Technical Appendix 12.1: Assessment of Energy Storage Facility

A12.1.1 In addition to the wind farm it is also proposed to include energy storage on site. An acoustic assessment in accordance with BS 4142:2014 + A1:2019[1] has been undertaken in order to determine the acoustic impact due to the operation of this part of the Proposed Development.

A12.1.2 The baseline data adopted is that recorded at a wind speed of 1 ms^{-1} during the background sound measurement surveys made to inform the acoustic assessment of operational noise from the proposed wind farm which correspond to the worst case, or quietest, levels.

A12.1.3 The main sources of sound within the Proposed Development are the inverters, transformers and air conditioning for the Energy Storage Systems (ESS). The ESS units are expected to be continuously charging and discharging. If there are any rest periods for the inverters these are likely to be infrequent and the Heating Ventilation and Air Conditioning systems (HVAC) would still be functioning.

A12.1.4 Acoustic emission data for the proposed equipment is detailed in Table 12.1.1. The data corresponds to the maximum acoustic emission for each device as advised by the manufacturer. Predictions based on this data therefore represent the worst case and the sound levels would be expected to be less when the site isn't operating at maximum capacity. The amount of the time that this is the case is unknown at this stage as it depends upon which services the site is used to provide.

Table 12.1.1: Acoustic Emission Data

Equipment	Sound Pressure Level at 1m, dB LAeq
PCS unit (inverter & transformer)	79
ESS unit HVAC	78
Auxiliary transformer	69

A12.1.5 Predicted specific sound levels due to the proposed energy storage facility at nearby residential properties, calculated using the ISO 9613-2 propagation model, are detailed in Table 12.1.2. A sound footprint for the energy storage facility is shown in Figure 12.1.1.

A12.1.6 The propagation model takes account of sound attenuation due to geometric spreading and atmospheric absorption. The assumed temperature and relative humidity are 10 ˚C and 70 % respectively.

A12.1.7 Ground effects are also taken into account by the propagation model, with a ground factor of 0.5 adopted to reflect a mix of hard and porous ground between the site and the assessment locations. A 4 m receiver height has been used. The effect of surface features such as buildings and trees has not been considered. There is a degree of conservatism built into the model as a result of the adoption of these settings.

A12.1.8 ISO 9613-2 is a downwind propagation model. Where conditions less favourable to sound propagation occur, such as when the assessment locations are crosswind or upwind of the proposed energy storage facility, the predicted sound levels would be expected to be less and the downwind predictions presented here would be regarded as conservative.

Table 12.1.2: Predicted Specific Sound Levels

House ID	Sound Pressure Level, dB L_{Aeq}
H1	19
H2	20
H3	20
H4	6
H5	3
H6	1
H7	6
H8	2
H9	4
H10	6
H11	8
H12	8
H13	8
H14	8
H15	8
H16	8
H17	8
H18	8
H19	8
H20	8
H21	8
H22	9
H23	8
H24	8
H25	9
H26	8
H27	9
H28	9

[1] "Methods for rating and assessing industrial and commercial sound", The British Standards Institution 2019

H29	10
H30	10
H31	10
H32	9
H33	9
H34	9
H35	8
H36	8
H37	8
H38	7
H39	7
H40	6
H41	6
H42	6
H43	6
H44	5
H45	6
H46	6
H47	5
H48	5
H49	5
H50	5
H51	3
H52	4
H53	3
H54	-4
H55	-2
H56	-3
H57	-3
H58	-3
H59	-1
H60	-2
H61	-4
H62	-4
H63	-4
H64	-4
H65	-4
H66	-6
H67	-8
H68	-7
H69	-8
H70	-5
H71	-8
H72	-2
H73	-2
H74	-3
H75	-2
H76	-3
H77	-3
H78	1
H79	3
H80	0
H81	1
H82	6
H83	7
H84	3
H85	4
H86	8

A12.1.9 The sound emitted by the inverter cooling fans and HVAC units can have distinctive character. A correction of 2 dB has been applied in the event that tones are just perceptible at the assessment locations. This is a conservative measure as it may not be the case in practice.

A12.1.10 The results of an acoustic assessment at the properties where the predicted sound level is largest relative to the background sound level, H2 & H3, are shown in Table 12.1.3. These results represent the worst case as the rating sound levels would be smaller relative to the background sound level at all other properties.

Table 12.1.3: BS 4142 Assessment Results

Results	Day	Night
Residual sound level	38 dB LAeq, 16 hour	29 dB LAeq, 16 hour
Background sound level	22 dB LA90, 10 min	24 dB LA90, 10 min
Predicted specific sound level	20 dB LAeq	
Acoustic feature correction	2 dB	

Rating sound level	22 dB LAeq	
Excess of rating level over background	0 dB	-2 dB
Predicted ambient sound level	38 dB LAeq, 16 hour	29 dB LAeq, 16 hour
Conclusion	Low impact	Low impact

A12.1.11 The proposed energy storage facility is predicted to have a low impact during both day and night-time periods as the rating sound level is at or below the existing background sound level.

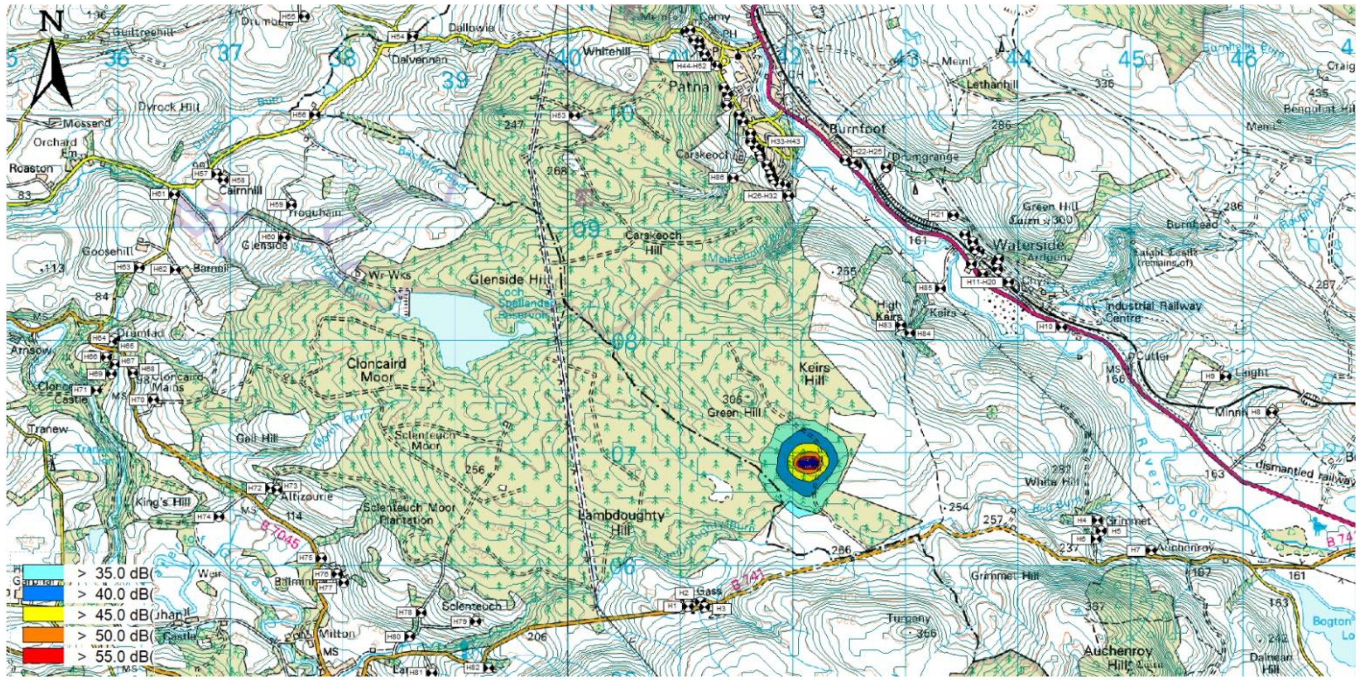
A12.1.12 There is expected to be no change in the ambient sound level during day or night-time periods due to the introduction of the energy storage facility, consistent with it having a low impact.

A12.1.13 The sound levels due to the proposed energy storage facility are predicted to be greater than 10 dB below the wind farm sound levels such that they would be deemed insignificant in comparison i.e. there would be no cumulative impact.

A12.1.14 In conclusion, the acoustic assessment shows that the impact due to the operation of the proposed energy storage facility is predicted to be low during both day and night-time periods such that no adverse impacts would be expected.

A12.1.15 Sound emitted during construction of the energy storage facility, including associated traffic flows, is not predicted to exceed the criteria specified in BS 52281:2009[2] such that significant effects would not be anticipated.

Figure 12.1.1: Predicted Energy Storage Sound Footprint



[2] 'Code of Practice for Noise and vibration control on construction and open sites - Part 1: Noise', British Standards Institution, BS 5228-1:2009

Technical Appendix 12.2: Issues Scoped Out of Wind Farm Noise Assessment

Low Frequency Noise

A12.2.1 The frequency range of 'audible noise' is generally taken to be 20 Hz to 20,000 Hz, with the greatest sensitivity to sound typically in the central 500 Hz to 4,000 Hz region. The range from 10 Hz to 200 Hz is generally used to describe 'low frequency noise', and noise with frequencies below 20 Hz used to describe 'infrasound'[1], although there is sometimes a lack of consistency regarding the definition of these terms in both common usage and the literature.

A12.2.2 Low frequency noise is always present, even in an ambient 'quiet' background[1]. It is generated by natural sources, including the sea, earthquakes, the rumble of thunder and wind. It is additionally an emission from many artificial sources found in modern life, such as household appliances (e.g. washing machines, dishwashers) and all forms of transport.

A12.2.3 Noise emitted from wind turbines covers a broad spectrum from low to high frequencies. In relation to human perception of the broadband noise produced by wind turbines, the dominant frequency range is not the low frequency or infrasonic ranges[2]. The reason for this is that the perception threshold for hearing in these ranges is much higher than for speech frequencies of between 250 Hz and 4000 Hz. As a result of this decreased sensitivity, wind turbine noise at the lowest frequencies of the range described as 'low frequency noise' would be below the average hearing threshold.

A12.2.4 A comprehensive literature review of 'Low Frequency Noise and Infrasound Associated with Wind Turbine Generator Systems', undertaken for the Ontario Ministry for the Environment in 2010, indicated that low frequency noise from wind turbines crosses the threshold boundary, and thus would be considered to become audible, above frequencies of around 40-50 Hz[2]. The degree of audibility depends upon the wind conditions, the degree of masking from background noise sources and the distance from the wind turbines[26].

A12.2.5 Although audible under some conditions, a paper; 'Infrasound and low frequency noise from wind turbines: exposure and health effects'[3], published by the authors of a literature review on the subject prepared for the Swedish Environmental Protection Agency in 2011[4], concludes that the level of low frequency noise produced by wind turbines does not exceed levels from other common sources, such as road traffic noise[3].

[1] 'A Review of Published Research on Low Frequency Noise and Its Effects', Leventhall, Report for DEFRA, May 2003

[2] 'Low Frequency Noise and Infrasound Associated with Wind Turbine Generator Systems, a Literature Review', Ontario Ministry of the Environment, OSS078696, December 2010

[3] 'Infrasound and low frequency noise from wind turbines: exposure and health effects', Bolin et al, Environmental Research Letters Volume 6, September 2011

[4] 'A literature review of infra and low frequency noise from wind turbines: exposure and health effects', prepared for Swedish Environmental Protection Agency, November 2011

A12.2.6 In response to an article published in the national press in 2004, alleging that low frequency noise from wind turbines may give rise to adverse health effects, the Department of Trade and Industry (DTI) commissioned the Hayes McKenzie Partnership to perform an independent study to investigate these claims[5]. The Government released the following advice based on the report's findings[6]:

"The report concluded that there is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines."

A12.2.7 This is re-iterated in the review undertaken for the Ontario Ministry for the Environment, which concludes that publications by medical professionals indicate that; at typical setback distances, the noise levels produced by wind turbines, including noise at low and infrasound frequencies, do not represent a direct health risk.

A12.2.8 The Oregon Health Authority's Public Health Division conducted a strategic Health Impact Assessment in response to a convergence of questions about potential health impacts from wind energy facilities in Oregon. The report, titled 'Strategic Health Impact Assessment on Wind Energy Development in Oregon[7]' states that:

"Some field studies have found that in some locations near wind turbine facilities, low frequency noise (frequencies between 10 and 200 Hz) may be near or at levels that can be heard by humans. However, there is insufficient evidence to determine if low frequency noise from wind turbines is associated with increased annoyance, disturbance or other health effects".

A12.2.9 Whilst low frequency content of the noise from wind farms shall be considered through the use of octave band specific noise emission and propagation modelling within the assessment presented here, it is considered that specific and targeted assessment on low frequency content of noise emissions from the proposed development is not necessary in light of available information and scientific reviews detailed above.

Infrasound

A12.2.10 In relation to infrasound in general, frequencies below 20 Hz may be audible, although tonality is lost below 16 - 18 Hz, thus losing a key element of perception[1]. In relation to modern, upwind turbines; there is strong evidence that the levels of infrasound produced are well below the average threshold of human hearing[2]. The aforementioned DTI report extended this conclusion to more sensitive members of the population[5]:

[5] 'The Measurement of Low Frequency Noise at Three UK Wind Farms', Hayes, Contract Number W/45/00656/00/00, URN 06/1412, 2006. Available at: https://webarchive.nationalarchives.gov.uk/20090609065010/http://www.berr.gov.uk/files/file31270.pdf

[6] 'Advice on findings of the Hayes McKenzie report on noise arising from Wind Farms', DTI, URN 06/2162, November 2006. Available at: https://webarchive.nationalarchives.gov.uk/20090609050816/http://www.berr.gov.uk/files/file35592.pdf

[7] 'Strategic Health Impact Assessment on Wind Energy Development in Oregon', Joshi et al, Oregon Health Authority Public Health Division, March 2013. Available at: https://www.oregon.gov/oha/ph/HealthyEnvironments/TrackingAssessment/HealthImpactAssessment/Documents/Wnd%20Energy%20HIA/Wind%20HIA_Final.pdf

"Even assuming the most sensitive members of the population have a hearing threshold which is 12 dB lower than the median hearing threshold, measured infrasound levels are well below this criterion".

