exceeded for 10% of the time, and so on.

The following figure presents a hypothetical 15 minute noise survey, illustrating various common statistical indices of interest.

Of particular relevance, are:

- L_{A1} The noise level exceeded for 1% of the 15 minute interval.
- L_{A10} The noise level exceeded for 10% of the 15 minute interval.

This is commonly referred to as the average maximum noise level.

- L_{A90} The noise level exceeded for 90% of the sample period.

This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

- L_{Aeq} The A-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given monitoring location for a particular time of day. A standardised method is available for determining these representative levels.

This method produces a level representing the ‘repeatable minimum’ L_{A10} noise level over the daytime and night-time measurement periods, as required by the EPA. In addition the method produces mean or ‘average’ levels representative of the other descriptors (L_{Aeq}, L_{A10}, etc).

5 Tonality

Tonal noise contains one or more prominent tones (ie distinct frequency components), and is normally regarded as more offensive than ‘broad band’ noise.

6 Impulsiveness

An impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.
7 Frequency Analysis
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.
The units for frequency are Hertz (Hz), which represent the number of cycles per second.
Frequency analysis can be in:
- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)
The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.

8 Vibration
Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of ‘peak’ velocity or ‘rms’ velocity.
The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as ‘peak particle velocity’, or PPV. The latter incorporates ‘root mean squared’ averaging over some defined time period.
Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.
The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V₀), where V₀ is the reference level (10⁻⁵ m/s). Care is required in this regard, as other reference levels may be used by some organizations.

9 Human Perception of Vibration
People are able to ‘feel’ vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual’s perception of motion or response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as ‘normal’ in a car, bus or train is considerably higher than what is perceived as ‘normal’ in a shop, office or dwelling.

10 Over-Pressure
The term ‘over-pressure’ is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

11 Ground-borne Noise, Structure-borne Noise and Regenerated Noise
Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed ‘structure-borne noise’, ‘ground-borne noise’ or ‘regenerated noise’. This noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.
Typical sources of ground-borne or structure-borne noise include tunnelling works, underground railways, excavation plant (eg rockbreakers), and building services plant (eg fans, compressors and generators).
The following figure presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.

The term ‘regenerated noise’ is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect of the discharge grill in the airstream. This secondary noise is referred to as regenerated noise.
## Traffic Data

### No Build

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<th>2018 Night-time</th>
<th>2028 Daytime</th>
<th>2028 Night-time</th>
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## Traffic Data

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<td>7,917</td>
<td>1,183</td>
<td>1,471</td>
<td>230</td>
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</tbody>
</table>
Residential Noise Predictions, No Build
Residential Noise Predictions, Build (Without Mitigation)
Receivers Considered for Additional Noise Mitigation
Noise Barrier Optimisation: NW_NB01

Weighted Points Distribution vs Barrier Height

- Total Weighted Points
- WHO Exceedance Points
- RNP Exceedance Points
- Barrier Area Points
- Maximum Design Height: 5.5 m
- Initial Design Height: 3.5 m
- Optimised Design Height: 3.5 m
- Triggered Receivers

Predicted Noise Level vs Barrier Height

- Most Affected Receiver
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers

Insertion Loss vs Barrier Height

- Most Benefiting Receiver
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers

Insertion Loss of Benefiting Receivers vs Barrier Height

- IL > 2.0 dB
- IL > 5.0 dB
- IL > 10.0 dB

Number of Receivers

- Benefiting Receivers: 38
- Triggered Receivers: 5
- Two Thirds Point: 1.7
- Existing Barrier Height: 0.0 m
- Barrier History: New

Barrier Area Points

- Maximum Design Height: 5.5 m
- Initial Design Height: 3.5 m
- Optimised Design Height: 3.5 m
Noise Barrier Optimisation: NW_NB02

**Predicted Noise Level vs Barrier Height**

- **Total Weighted Points**
- **WHO Exceedance Points**
- **RNP Exceedance Points**
- **Barrier Area Points**
- **Maximum Design Height: 8.0 m**
- **Initial Design Height: 3.0 m**
- **Optimised Design Height: 3.0 m**
- **Triggered Receivers**

**Weighted Points Distribution vs Barrier Height**

- **Benefiting Receivers: 41**
- **Triggered Receivers: 8**
- **Two Thirds Point: 3.3**
- **Existing Barrier Height: 0.0 m**
- **Barrier Length: 366 m**
- **Maximum Design Height: 8.0 m**
- **Initial Design Height: 3.0 m**
- **Optimised Design Height: 3.0 m**

**Insertion Loss vs Barrier Height**

- **Most Benefiting Receiver**
- **90th %ile of Triggered Receivers**
- **66th %ile of Triggered Receivers**
- **90th %ile of All Receivers**
- **66th %ile of All Receivers**
- **Maximum Design Height: 8.0 m**
- **Initial Design Height: 3.0 m**
- **Optimised Design Height: 3.0 m**