A12.2.11 As such[3]:

"infrasound from wind turbines is not audible at close range and even less so at distances where residents are living".

A12.2.12 In February 2005, the BWEA[8] published background information on low frequency noise from wind farms[9]. The conclusion states that:

"It has been repeatedly shown, by measurements of wind turbine noise undertaken in the UK, Denmark, Germany and the USA over the past decade, and accepted by experienced noise professionals, that the levels of infrasonic noise and vibration radiated from modern upwind configuration wind turbines are at a very low level; so low that they lie below the threshold of perception, even for those people who are particularly sensitive to such noise, and even on an actual wind turbine site".

A12.2.13 The BWEA report goes on to quote Dr Geoff Leventhall, author of the DEFRA report on 'Low Frequency Noise and its Effects', as saying:

"I can state, quite categorically, that there is no significant infrasound from current designs of wind turbines".

A12.2.14 With regard to health effects, the DTI report quotes the document 'Community Noise', prepared for the World Health Organisation (WHO), which states that[5]:

"there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects".

A12.2.15 The DTI report goes on to conclude that:

"infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour".

A12.2.16 Furthermore, researchers at Keele University explain that:

"The infrasound generated by wind turbines can only be detected by the most sensitive equipment, and again this is at levels far below that at which humans will detect the low frequency sound. There is no scientific evidence to suggest that infrasound has an impact on human health." [10]

A12.2.17 In January 2013 the Environment Protection Authority, South Australia, presented their findings of a study into the level of infrasound within typical environments with a particular focus on comparing wind farm environments to urban and rural environments away from wind farms[11]. The report states:

"This study concludes that the level of infrasound at houses near the wind turbines assessed is no greater than that experienced in other urban and rural environments, and is also significantly below the human perception threshold. Also, that the contribution of wind turbines to the measured infrasound levels is insignificant in comparison with the background level of infrasound in the environment."

A12.2.18 The Australian Medical Association[12] in March 2014 issued a position statement which detailed their findings on the health impacts due to the generation of infrasound from wind turbines. The findings concluded that:

"The available Australian and international evidence does not support the view that the infrasound or low frequency sound generated by wind farms, as they are currently regulated in Australia, causes adverse health effects on populations residing in their vicinity. The infrasound and low frequency sound generated by modern wind farms in Australia is well below the level where known health effects occur, and there is no accepted physiological mechanism where sub audible infrasound could cause health effects".

A12.2.19 In April 2015, at the International Conference on Wind Turbine Noise in Glasgow[13], a number of papers were presented on Low Frequency Noise and Infrasound. The findings of the research work undertaken were as follows.

A12.2.20 A paper by Berger et al[14], investigates whether current audible noise-based guidelines for wind turbines account for the protection of human health, given the levels of infrasound and low frequency noise typically produced by wind turbines. New field measurements of indoor infrasound and outdoor low frequency noise at locations between 400m and 900m from the nearest turbine, which were previously underrepresented in the scientific literature, are reported and put into context with existing published work. The findings concluded that:

"The analysis showed that indoor IS (infrasound) levels were below auditory threshold levels while LFN (low frequency noise) levels at distances >500m were similar to background LFN levels. Overall, the available data from this and other studies suggest that health-based audible noise wind turbine siting guidelines provide an effective means to evaluate, monitor, and protect potential receptors from audible noise as well as IS and LFN".

[8] BWEA is now known as RenewableUK, a group representing the concerns of companies in the Renewable Energy Industry

[9] 'Low Frequency Noise and Wind Turbines', The British Wind Energy Association, 2005

[10] 'Wind farm noise', Styles & Toon, printed in the Scotsman newspaper as a rebuttal of claims made by the Renewable Energy Foundation, August 2005

[11] 'Infrasound Levels Near Windfarms and in Other Environments', Environment Protection Authority & Resonate Acoustics, January 2013. Available at: https://www.epa.sa.gov.au/files/477912_infrasound.pdf

[12] "AMA Position - Wind Farms and Health 2014", Australian Medical Association, March 2014

[13] International Conference on Wind Turbine Noise, An INCE Series of International Conferences on Wind Turbine Noise Held Biennially, Wind Turbine Noise 2015, 20th – 23rd April 2015, Glasgow

[14] "Health-based Audible Noise Guidelines Account for Infrasound and Low Frequency Noise Produced by Wind Turbines", Berger et al, Frontiers in Public Health, 24 February 2015

A12.2.21 Research by Hansen et al[15] proposed to examine the effect of infrasound tonal components on perceived low frequency noise annoyance for short exposure durations. The investigated spectra were synthesized based on measured wind turbine noise, which consisted of amplitude modulated tonal components. Listening tests were developed, based on data measured outside a residence, 1.3 km from a wind farm in South Australia. The research concluded that:

"For evaluation times of 5 minutes, it has been shown that for the persons tested, the presence of infrasound at realistic levels does not influence audibility, annoyance or ability to fall asleep."

A12.2.22 Leventhall[16] presented a paper which assesses the scientific basis of the "Plympton-Wyoming bylaw". This is a bylaw which has recently introduced limits on infrasound from wind turbines. The author concludes:

"Science does not support the conditions of the bylaw, which is largely aimed at restricting blade pass tones. There is no evidence that the very low level of blade pass tones affects humans, whilst there is evidence that it does not."

A12.2.23 The work carried out by Tonin et al[17] was an investigation into the effect on the reported pathological symptoms of simulated infrasound produced by wind turbines. The infrasound waveform was generated using a custom-made headphone apparatus. Volunteers were manipulated into states of either high or low expectancy of negative effects from infrasound and their reactions to either infrasound or a sham noise were recorded in a double blind experiment. The findings of the investigation state that:

"It was found, at least for the short-term exposure times conducted here-in, that the simulated infrasound has no statistically significant effect on the symptoms reported by volunteers, however the state of prior concern that volunteers had about the effect of infrasound has a statistically significant influence."

A12.2.24 A study by Walker & Celano[18] considered the subjective effects of wind turbine noise in a controlled environment and how to faithfully generate acoustic signatures produced by actual turbines. Field measurements indicate that theses signatures encompass a wide frequency range, extending from below 1Hz to several kHz. The authors present conceptual descriptions and preliminary demonstrations of an infrasound synthesizer that is capable of producing turbine-faithful signals at least 10 dB greater than experienced in the field. The authors concluded from their research:

"It has been demonstrated that simulation of wind turbine noise and infrasound levels representative of those observed at distances of 100 meters can be accomplished in a typical residential-sized room with a modest array of electro-acoustic actuators. To date, subjective reactions to the synthesized signals are not conclusive due to the small number of test subjects and constrained exposure times. However, no individual thus far has reported any sensation when exposed to infrasound alone at peak levels up to 97dB."

A12.2.25 Therefore, in accordance with literature, it is not considered appropriate or relevant to undertake specific assessment in relation to infrasound for the proposed development.

Sleep Disturbance

A12.2.26 Research evidence supports the conclusion that noise from any source would result in measurable effects on sleep when it reaches a certain level. Such effects may comprise changes in sleep state without those exposed actually awakening, or they may comprise complete awakenings. Either of these responses may or may not have a consequential long-term effect on wellbeing depending on the subjects concerned and the extent of the effects being considered.

A12.2.27 There is no reason why wind turbine noise should be any different to other forms of noise, in that there will be a certain level at which wind turbine noise would impact on the sleep of those exposed to it. As with other forms of noise, some variability in response across the exposed population would be expected, with some people being more noise sensitive and others more noise tolerant.

A12.2.28 While some studies have found an association between wind turbine noise and sleep disturbance, others have not[19]. A selection of these studies is summarised below, followed by an explanation of how the night time noise limit recommended by the ETSUR-97[20] guidelines, used to assess wind farm noise in the UK, was derived and an outline of the latest WHO advice.

A12.2.29 A review undertaken by the Chief Medical Officer of Health of Ontario[21] in response to public health concerns about wind turbine noise concluded that:

"...while some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects..."

15 "Perception and annoyance of low frequency noise versus infrasound in the context of wind turbine noise", Hansen et al, Sixth International Meeting on Wind Turbine Noise, Glasgow, April 2015

16 "On the overlap region between wind turbine infrasound and infrasound from other sources and its relation to criteria", G Leventhall, Sixth International Meeting on Wind Turbine Noise, Glasgow, April 2015

17 "Response to Stimulated Wind Farm Infrasound Including Effect of Expectation", Tonin et al, Sixth International Meeting on Wind Turbine Noise, Glasgow, April 2015

18 "Progress Report on Synthesis of Wind Turbine Noise and Infrasound", Walker & Celano, Sixth International Meeting on Wind Turbine Noise, Glasgow, April 2015

19 'A Review of the Potential Impacts of Wind Farm Noise on Sleep', Micic et al., Acoustics Australia, February 2018

20 'The Assessment and Rating of Noise from Wind Farms', The Working Group on Noise from Wind Turbines, ETSU Report for the DTI, ETSU-R-97, September 1996. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/49869/ETSU_Full_copy__Searchable_.pdf

21 'The Potential Health Impact of Wind Turbines', Chief Medical Officer of Health (CMOH) Report, May 2010. Available at: http://health.gov.on.ca/en/common/ministry/publications/reports/wind_turbine/wind_turbine.pdf

A12.2.30 A report published the Massachusetts Department of Environmental Protection concludes that[22]:

"Evidence regarding wind turbine noise and human health is limited. There is limited evidence of an association between wind turbine noise and both annoyance and sleep disruption, depending on the sound pressure level at the location of concern".

A12.2.31 A study carried out by Health Canada[23] found that self-reported sleep (including general disturbance, use of sleep medication, diagnosed sleep disorders and sleep quality) was not associated with wind turbine noise exposure. Furthermore, when sleep quality was measured objectively, calculated wind turbine noise levels outside the participants' homes were not found to be associated with sleep efficiency, the rate of awakenings, duration of awakenings, total sleep time, or how long it took to fall asleep.

A12.2.32 In contrast to the conclusions of the three studies described above, a report entitled 'Sleep Disturbance and Wind Turbine Noise' by Dr Christopher Hanning reviewed the potential consequences of wind turbine noise and its effect on sleep and health, making recommendations on setback distances[24]. The report was created on behalf of 'Stop Swinford Wind Farm Action Group' (SSWFAG) and states that:

"There can be no doubt, that groups of industrial wind turbines ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby."

A12.2.33 In another article by Dr Hanning and Professor Alun Evans published in the British Medical Journal[25] it states:

"A large body of evidence now exists to suggest that wind turbines disturb sleep and impair health at distances and external noise levels that are permitted in most jurisdictions, including the United Kingdom."

A12.2.34 A criticism of Dr Hanning's work is its focus on recommending a fixed setback distance between wind turbines and residential properties. This generalisation obscures the link between noise level and sleep disturbance in that it does not account for variations in the size of wind farm sites and differences in the noise levels emitted by different turbine types. Care is required when interpreting the findings of studies undertaken in multiple countries as different noise limits would likely apply such that the participants could be exposed to different noise levels. It might also be the case that the relevant noise guidance in a given country has changed over time such that older wind farms were assessed against different standards. Other differences between countries might include the specification of a noise limit that applies at all times or separate limits for day and night time periods. If separate limits for day and night time periods are defined it may be the case that the noise limit for one period effectively restricts the amount of noise that can be emitted during the other period such that the limit for the period where a higher limit is permitted on paper is rarely, if ever, reached in practice.

A12.2.35 UK wind farm noise guidance, ETSUR97, states that different limits should be applied during daytime and night-time periods. The daytime limits are intended to preserve outdoor amenity, while the night-time limits are intended to prevent sleep disturbance. A lower fixed limit of 35-40 dB L_{A90} applies during daytime periods. The night-time lower fixed limit of 43 dB L_{A90} is derived from the 35 dB(A) sleep disturbance criterion referred to in ETSUR97, with an allowance of 10 dB for attenuation through an open window (which is at the conservative end of the 10 – 15 dB range deemed typical) and a correction of 2 dB to allow for the use of L_{A90}, rather than L_{Aeq}.

A12.2.36 The 35 dB(A) sleep disturbance criterion was consistent with WHO advice at the time[26]. The WHO Guidelines for Community Noise[27], published in 1995, reduced the indoor limit to 30 dB L_{Aeq} but translated this into an outdoor limit of 45 dB L_{Aeq} which remained consistent with the recommendations of ETSU-R-97.

A12.2.37 The Night Noise Guidelines for Europe[28], published by the WHO in 2009, recommend target levels for the protection of public health from night time noise. The limits proposed are aspirations and have yet to be adopted by any EU Member State. The Night Noise Guideline (NNG) is an outdoor annualised free field noise level of 40 dB L_{Aeq} during night time periods. An interim target of 55 dB L_{Aeq} is recommended in situations where the NNG is not feasible in the short term. Annual averaging would allow noise levels in excess of 40 dB L_{Aeq} to occur for a certain amount of the time without the NNG being breached. The WHO guidelines are therefore not directly comparable to the noise limits for the Proposed Development derived from ETSUR-97 as these are specified as levels that should not be exceeded. Likewise, the predicted wind farm noise levels shown in the acoustic assessment are not directly comparable to the NNG as they do not represent annual average night time values. The annual average wind farm noise level would depend upon the range of wind speeds and wind directions experienced during night time periods over the year in question.

A12.2.38 The Environmental Noise Guidelines for the European Region[29], published by the WHO in 2018, are described as complementary to the Night Noise Guidelines and state that:

"No statistically significant evidence was available for sleep disturbance related to exposure from wind turbine noise at night."