**Insertion Loss of Benefiting Receivers vs Barrier Height**

- **IL > 2.0 dB**
- **IL > 5.0 dB**
- **IL > 10.0 dB**
## Noise Barrier Optimisation: NW_NB03a

### Weighted Points Distribution vs Barrier Height
- **Total Weighted Points**: 3500
- **WHO Exceedance Points**: 90th %ile of Triggered Receivers
- **RNP Exceedance Points**: 66th %ile of Triggered Receivers
- **Barrier Area Points**: 90th %ile of All Receivers

### Predicted Noise Level vs Barrier Height
- **Maximum Design Height**: 6.5 m
- **Initial Design Height**: 3.5 m
- **Optimised Design Height**: 5.5 m

### Insertion Loss vs Barrier Height
- **Benefiting Receivers**: 59
- **Triggered Receivers**: 19
- **Two Thirds Point**: 6.3
- **Existing Barrier Height**: 0.0 m
- **Barrier Length**: 270 m

### Insertion Loss of Benefiting Receivers vs Barrier Height
- **90th %ile of Triggered Receivers**: IL > 2.0 dB
- **66th %ile of Triggered Receivers**: IL > 5.0 dB
- **90th %ile of All Receivers**: IL > 10.0 dB
Noise Barrier Optimisation: NW_NB03b

Weighted Points Distribution vs Barrier Height

Predicted Noise Level vs Barrier Height

Insertion Loss vs Barrier Height

Insertion Loss of Benefiting Receivers vs Barrier Height

Most Affected Receiver
90th %ile of Triggered Receivers
66th %ile of Triggered Receivers
90th %ile of All Receivers
66th %ile of All Receivers
Maximum Design Height: 2.5 m
Initial Design Height: 2.0 m
Optimised Design Height: 2.5 m

Benefiting Receivers: 96
Triggered Receivers: 2
Two Thirds Point: 0.7
Existing Barrier Height: 0.0 m
Barrier History: New
Barrier Length: 338 m

WHO Exceedance Points
RNP Exceedance Points
Barrier Area Points
Maximum Design Height: 2.5 m
Initial Design Height: 2.0 m
Optimised Design Height: 2.5 m

IL > 2.0 dB
IL > 5.0 dB
IL > 10.0 dB
Noise Barrier Optimisation: NW_NB04

Weighted Points Distribution vs Barrier Height

- Total Weighted Points
- WHO Exceedance Points
- RNP Exceedance Points
- Barrier Area Points
- Maximum Design Height: 6.0 m
- Initial Design Height: 3.5 m
- Optimised Design Height: 6.0 m
- Triggered Receivers

Predicted Noise Level vs Barrier Height

- Most Affected Receiver
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers
- Maximum Design Height: 6.0 m
- Initial Design Height: 3.5 m
- Optimised Design Height: 6.0 m

Insertion Loss vs Barrier Height

- Most Benefiting Receiver
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers
- Maximum Design Height: 6.0 m
- Initial Design Height: 3.5 m
- Optimised Design Height: 6.0 m

Insertion Loss of Benefiting Receivers vs Barrier Height

- IL > 2.0 dB
- IL > 5.0 dB
- IL > 10.0 dB

Benefiting Receivers: 68
Triggered Receivers: 23
Two Thirds Point: 7.7
Existing Barrier Height: 0.0 m
Barrier History: New
Barrier Length: 350 m
Noise Barrier Optimisation: NW_SB01

**Weighted Points Distribution vs Barrier Height**

- Total Weighted Points
- WHO Exceedance Points
- RNP Exceedance Points
- Barrier Area Points
- Maximum Design Height: 8.0 m
- Initial Design Height: 4.0 m
- Optimised Design Height: 4.0 m
- Triggered Receivers

**Predicted Noise Level vs Barrier Height**

- Most Affected Receiver
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers
- Maximum Design Height: 8.0 m
- Initial Design Height: 4.0 m
- Optimised Design Height: 4.0 m

**Insertion Loss vs Barrier Height**

- Most Benefiting Receiver
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers
- Maximum Design Height: 8.0 m
- Initial Design Height: 4.0 m
- Optimised Design Height: 4.0 m

**Insertion Loss of Benefiting Receivers vs Barrier Height**

- IL > 2.0 dB
- IL > 5.0 dB
- IL > 10.0 dB

**Benefiting Receivers**

- 15 Benefiting Receivers
- 6 Triggered Receivers
- Two Thirds Point: 2.7
- Existing Barrier Height: 0.0 m
- Barrier Length: 152 m