A12.2.39 Since ETSU-R-97 accounted for sleep disturbance when setting night time noise limits and continues to be endorsed by planning guidance it is concluded that protection from sleep

[22] 'Wind Turbine Health Impact Study: Report of Independent Expert Panel', Ellenbogen et al, Massachusetts Department of Environmental Protection & Public Health, January 2012. Available at: https://www.mass.gov/doc/wind-turbine-health-impact-study-report-of-independent-expert-panel/download

[23] "Wind Turbine Noise and Health Study: Summary of Results", Health Canada, November 2014. Available at: http://www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php

[24] 'Sleep Disturbance and Wind Turbine Noise', Hanning, on behalf of Stop Swinford Wind Farm Action Group (SSWFAG), June 2009

[25] 'Wind Turbine Noise', Hanning et al, British Medical Journal, March 2012

[26] 'WHO Environmental Health Criteria 12 – Noise', World Health Organisation, 1980. Available at: https://apps.who.int/iris/handle/10665/39458

[27] 'WHO Guidelines for Community Noise', World Health Organisation, 1999. Available at: https://apps.who.int/iris/handle/10665/66217

[28] 'Night Noise Guidelines for Europe', World Health Organisation, 2009. Available at: https://www.euro.who.int/en/health-topics/environment-and-health/noise/publications/2009/night-noise-guidelines-for-europe

[29] 'Environmental Noise Guidelines for the European Region, World Health Organisation, 2018. Available at: https://www.euro.who.int/en/health-topics/environment-and-health/noise/environmental-noise-guidelines-for-the-european-region

disturbance is considered within the acoustic impact assessment of the proposed development.

Vibration

A12.2.40 Structure borne noise, originating in vibration, is also low frequency, as is neighbour noise heard through a wall, since walls generally block higher frequencies more than lower frequencies.

A12.2.41 In 2004/2005, researchers at Keele University investigated the effects of the extremely low levels of vibration resulting from wind farms on the operation of the seismic array at Eskdalemuir, one of the most sensitive installations in the world[10]. The results of this study have frequently been misinterpreted and, to clarify the position, the authors have explained that:

"*The levels of vibration from wind turbines are so small that only the most sophisticated instrumentation and data processing can reveal their presence, and they are almost impossible to detect.*"

A12.2.42 They go on to say:

"*Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise - they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of humans sensing the vibration and absolutely no risk to human health.*"

A12.2.43 The Ministry of Defence's approach to safeguarding the Eskdalemuir seismic array is to allocate a budget in terms of the cumulative level of seismic vibration from wind turbines. This restricts the number of wind farms that can be located within a certain distance of the Eskdalemuir seismic array (EKA) without adversely impacting upon its operation. In June 2014, a report was prepared by Xi Engineering Consultants with the full cooperation and significant input from the Ministry of Defence[30]. The report builds on initial Phase 0 work which identified that the current budget over estimates the seismic vibration produced by wind turbines and that there is a likelihood of significant prospective head room that would allow the building of wind farms without breaching the 0.336 nm threshold. The goal of the research was to produce an algorithm that could better predict the amplitude of seismic vibrations produced by wind turbines in the 0.5 to 0.8 Hz passband, which might allow the exploitation of wind resource in the Southern Uplands while maintaining protection of the detection capabilities of EKA. The work of the research allows for the determination of how close to EKA wind turbines can be built while optimising the generating capacity within the consultation zone. The application of a physics based algorithm allowed for the calculation of cumulative seismic vibration at EKA. From these calculations they were able to predict that:

"*The cumulative amplitude of all turbines currently allocated budget and currently subject to objection with a utilisation factor of unity and minimum hub height of 40 m is 0.193833 nm.*"

A12.2.44 This value falls well below the 0.336 nm threshold as set by the MOD.

A12.2.45 A scientific advisory panel comprising independent experts in acoustics, audiology, medicine and public health conducted a comprehensive review of the available literature on the issue of perceived health effects of wind turbines, titled 'Wind Turbine Sound and Health Effects - An Expert Panel Review', and prepared a report for the American and Canadian Wind Energy Associations in December 2009[31]. The authors explain that:

"*Vibration of the body by sound at one of its resonant frequencies occurs only at very high sound levels and is not a factor in the perception of wind turbine noise*".

A12.2.46 The authors further state that:

"*Airborne sound can cause detectable body vibration, but this occurs only at very high levels — usually above sound pressure levels of 100 dB. There is no scientific evidence to suggest that modern wind turbines cause perceptible vibration in homes or that there is an associated health risk*".

A12.2.47 Therefore, in accordance with relevant literature and evidential reviews, it is not considered appropriate or relevant to undertake specific assessment in relation to vibration caused by the operation of the proposed development.

Aerodynamic Modulation

A12.2.48 A noise sometimes associated with wind turbines and commonly referred to as 'blade swish' is the modulation of aerodynamic noise produced at blade passing frequency (the frequency at which a blade passes a fixed point). This noise character is acknowledged by, and accounted for, in the recommendations of ETSU-R-97[20]. However the aforementioned DTI report[5] noted that 'Aerodynamic Modulation', alternatively referred to as 'Amplitude Modulation' (AM) was, in some isolated circumstances, occurring in ways not anticipated by ETSU-R-97. AM above and beyond that considered by ETSU-R-97 is often referred to as Excess, or Other, Amplitude Modulation (EAM/OAM).

A12.2.49 In December 2013, the wind industry trade association, RenewableUK, published detailed new scientific research[32] into causes and effects of wind turbine AM. The work was carried out by a group of independent experts, including academics from the Universities of Salford

[30] "Seismic vibration produced by wind turbines in the Eskdalemuir region. Release 2.0 of Substantial Research project" prepared by Xi Engineering Consultants Ltd, Document Number FMB_203_FINAL_V5R, 15th June 2014

[31] 'Wind Turbine Sound and Health Effects - An Expert Panel Review', W.D. Colby et al, December 2009. Available at: https://canwea.ca/pdf/talkwind/Wind_Turbine_Sound_and_Health_Effects.pdf

[32] 'Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effects', RenewableUK, December 2013. Available at: http://usir.salford.ac.uk/id/eprint/33475/

and Southampton, the National Aerospace Laboratory of the Netherlands, Hoare Lea Acoustics, Robert Davies Associates and DTU Riso in Denmark.

A12.2.50 The Chairman of the IOA Noise Working Group said of the study:

"This research is a significant step forward in understanding what causes amplitude modulation from a wind turbine, and how people react to it."

A12.2.51 The RenewableUK work encouraged further research in the area, which has led to the identification of suitable mitigation methods. At the EWEA Technology Workshop on Wind Turbine Sound in 2014, Hoare Lea Acoustics presented a paper entitled: "Measurements to assess the effectiveness of turbine modifications to reduce the occurrence of AM in the far-field" [33]. The paper concludes that turbine blade modifications can result in significant reductions in AM in the far-field and that similar effects can also be achieved through blade pitch modification.

A12.2.52 The authors state that:

"This shows that effective mitigation of AM on operational turbines is technically feasible."

A12.2.53 The other notable outcome of the RenewableUK research was a proposed planning condition informed by listening tests and work undertaken to determine how AM should be measured. The IOA recommended a period of testing and validation before the condition was adopted such that the work again proved valuable as a catalyst for further research.

A12.2.54 The IOA created a dedicated AM Working Group to undertake the further testing and validation recommended. A discussion document[34] on methods for rating amplitude modulation in wind turbine noise was published in April 2015. The document proposed a definition of AM and provided a literature review of the available metrics before selecting three for detailed discussion. The intention was to obtain feedback from the acoustic community, allowing a preferred rating method to be selected following the consultation period. The final report[35], detailing the recommended metric for the quantification of the level of AM in wind turbine noise, and the reasoning behind it, was published in August 2016.

A12.2.55 A separate, government funded, study was commissioned by the Department of Energy and Climate Change (DECC) with a view to recommending how an appropriate AM threshold should be defined. A report summarising the work[36], undertaken by WSP Parsons Brinkerhoff, was published in August 2016 and proposes an appropriate penalty scheme informed by studies into subjective response to a given level of AM.

A12.2.56 There is therefore a method of quantification of the level of AM over a given 10 minute period and the appropriate penalty to apply where necessary. It should be noted that this is in addition to any penalty for tonal noise.

A12.2.57 There are no standard or agreed methods, however, by which to predict with any certainty, the likelihood of AM occurring at a level requiring a penalty, only some possible indicators such as relatively high wind shear conditions under certain circumstances or particular turbine designs and/or dimensions for example.

A12.2.58 Appropriate elements for a planning condition to control AM were proposed by the acoustic experts undertaking the research. The specific wording for a condition was not within the scope of the research report and it was noted that legal advice would be required to ensure any proposed condition for a particular proposal met the necessary policy guidance tests.

Wind Turbine Syndrome

A12.2.59 The condition proposed by paediatrician Dr Nina Pierpont in her report 'Wind Turbine Syndrome: A Report on a Natural Experiment' cites a range of physical sensations and effects as being caused by living near a wind farm[37]. This study is based on a series of interviews comprising a study group of 10 families. It is a self-published report with none of the research being published in any peer reviewed medical journal.

A12.2.60 In a NHS response to the Pierpont report, a report titled 'Are wind farms a health risk?' states that there is no conclusive evidence that wind turbines have an effect on health or are causing the set of symptoms described as 'wind turbine syndrome'[38]. It was noted that the group study by Pierpont was not sufficient to grant the claims stated.

A12.2.61 The aforementioned report 'Wind Turbine Sound and Health Effects - An Expert Panel Review'[31], prepared by a scientific advisory panel for the American and Canadian Wind Energy Associations, concludes that Wind Turbine Syndrome is:

"*not a recognized medical diagnosis, is essentially reflective of symptoms associated with noise annoyance and is an unnecessary and confusing addition to the vocabulary on noise*".

A12.2.62 The report went on to say:

"There are no unique symptoms or combinations of symptoms that would lead to a specific pattern of this hypothesized disorder."

A12.2.63 An independent review of the state of knowledge about the alleged health condition was carried out[39]. This report includes three expert opinions provided by: Richard J.Q. McNally - Reader in Epidemiology at the Institute of Health and Society Newcastle University; Geoff Leventhall – an independent consultant specialising in low frequency noise, infrasound and vibration; and Mark E. Lutman - Professor of Audiology at the University of Southampton.

[33] 'Measurements to assess the effectiveness of turbine modifications to reduce the occurrence of AM in the far-field', Bullmore & Cand, Hoare Lea Acoustics, EWEA Technology Workshop: Wind Turbine Sound 2014, Malmo, Sweden, December 2014

[34] 'Methods for Rating Amplitude Modulation in Wind Turbine Noise', Institute of Acoustics Amplitude Modulation Working Group, April 2015. Available at https://www.ioa.org.uk/publications/wind-turbine-noise

[35] 'A Method for Rating Amplitude Modulation in Wind Turbine Noise', Institute of Acoustics Amplitude Modulation Working Group, August 2016. Available at https://www.ioa.org.uk/publications/wind-turbine-noise

[36] 'Wind Turbine AM Review', Phase 2 Report, WSP Parsons Brinckerhoff for DECC, August 2016. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/562186/Phase_2_Report_-_Wind_Turbine_AM_Review_Issue_3__FINAL_.pdf

[37] 'Wind Turbine Syndrome - A Report on a Natural Experiment', Pierpont, K-Selected Books, 2009

[38] 'Are wind farms a health risk?', NHS, August 2009. Available at: https://www.nhs.uk/news/lifestyle-and-exercise/are-wind-farms-a-health-risk/

[39] 'Wind Turbine Syndrome (WTS) - An independent review of the state of knowledge about the alleged health condition', RenewableUK, July 2010

Their critique of Pierpont's study concludes that the reported symptoms are the effects mediated by stress and anxiety when exposed to an adverse element in their environment. There is no evidence that they are patho-physiological effects of wind turbine noise.

A12.2.64 A paper by Pedersen explores data from three cross-sectional studies comprising A-weighted sound pressure levels of wind turbine noise, and subjectively measured responses from 1,755 people, to find the relationships between sound levels and aspects of health and well-being[40]. It was concluded that there is no consistent association between wind turbine noise exposure and the symptoms associated with Wind Turbine Syndrome.

A12.2.65 A study conducted by Simon Chapman, Professor of Public Health at Sydney University, provides evidence that noise and health complaints about wind turbines are psychogenic[41]. The authors conclude that:

"*In view of scientific consensus that the evidence for wind turbine noise and infrasound causing health problems is poor, the reported spatio-temporal variations in complaints are consistent with psychogenic hypotheses that health problems arising are communicated diseases with nocebo effects likely to play an important role in the aetiology of complaints*".

A12.2.66 Therefore, in accordance with this literature and the studies detailed above, it is not considered appropriate or relevant to undertake any assessment in relation to Wind Turbine Syndrome in relation to the proposed development.

Wind Turbine Noise and Associated Health Effects Studies

A12.2.67 In 2014 Health Canada released its findings from the "Wind Turbine Noise and Health Study"[23]. Health Canada, in partnership with Statistics Canada, conducted the study between residents of southern Ontario and Prince Edward Island where there were a sufficient number of homes within the vicinity of wind turbine installations. Twelve and six wind turbine developments were sampled in Ontario and PEI, representing 315 and 84 wind turbines, respectively. All potential homes within approximately 600 m of a wind turbine were selected, as well as a random selection of homes between 600 m and 10 km. A total of 1,238 households participated out of a possible 1,570.

A12.2.68 The study was comprised of three parts: an in-person questionnaire given to randomly selected participants living at various distances from wind turbines; a collection of physical health measures that assessed stress levels using hair cortisol, blood pressure and resting heart rate as well as measures of sleep quality; and more than 4,000 hours of wind turbine noise measurements conducted by Health Canada to support calculations of wind turbine noise levels (WTN) in all homes in the study.

[40] 'Health aspects associated with wind turbine noise—results from three field studies' Pedersen, Noise Control Engineering Journal, Volume 59, Issue 1, 2011

[41] 'Spatio-temporal differences in the history of health and noise complaints about Australian wind farms: evidence for the psychogenic, communicated disease hypothesis', Chapman et al, University of Sydney, 2013

A12.2.69 Health Canada broke the findings into five parts: illness and chronic disease, stress, sleep, annoyance and quality of life and noise.

A12.2.70 Under Self-reported Illnesses and Chronic Diseases, Health Canada states:

"*Self-reports of having been diagnosed with a number of health conditions were not found to be associated with exposure to WTN levels. These conditions included, but were not limited to chronic pain, high blood pressure, diabetes, heart disease, dizziness, migraines, ringing, buzzing or whistling sounds in the ear (i.e., tinnitus)*".

A12.2.71 Under the heading of Self-reported Stress, Health Canada states no association was found between the multiple measures of stress (such as hair cortisol, blood pressure, heart rate, self-reported stress) and exposure to wind turbine noise.

"*Self-reported stress, as measured by scores on the Perceived Stress Scale, was not found to be related to exposure to WTN levels*".

A12.2.72 For Self-reported Sleep:

"*Results of self-reported measures of sleep, that relate to aspects including, but not limited to general disturbance, use of sleep medication, diagnosed sleep disorders and scores on the Pittsburgh Sleep Quality Index (PSQI), did not support an association between sleep quality and WTN levels*".

A12.2.73 However, the study states, while some people reported some of the aforementioned health conditions, their existence was not found to change in relation to exposure to wind turbine noise.

A12.2.74 An association was found, however, between increasing levels of wind turbine noise and individuals reporting to be very or extremely annoyed. No association was found with any significant changes in reported quality of life or with overall quality of life and satisfaction with health. This was assessed using the abbreviated version of the World Health Organization's Quality of Life Scale.

"*The overall conclusion to emerge from the study findings is that the study found no evidence of an association between exposure to WTN and the prevalence of self-reported or measured health effects beyond annoyance. Collectively, the findings related to annoyance suggest that health and well-being effects may be partially related to activities that influence community annoyance, over and above exposure to WTN. Therefore, efforts that aim to identify and mitigate high levels of annoyance with wind turbines may have benefits that go beyond annoyance*" [42].

A12.2.75 Lastly, under noise, calculated noise levels were found to be below levels that would be expected to directly affect health, according to the World Health Organization Community Noise Guidelines, 1999.

[42] 'Wind Turbine Noise and Health Study: Summary of Results', Michaud, Sixth International Meeting on Wind Turbine Noise, Glasgow, April 2015

A12.2.76 A review conducted by McCunney et al[43] in November 2014, examines the literature related to health effects of wind turbines. The review was intended to assess the peer-reviewed literature regarding evaluations of potential health effects among people living in the vicinity of wind turbines. It included analysis and commentary of the scientific evidence regarding potential links to health effects, such as stress, annoyance, and sleep disturbance, among others, that have been raised in association with living in proximity to wind turbines. Also addressed were specific components of noise associated with wind turbines such as infrasound and low-frequency sound and their potential health effects.

A12.2.77 The review attempts to address the following questions regarding wind turbines and health:

A12.2.78 Is there sufficient scientific evidence to conclude that wind turbines adversely affect human health? If so, what are the circumstances associated with such effects and how might they be prevented?

A12.2.79 Is there sufficient scientific evidence to conclude that psychological stress, annoyance, and sleep disturbance can occur as a result of living in proximity to wind turbines? Do these effects lead to adverse health effects? If so, what are the circumstances associated with such effects and how might they be prevented?

A12.2.80 Is there evidence to suggest that specific aspects of wind turbine sound such as infrasound and low-frequency sound have unique potential health effects not associated with other sources of environmental noise?

A12.2.81 The co-authors represent professional experience and training in occupational and environmental medicine, acoustics, epidemiology, otolaryngology, psychology, and public health.

A12.2.82 The findings of the review are summarised thus:

- Measurements of low-frequency sound, infrasound, tonal sound emission, and amplitude-modulated sound show that infrasound is emitted by wind turbines. The levels of infrasound at customary distances to homes are typically well below audibility thresholds.
- No cohort or case–control studies were located in this updated review of the peer-reviewed literature. Nevertheless, among the cross-sectional studies of better quality, no clear or consistent association is seen between wind turbine noise and any reported disease or other indicator of harm to human health.
- Components of wind turbine sound, including infrasound and low-frequency sound have not been shown to present unique health risks to people living near wind turbines.
- Annoyance associated with living near wind turbines is a complex phenomenon related to personal factors. Noise from turbines plays a minor role in comparison with other factors in leading people to report annoyance in the context of wind turbines.

A12.2.83 The WHO's Environmental Noise Guidelines[29] conditionally recommend that average exposure to wind turbine noise is limited to 45 dB L_{den} as wind turbine noise above this level is associated with adverse health effects. The recommendation is conditional as evidence of the adverse effects of wind turbine noise was rated as being of low quality. The limit is set at this level as there was deemed to be sufficient, albeit still low quality, evidence that this represented the threshold at which 10 % of people would be expected to be highly annoyed. The risk of other health outcomes at given levels of wind turbine noise could not be assessed due to a lack of evidence.

A12.2.84 The day-evening-night level (L_{den}) is an annual average L_{eq} with a 5 dB penalty applied to noise levels occurring during the evening and a 10 dB penalty applied to noise levels during the night. The WHO limit is not directly comparable to the noise limits for the Proposed Development derived from ETSUR-97 which are specified as L_{90} levels that should not be exceeded. Likewise, the predicted wind farm noise levels shown in the acoustic assessment are not directly comparable to the WHO limit as they do not represent annual average values and do not have the penalties applicable during evening and night time periods applied. The annual average wind farm noise level experienced by nearby residents would depend upon the range of wind speeds and wind directions over the year in question.

A12.2.85 Given the lack of evidence of health effects caused by wind turbine noise, the conditional nature of the WHO guidance and the continued endorsement of ETSU-R-97 by planning policy, no additional assessment of health effects due to the proposed development has been undertaken.

[43] "Wind Turbines and Health: A Critical Review of the Scientific Literature" McCunney et al, Journal of Occupational & Environmental Medicine, November 2014

Technical Appendix 12.3: Calculating Standardised Wind Speed

Introduction

A12.3.1 In order to derive appropriate noise limits the ETSU-R-97 guidance requires the correlation of background noise survey data with wind speed data referenced to 10 m height. In contrast, acoustic emission measurements on wind turbines are undertaken in accordance with international standard IEC 61400-11, 'Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques'[1], which specifies that the turbine noise emission should be reported as a function of 'standardised' wind speed at 10 m height. In practice this involves extrapolating hub height wind speed down to 10 m height using a specified, and fixed, relationship. The resulting 'standardised' 10 m wind speed is essentially a proxy for hub height wind speed which is the primary driver of noise emission from the turbine.

A12.3.2 The use of a fixed relationship between hub height and 10 m wind speed means that potential exists for the background noise data and acoustic emission data to be misaligned i.e. a wind speed measured at 10 m height is not necessarily equivalent to a 'standardised' 10 m wind speed of the same magnitude, with the difference depending upon the site specific shear exponent (the rate of change of wind speed with height).

Methodology

Accounting for Site Specific Shear

A12.3.3 To account for the effects of site-specific shear, the background noise data is referenced to the same wind speed as the acoustic emission data. The approach used is consistent with that recommended in an article published in the Institute of Acoustics Bulletin and the subsequent Good Practice Guide (option b in paragraph 2.6.3).

A12.3.4 To account for site specific wind shear effects in accordance with the aforementioned approach, the standardised 10 m height wind speed is found by:

- Calculating the shear exponent from the wind speed measured at two heights on the mast. Anemometers at 45 m and 75 m are used for the calculation as both are side-mounted on the mast and therefore equally impacted by tower shadow. The lower shear anemometer is greater than 15 m below the upper shear anemometer as recommended by the Good Practice Guide. The following formula is used to determine the shear exponent:

$$\alpha = \frac{\log\left(\frac{v_2}{v_1}\right)}{\log\left(\frac{h_2}{h_1}\right)}$$

Where: v_2 = upper anemometer wind speed

v_1 = lower anemometer wind speed

h_2 = height of upper shear anemometer (75 m)

h_1 = height of lower shear anemometer (45 m)

a = wind shear exponent

- Extrapolating the wind speed measured at the 80 m anemometer to 125 m using the calculated wind shear exponent. The 80 m anemometer is greater than 60 % of the proposed hub height as recommended by the Good Practice Guide. The 125 m wind speed for each 10 minute period may be calculated using this equation:

$$v_{hub} = v_{top}\left(\frac{h_{hub}}{h_{top}}\right)^{\alpha}$$

Where: v_{top} = wind speed measured by top anemometer

v_{hub} = wind speed at proposed hub height

h_{top} = height of top anemometer (80 m)

h_{hub} = maximum proposed hub height (125 m)

a = calculated wind shear exponent

- The corresponding 'standardised' 10 m wind speeds are then calculated from the derived hub height wind speed using the following formula and it is this resultant standardised 10m wind speed that shall be used in correlation with the measured background noise levels:

$$v_S = v_{hh}\left[\frac{ln\,\frac{z_{ref}}{z_0}}{ln\,\frac{hh}{z_0}}\right]$$

Where: v_s is the 'standardised' wind speed

v_{hh} is the hub height wind speed

z_0 is the reference roughness length (0.05 m)

z_{ref} is the reference height (10 m)

hh is the maximum proposed hub height (125 m)

[1] 'Wind turbine generator systems – Part 11: Acoustic noise measurement techniques', IEC 61400-11:2003 (Amendment 1: 2006)

- The resulting 'standardised' 10 m wind speed is correlated with the measured background noise survey data.

A12.3.5 Referencing the background noise levels to standardised 10 m wind speed calculated from the wind speed at 125 m height means that the resulting noise limits will also be referenced to wind speed at this height. This allows the predicted noise levels for turbines with 125 m hub heights to be fairly compared to the noise limits as they are both referenced to the same hub height wind speed.

Accounting for Multiple Hub Heights

A12.3.6 As previously mentioned, some of the proposed turbines have a hub height of 105 m. In order to account for site-specific shear the wind speed at 105 m shall be calculated from the 125 m wind speed and the long-term average shear exponent for the site (0.246). The acoustic emission data at 105 m can then be determined by using the 105 m wind speed to interpolate between the known data points for hub height wind speed (the equivalent 125 m wind speed for each standardised 10 m wind speed) and acoustic emission. The calculation for the Vestas V150 6 MW machine is shown in Table 12.3.1.

Table 12.3.1 - Acoustic Emission Data Accounting for Site-Specific Shear

Standardised 10m Height Wind Speed, v_{10} (ms^{-1})	Equivalent 125 m Wind Speed (ms^{-1})	105 m Wind Speed (ms^{-1})	Acoustic Emission at 125 m Wind Speed, dB(A)	Acoustic Emission at 105 m Wind Speed, dB(A)
1	1.5	1.4	95.0	95.0
2	3.0	2.8	95.0	95.0
3	4.4	4.2	95.0	95.0
4	5.9	5.7	98.6	98.0
5	7.4	7.1	103.0	102.1
6	8.9	8.5	106.3	105.5
7	10.3	9.9	106.8	106.7
8	11.8	11.3	106.9	106.9
9	13.3	12.7	106.9	106.9
10	14.8	14.1	106.9	106.9
11	16.2	15.6	106.9	106.9
12	17.7	17.0	106.9	106.9

A12.3.7 Looking at the results for a standardised 10 m wind speed of 5 ms^{-1} we can see this is a proxy for a 125 m hub height wind speed of 7.4 ms^{-1}. A wind speed of 7.4 ms^{-1} at hub height results in a sound power level of 101.0 dB(A) as it is the wind speed at hub height which drives the acoustic emission. When the wind speed at 125 m is 7.4 ms^{-1} the wind speed at 105 m height is 7.1 ms^{-1} based on the site-specific shear exponent for Sclenteuch. It follows that the acoustic emission from the turbines with 105 m hub height will therefore be less than 101.0 dB(A) as the hub height wind speed is less than 7.4 ms^{-1}.

A12.3.8 The wind speed at 105 m height can be used to determine the sound power level as we know that a hub height wind speed of 7.4 ms^{-1} results in an acoustic emission of 101.0 dB(A) and that a hub height wind speed of 5.9 ms^{-1} (a standardised 10 m wind speed of 4 ms^{-1} results in an acoustic emission of 96.6 dB(A). The acoustic emission when the hub height wind speed is 7.1 ms^{-1} will be somewhere between these values and is calculated to be 100.1 dB(A) if the change is linear.

A12.3.9 The same calculation is performed to account for site-specific shear effects in the cumulative assessment as the existing Dersalloch wind farm consists of Siemens D3 turbines with hub heights of 64.5 m and 74.5 m. As above, the 64.5 m and 74.5 m wind speeds are calculated from the reference 125 m wind speed and long-term average site-specific shear exponent. The resulting wind speeds and acoustic emission data are shown in Table 12.3.2.

Table 12.3.2 - Accounting for Site-Specific Shear at Additional Heights

Standardised 10m Height Wind Speed, v_{10} (ms^{-1})	74.5 m Wind Speed (ms^{-1})	64.5 m Wind Speed (ms^{-1})	Acoustic Emission at 74.5 m Wind Speed, dB(A)	Acoustic Emission at 64.5 m Wind Speed, dB(A)
1	1.3	1.3	96.1	96.1
2	2.6	2.5	96.1	96.1
3	3.9	3.8	96.1	96.1
4	5.2	5.0	96.1	96.1
5	6.5	6.3	99.3	98.7
6	7.8	7.5	104.0	103.0
7	9.1	8.8	107.1	106.4
8	10.4	10.0	108.4	108.1
9	11.7	11.3	108.9	108.9
10	13.0	12.5	109.0	109.0
11	14.3	13.8	109.0	109.0
12	15.6	15.1	109.0	109.0

A12.3.10 Predicted noise levels based on the acoustic emission data shown in Tables 12.3.1 and 12.3.2 can be fairly compared to noise limits referenced to 125 m hub height as site-specific shear effects have been accounted for in calculating the acoustic emission data for turbines with hub heights differing from 125 m.

Conclusion

A12.3.11 The effects of site-specific shear shall be accounted for using the methods outlined in this appendix. An additional step is required for assessments considering turbines with multiple hub heights so that the acoustic emission data reflects the wind speed at each hub height based on site-specific conditions. This allows the resulting predicted noise levels to be fairly compared with the derived noise limits.