**Maximum Design Height**

- 8.0 m

**Initial Design Height**

- 4.0 m

**Optimised Design Height**

- 4.0 m

**WHO Exceedance Points**

- 90th %ile of Triggered Receivers

**RNP Exceedance Points**

- 66th %ile of Triggered Receivers

**Barrier Area Points**

- 90th %ile of All Receivers

**66th %ile of All Receivers**

- Maximum Design Height: 8.0 m
- Initial Design Height: 4.0 m
- Optimised Design Height: 4.0 m

**12 Benefited Receivers**

- Minimum Design Height: 8.0 m
- Initial Design Height: 4.0 m
- Optimised Design Height: 4.0 m

**200 Benefited Receivers**

- Minimum Design Height: 8.0 m
- Initial Design Height: 4.0 m
- Optimised Design Height: 4.0 m
Noise Barrier Optimisation: NW_SB02a

Weighted Points Distribution vs Barrier Height

Predicted Noise Level vs Barrier Height

Total Weighted Points

WHO Exceedance Points

RNP Exceedance Points

Maximum Design Height: 5.0 m

Triggered Receivers

Initial Design Height: 3.0 m

Optimised Design Height: 4.0 m

WHO Exceedance Points

RNP Exceedance Points

Maximum Design Height: 5.0 m

Optimised Design Height: 4.0 m

8 Initial Design Height: 3.0 m 65 Maximum Design Height: 5.0 m

Optimised Design Height: 4.0 m

Triggered Receivers

Two Thirds Point: 3.0

Existing Barrier Height: 0 m

Barrier History: New

Barrier Length: 192 m

Insertion Loss vs Barrier Height

Insertion Loss of Benefiting Receivers vs Barrier Height

Benefiting Receivers: 18

TrIGGERed Receivers: 9

90th %ile of Triggered Receivers

66th %ile of Triggered Receivers

90th %ile of All Receivers

66th %ile of All Receivers

12 Maximum Design Height: 5.0 m

Initial Design Height: 3.0 m

Optimised Design Height: 4.0 m

IL > 2.0 dB

IL > 5.0 dB

IL > 10.0 dB
Noise Barrier Optimisation: NW_SB02b

Weighted Points Distribution vs Barrier Height

- Total Weighted Points
- WHO Exceedance Points
- RNP Exceedance Points
- Barrier Area Points
- Maximum Design Height: 7.0 m
- Initial Design Height: 6.0 m
- Optimised Design Height: 7.0 m

Predicted Noise Level vs Barrier Height

- Most Affected Receiver
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers
- Maximum Design Height: 7.0 m
- Initial Design Height: 6.0 m
- Optimised Design Height: 7.0 m

Insertion Loss vs Barrier Height

- Most Benefiting Receiver
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers
- Maximum Design Height: 7.0 m
- Initial Design Height: 6.0 m
- Optimised Design Height: 7.0 m

Insertion Loss of Benefiting Receivers vs Barrier Height

- IL > 2.0 dB
- IL > 5.0 dB
- IL > 10.0 dB
Noise Barrier Optimisation: NW_SB03

**Weighted Points Distribution vs Barrier Height**

- Total Weighted Points
- WHO Exceedance Points
- RNP Exceedance Points
- Barrier Area Points
- Maximum Design Height: 4.5 m
- Initial Design Height: 3.0 m
- Optimised Design Height: 4.5 m
- Triggered Receivers

**Predicted Noise Level vs Barrier Height**

- Most Affected Receiver
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers
- Maximum Design Height: 4.5 m
- Initial Design Height: 3.0 m
- Optimised Design Height: 4.5 m

**Insertion Loss vs Barrier Height**

- Benefiting Receivers: 13
- Triggered Receivers: 6
- Two Thirds Point: 2.0
- Existent Barrier Height: 0.0 m
- Barrier Length: 153 m

**Insertion Loss of Benefiting Receivers vs Barrier Height**

- IL > 2.0 dB
- IL > 5.0 dB
- IL > 10.0 dB

**Number of Receivers**

- 14
- 90th %ile of Triggered Receivers
- 66th %ile of Triggered Receivers
- 90th %ile of All Receivers
- 66th %ile of All Receivers
- Maximum Design Height: 4.5 m
- Initial Design Height: 3.0 m
- Optimised Design Height: 4.5 m

**Noise Barrier Height (m)**

- 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0

- 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0

- 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
Operational Noise Assessment Table
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Note 1: A '*' denotes that the predicted reception is a 1-hour event level.
Note 2: RES = residential, OPW = Other Place of Worship, OED = Other Education, OCC = Other Childcare.
Note 3: Addresses are based on third party data and should be regarded as indicative.
At-Property Treatment Locations, Build (With Mitigation)