Technical Appendix 12.4: Propagation Height & Valley Effect

A12.4.1 To model the propagation of noise between each proposed turbine and residential property in accordance with the Institute of Acoustics Good Practice Guide (IoA GPG) the mean propagation height has to be calculated in order to determine whether the correction specified by the guidance for propagation over a concave ground profile, or where the ground falls away significantly between the source and receiver, is applicable.

A12.4.2 3 dB(A) would be added to the noise level predicted by the ISO 9613-2 propagation model for the specific turbines and properties where the threshold specified by the IoA GPG is exceeded although there are no instances where this occurs for the proposed development.

Technical Appendix 12.5: Background Noise Survey Photos

Photo 1: Noise Apparatus in Relation to Altizeurie Cottage

Photo 2: Noise Apparatus in Relation to Barneil Farm

Photo 3: Noise Apparatus in Relation to Gass Farm

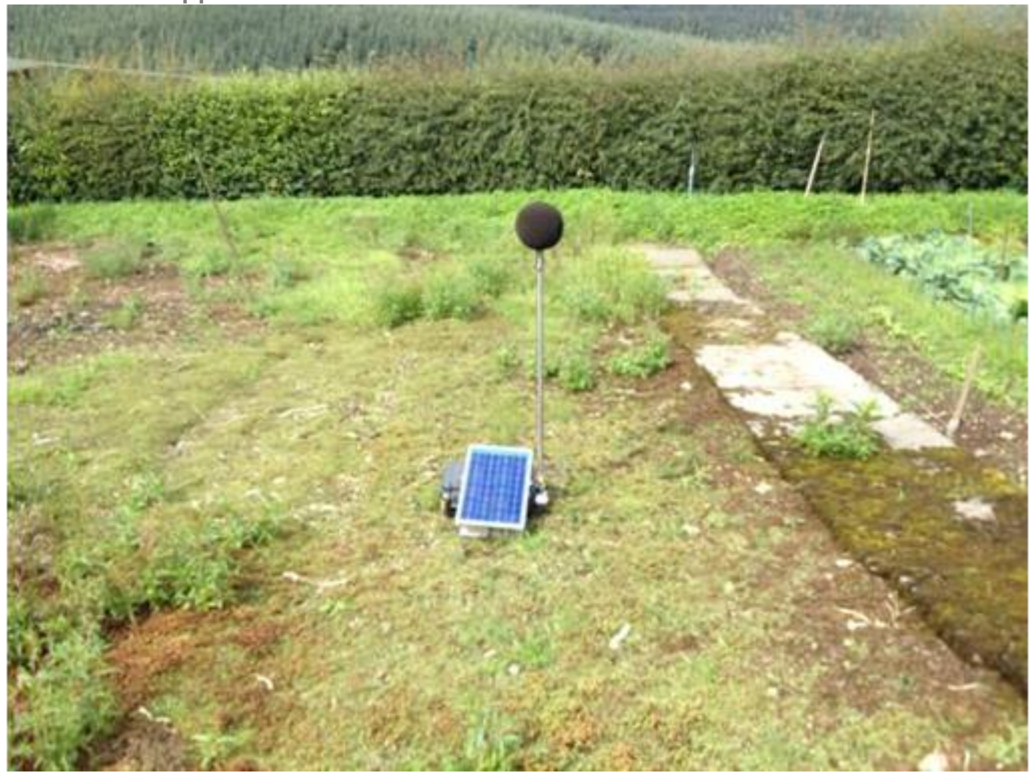


Photo 4: Noise Apparatus in Relation to Glenhead

Photo 5: Noise Apparatus in Relation to High Kiers

Photo 6: Noise Apparatus in Relation to Patna

Technical Appendix 12.6: Background Noise Assessment Instrumentation Records

Survey Location	Altizeurie Cottage	Barneil Farm	Gass Farm	Glenhead	High Keirs	Patna
Sound Level Meter Type	Rion NL-31	Rion NL-31	Rion NL-31	Rion NL-31	Rion NL-32	Rion NL-32
Sound Level Meter Serial No.	00983380	00952272	00952274	00952273	00103136	01182957
Sound Level Meter Calibration Certificate No.	05759	06347	06348	05760	011219	101132
Date of Issue	22/02/2011	08/02/12	08/02/12	22/02/12	17/01/12	27/10/11
Microphone Serial No.	315831	309098	309102	315828	316489	315497
Preamp Serial No.	28713	17123	17126	17125	31873	28891
Calibrator Type	Rion NC-74	Rion NC-74	Rion NC-74	Rion NC-74	Rion NC-74	Rion NC-74
Calibrator Serial No.	34851904	34851904	34851904	34851904	34851904	34851904
Calibrator Certificate No.	05745	05745	05745	05745	05745	05745
Date of Issue	22/02/2011	22/02/2011	22/02/2011	22/02/2011	22/02/2011	22/02/2011

Technical Appendix 12.7: Charts

Chart 12.1: Wind Speed and Direction during the Background Noise Survey

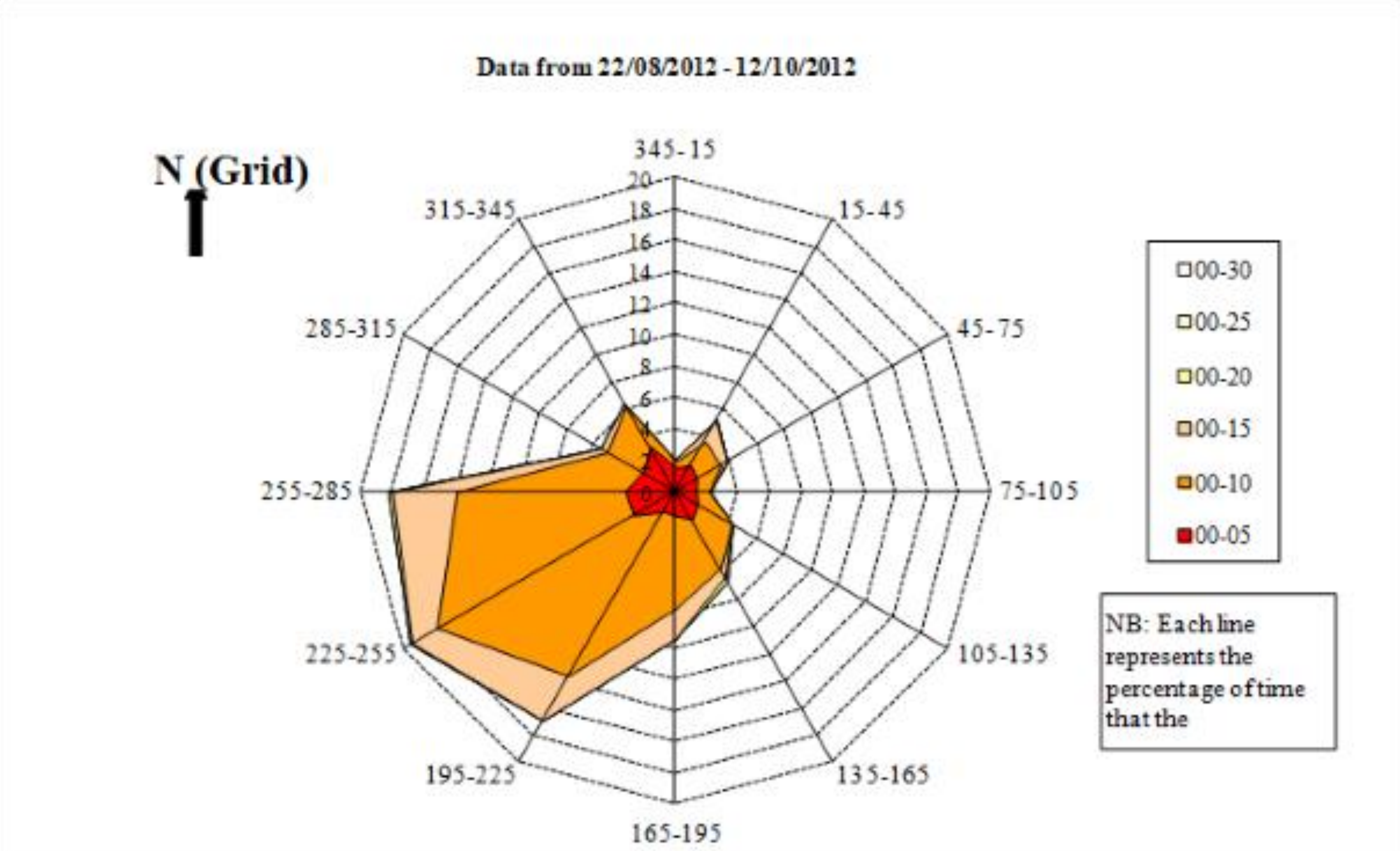


Chart 12.2: Measured Wind Rose over an Extended Period

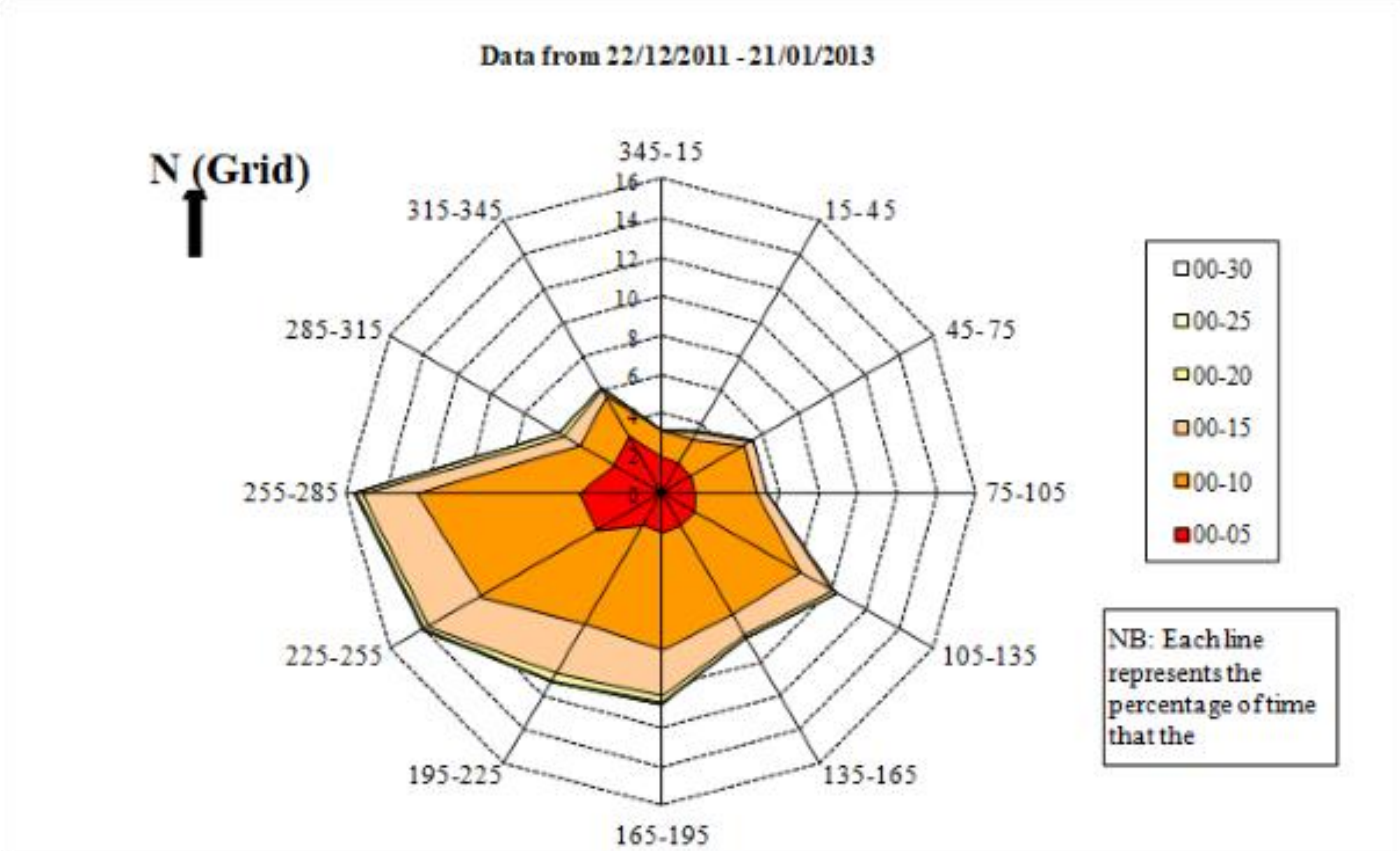


Chart 12.3: Downwind Predicted Noise Levels, Daytime Noise Limits and Background Noise Levels during Quiet Daytime Periods at Altizeurie Cottage

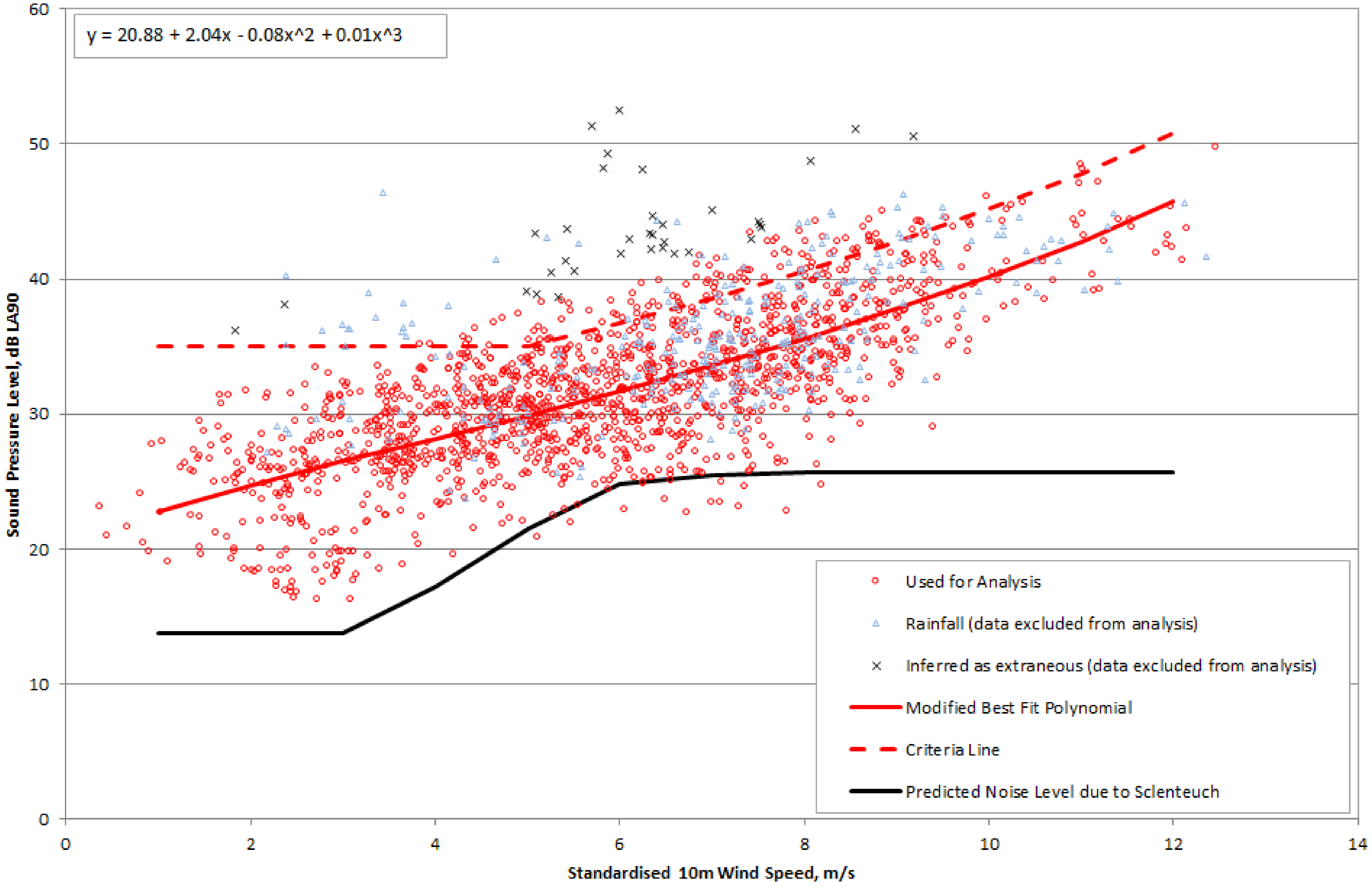


Chart 12.4: Downwind Predicted Noise Levels, Daytime Noise Limits and Background Noise Levels during Quiet Daytime Periods at Barneil Farm

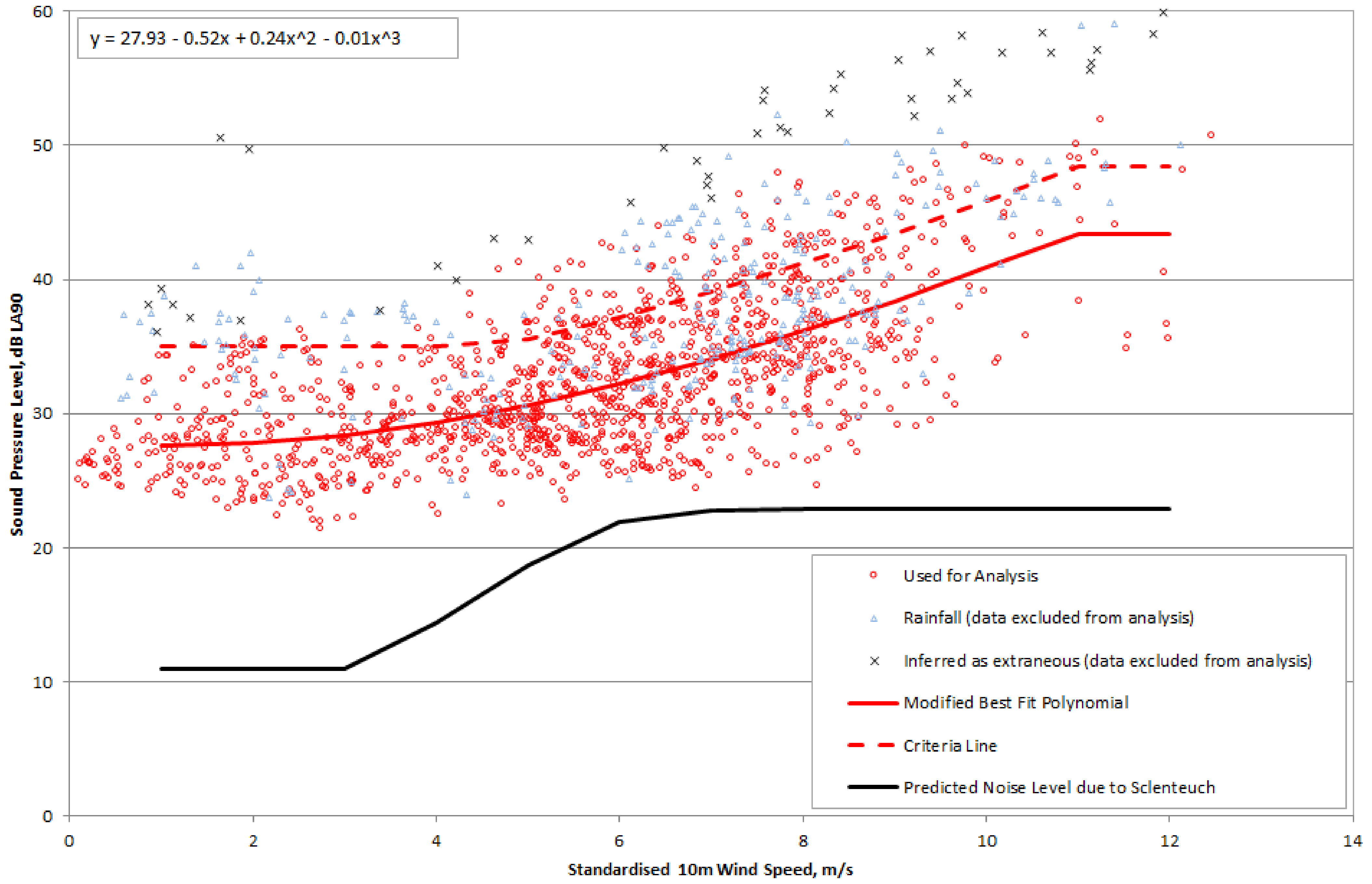


Chart 12.5: Downwind Predicted Noise Levels, Daytime Noise Limits and BackgroundNoise Levels during Quiet Daytime Periods at Gass Farm

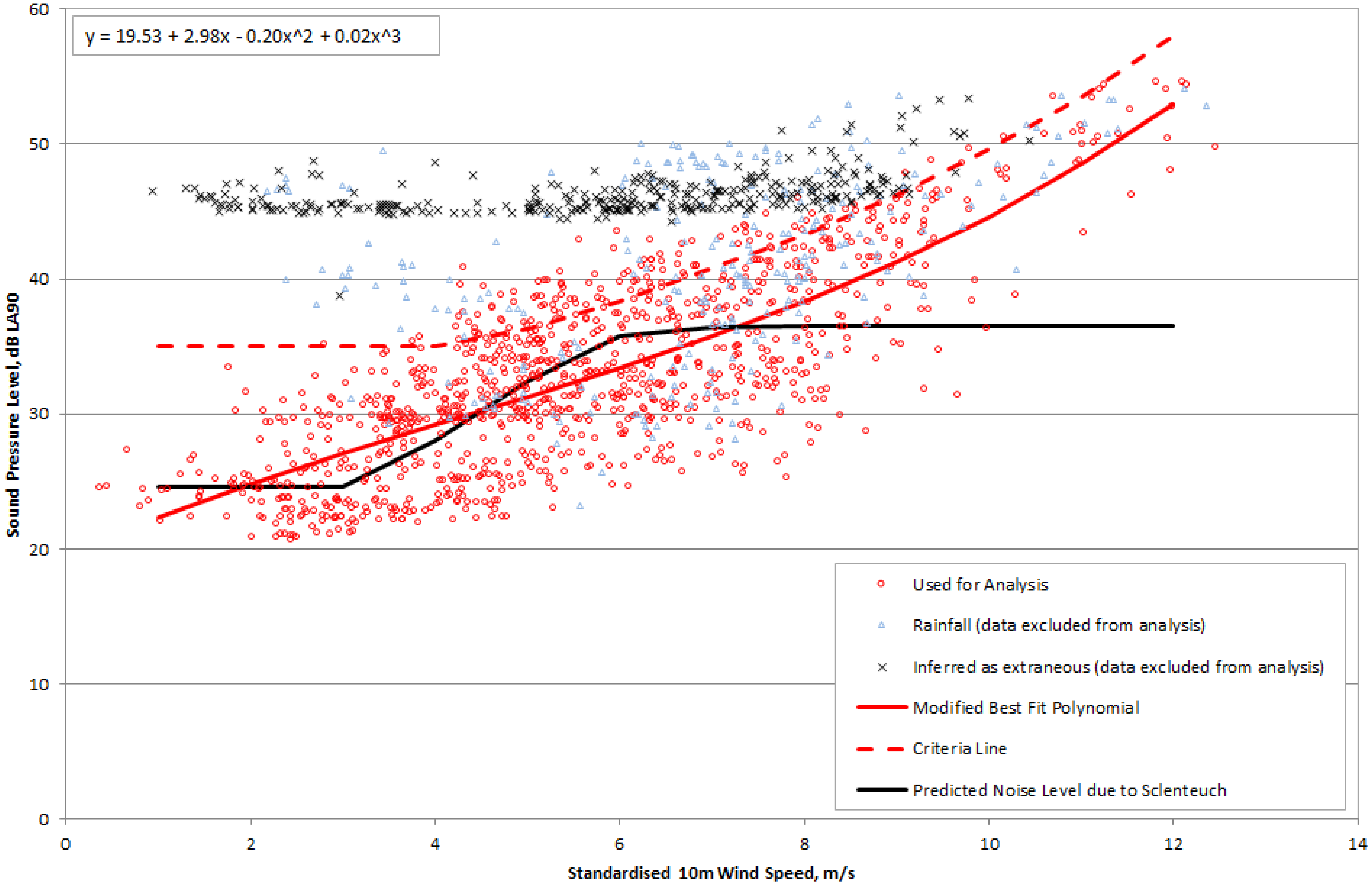


Chart 12.6: Downwind Predicted Noise Levels, Daytime Noise Limits and Background Noise Levels during Quiet Daytime Periods at Glenhead

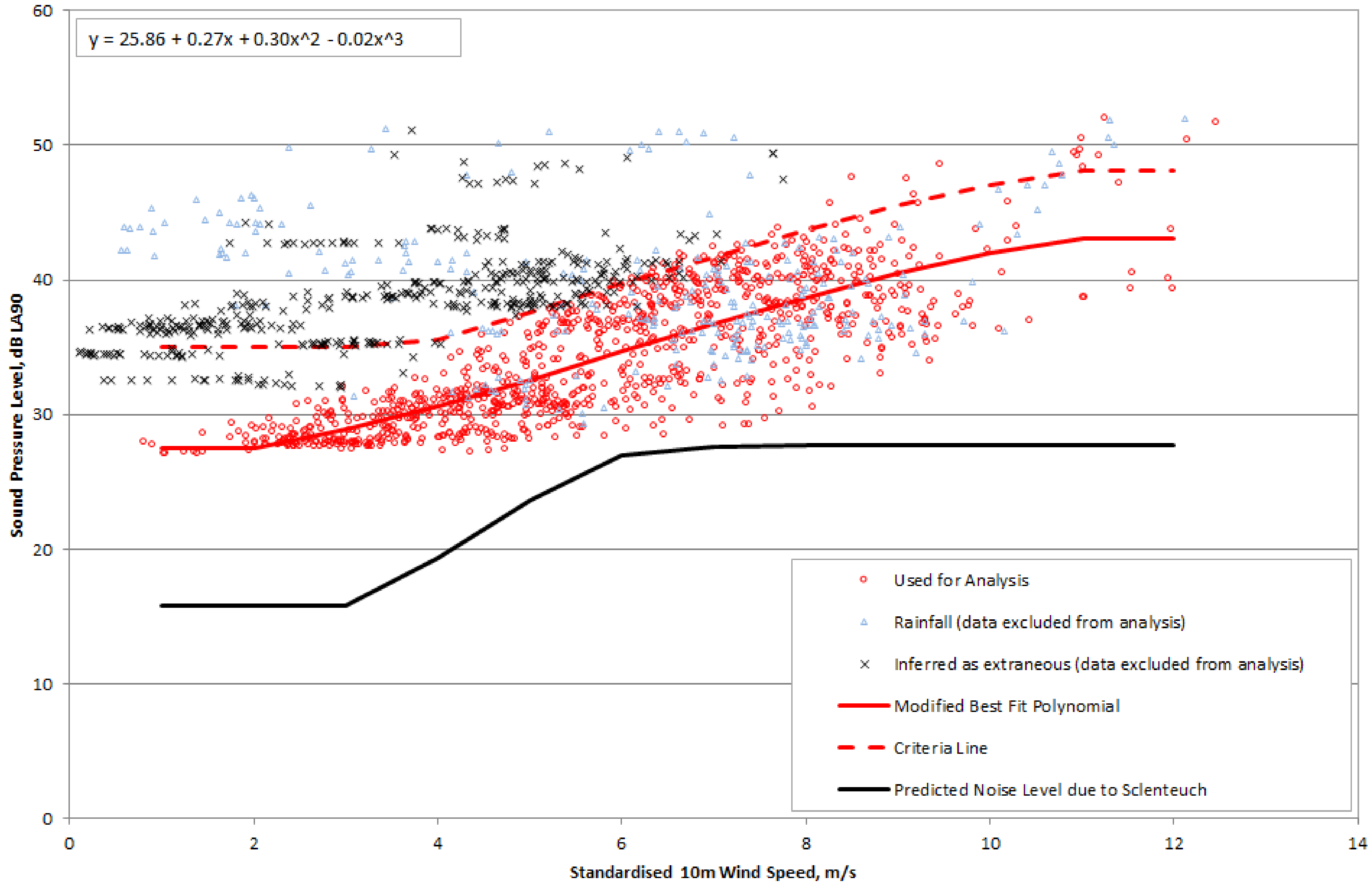


Chart 12.7: Downwind Predicted Noise Levels, Daytime Noise Limits and Background Noise Levels during Quiet Daytime Periods at High Keirs

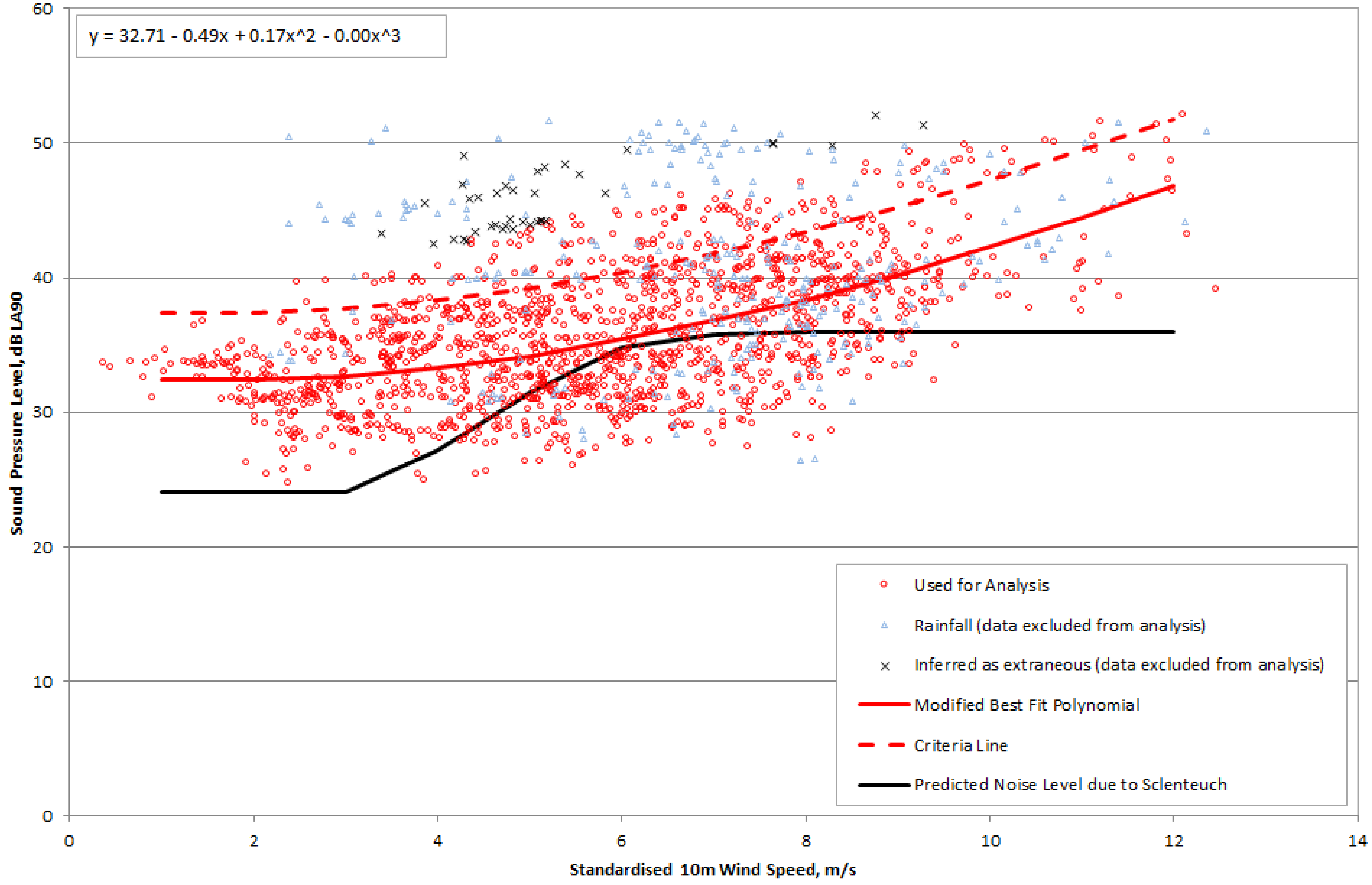


Chart 12.8: Downwind Predicted Noise Levels, Daytime Noise Limits and Background Noise Levels during Quiet Daytime Periods at Patna

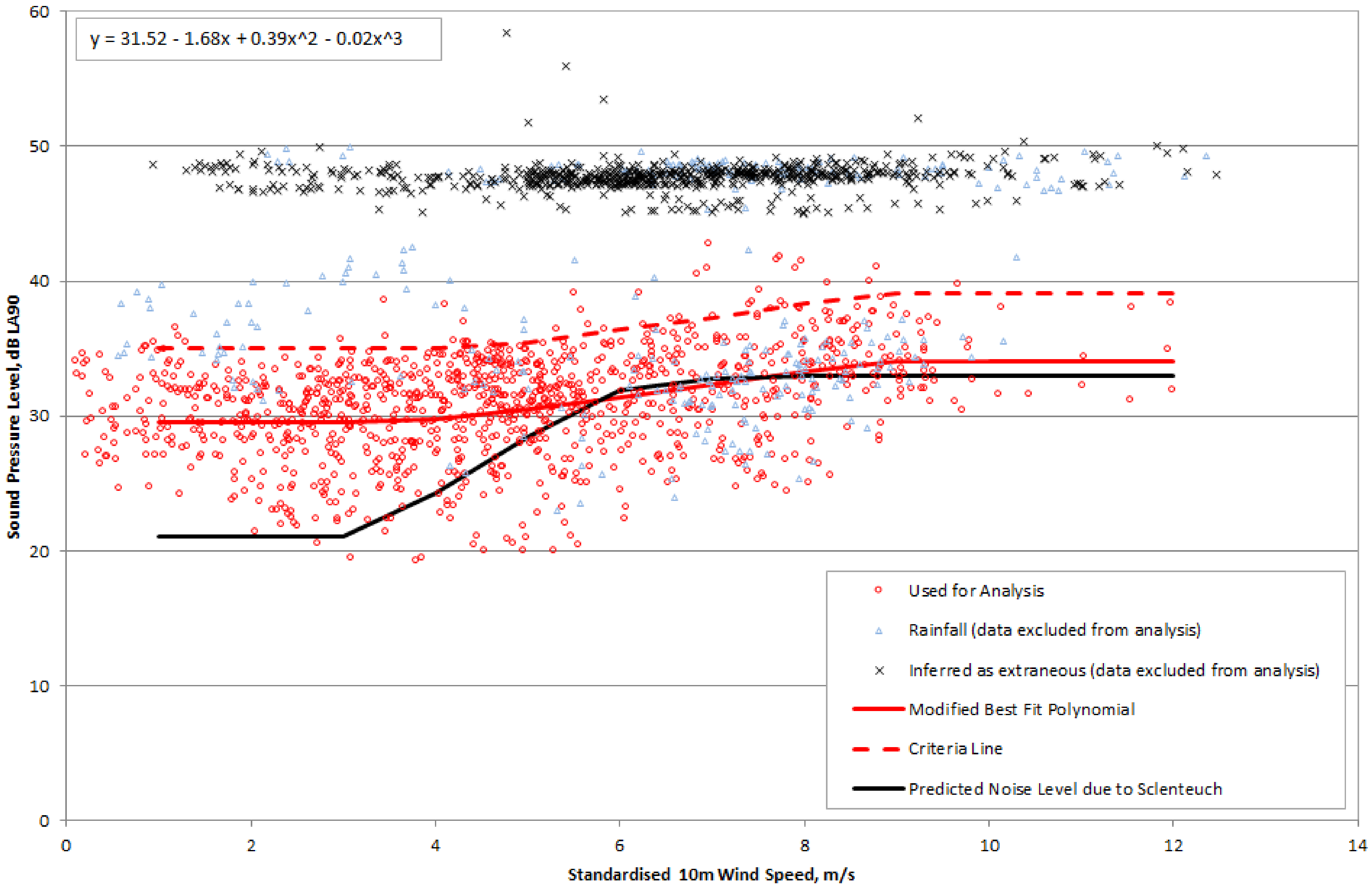


Chart 12.9: Downwind Predicted Noise Levels, Noise Limits and Background Noise Levels during Night-Time Periods at Altizeurie Cottage

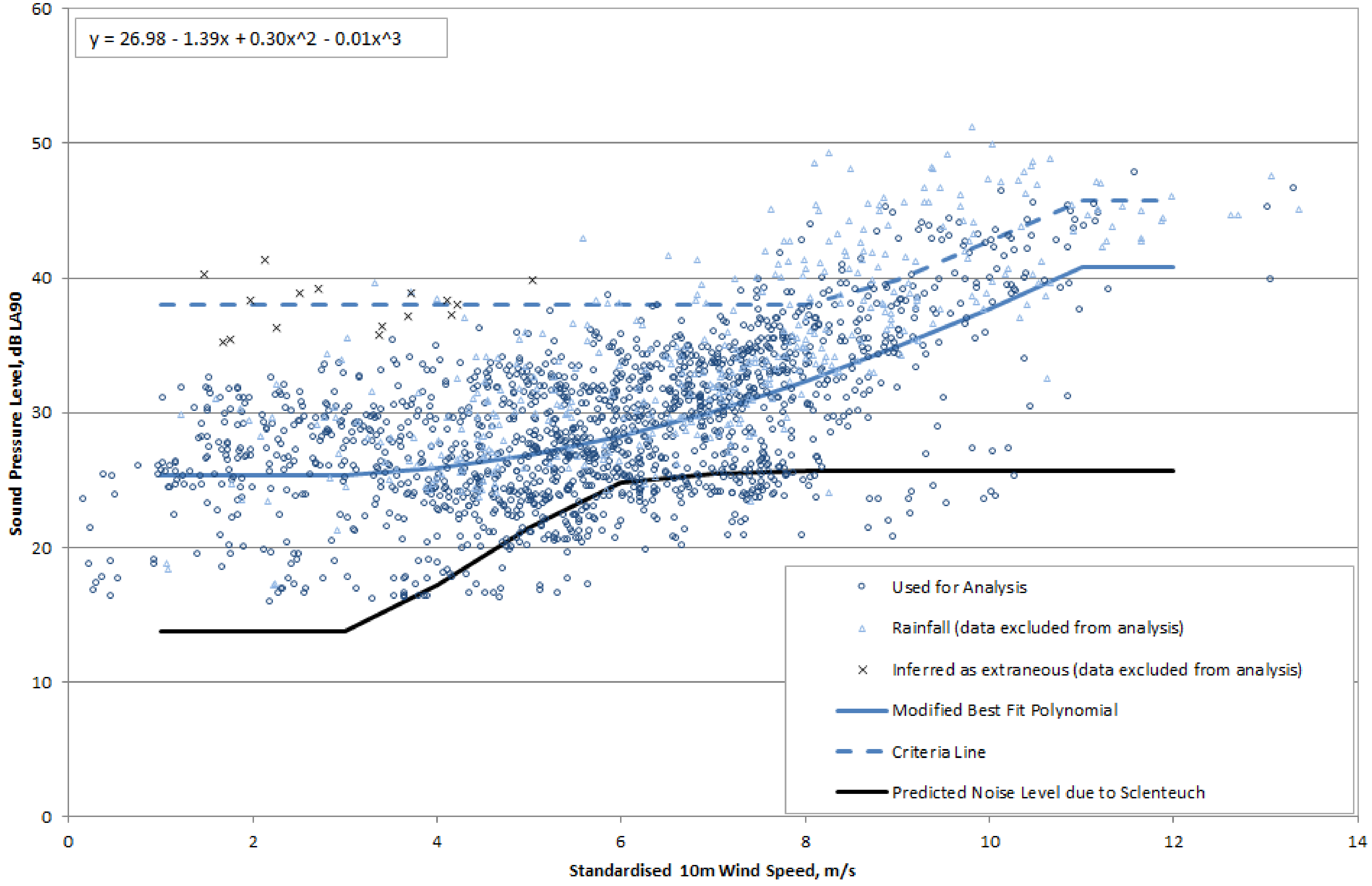


Chart 12.10: Downwind Predicted Noise Levels, Noise Limits and Background Noise Levels during Night-Time Periods at Barneil Farm

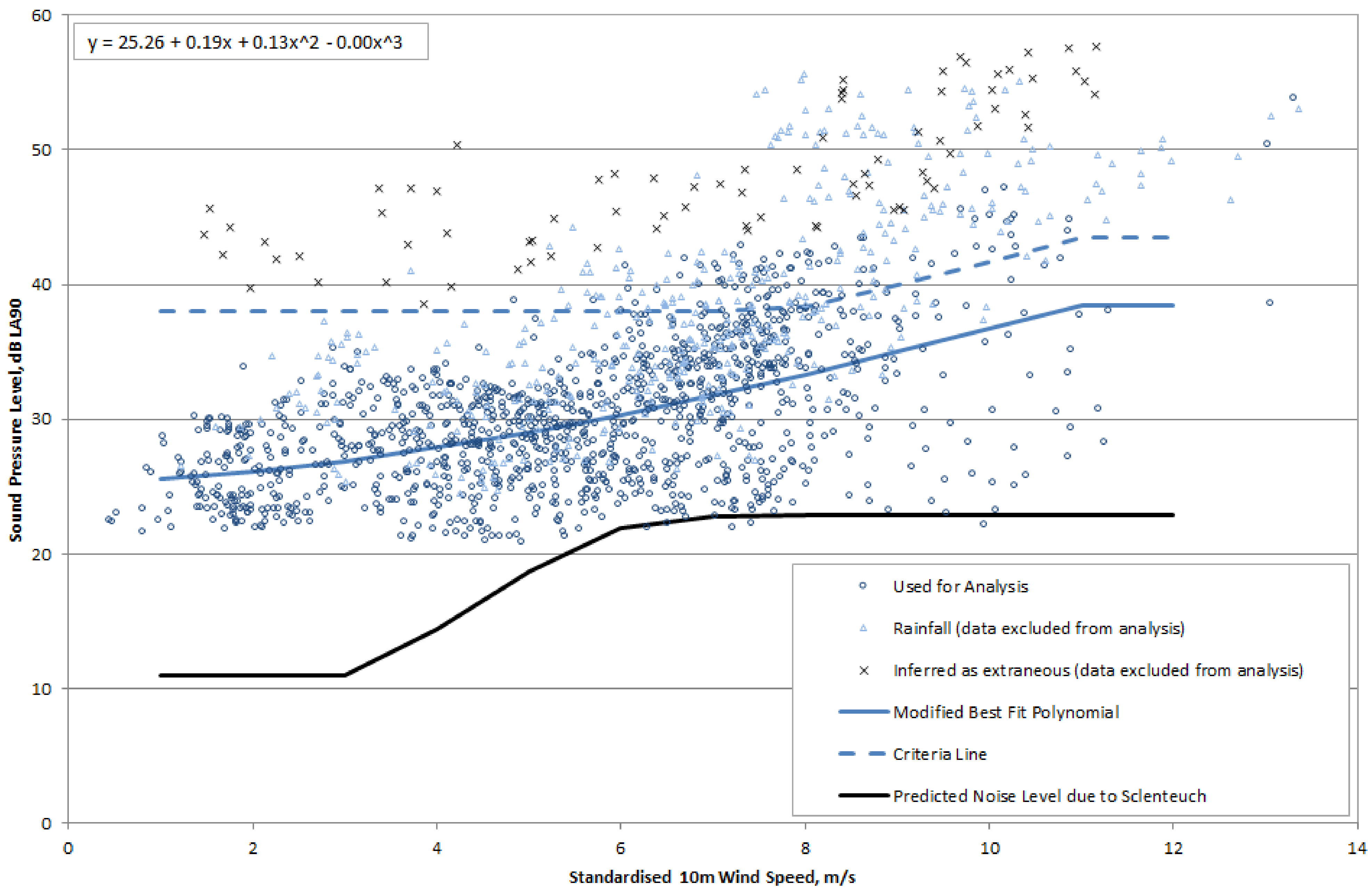


Chart 12.11: Downwind Predicted Noise Levels, Noise Limits and Background Noise Levels during Night-Time Periods at Gass Farm

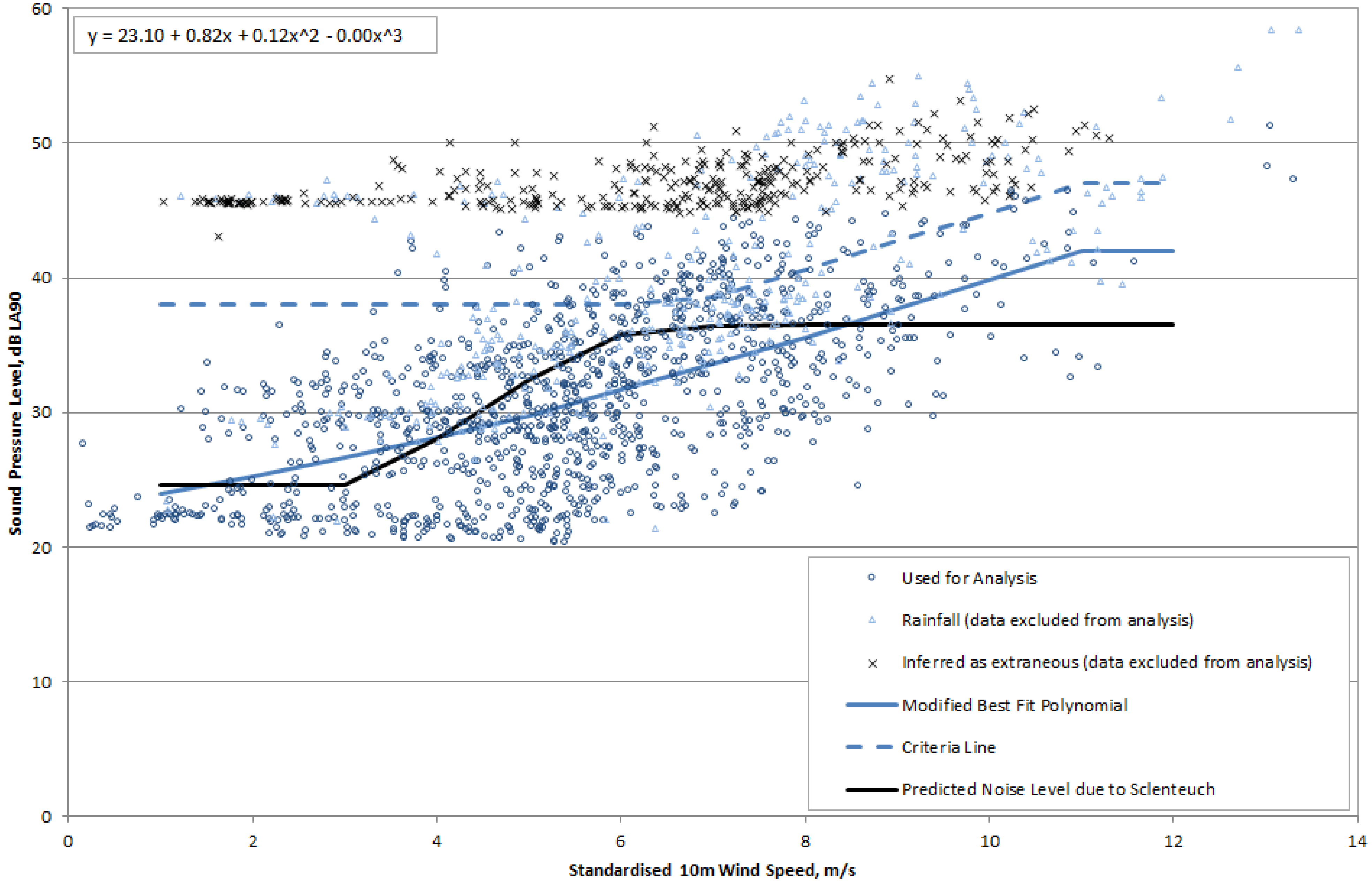


Chart 12.12: Downwind Predicted Noise Levels, Noise Limits and Background Noise Levels during Night-Time Periods at Glenhead

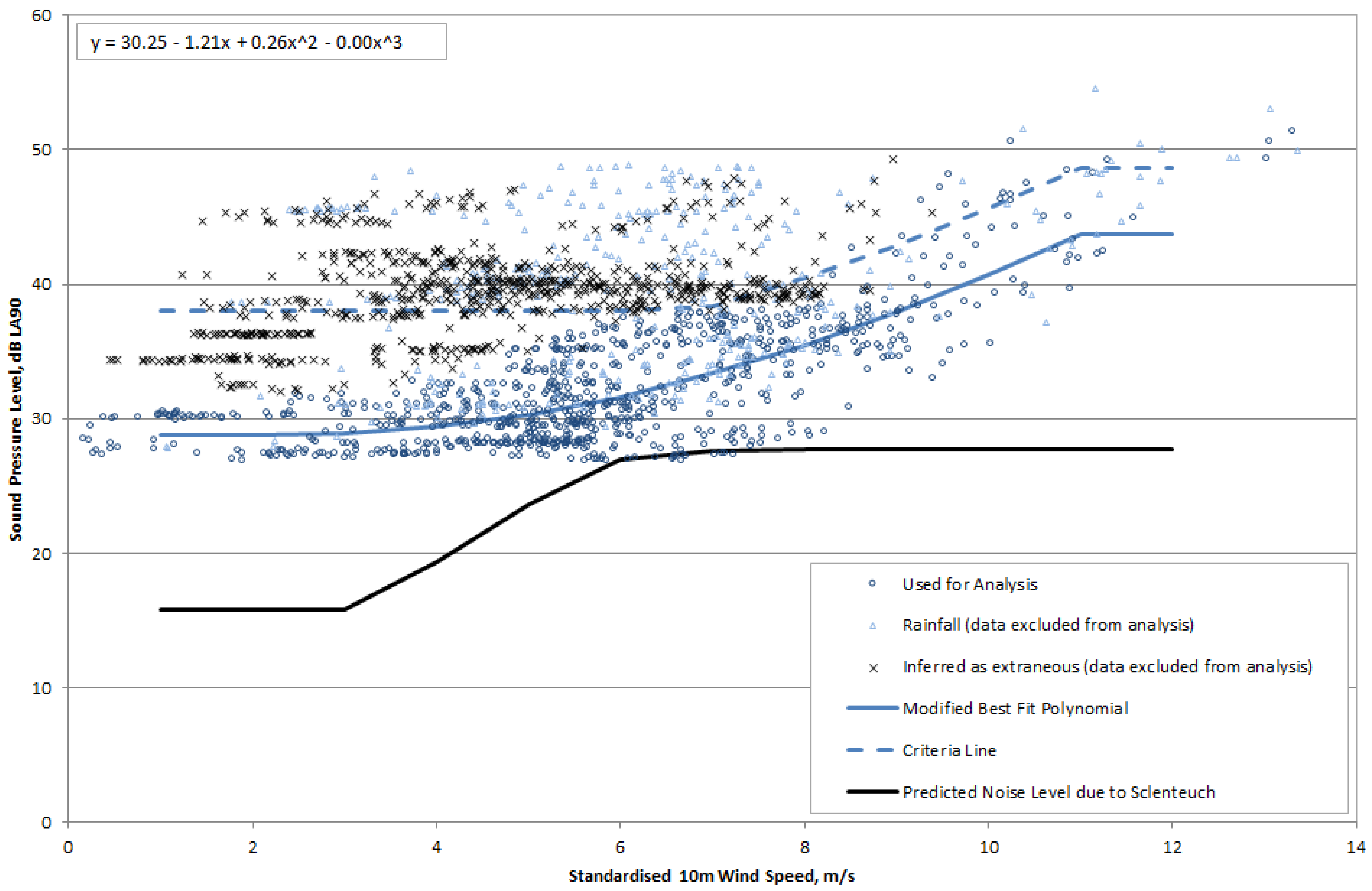


Chart 12.13: Downwind Predicted Noise Levels, Noise Limits and Background Noise Levels during Night-Time Periods at High Keirs

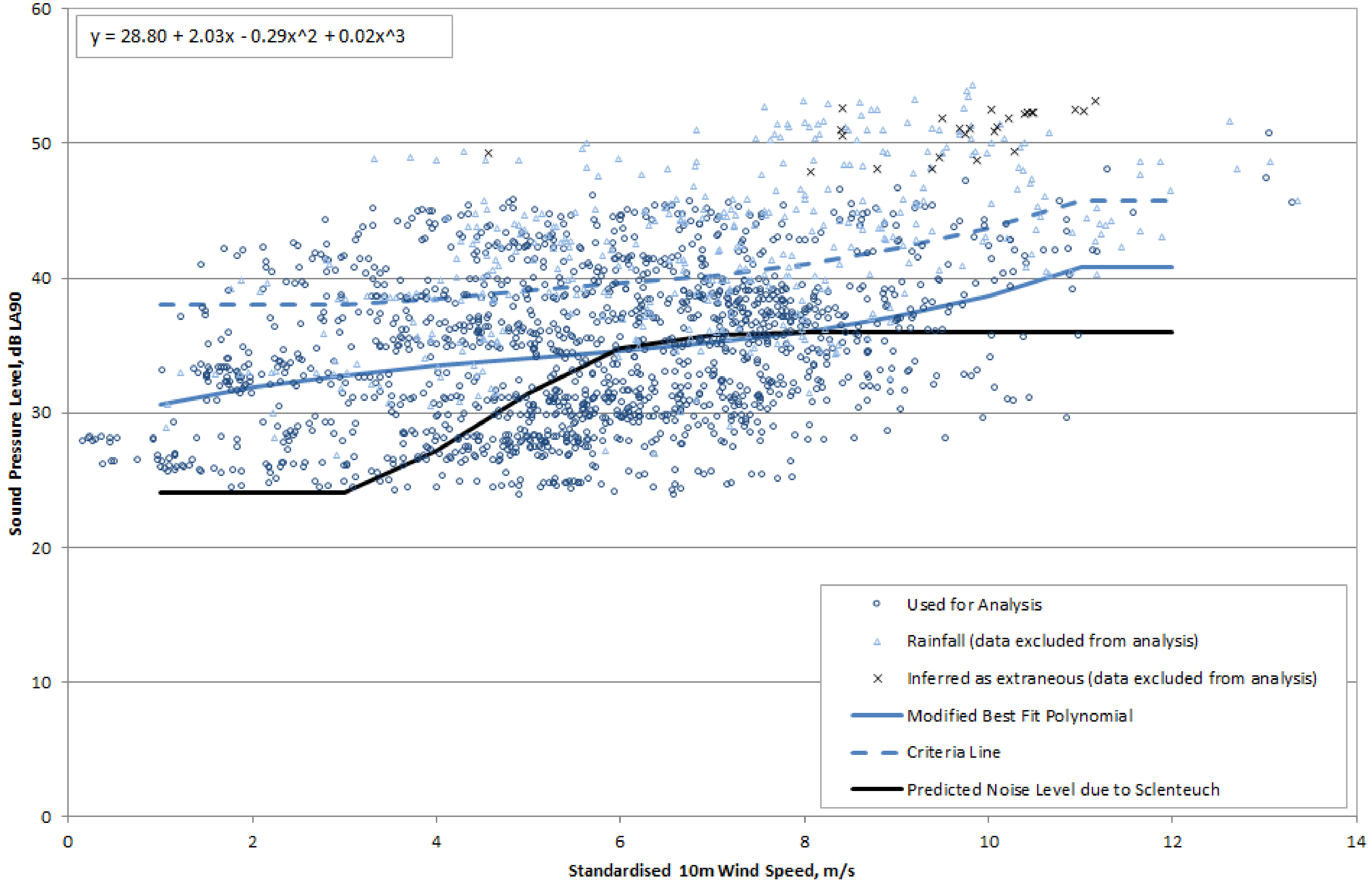


Chart 12.14: Downwind Predicted Noise Levels, Noise Limits and Background Noise Levels during Night-Time Periods at Patna

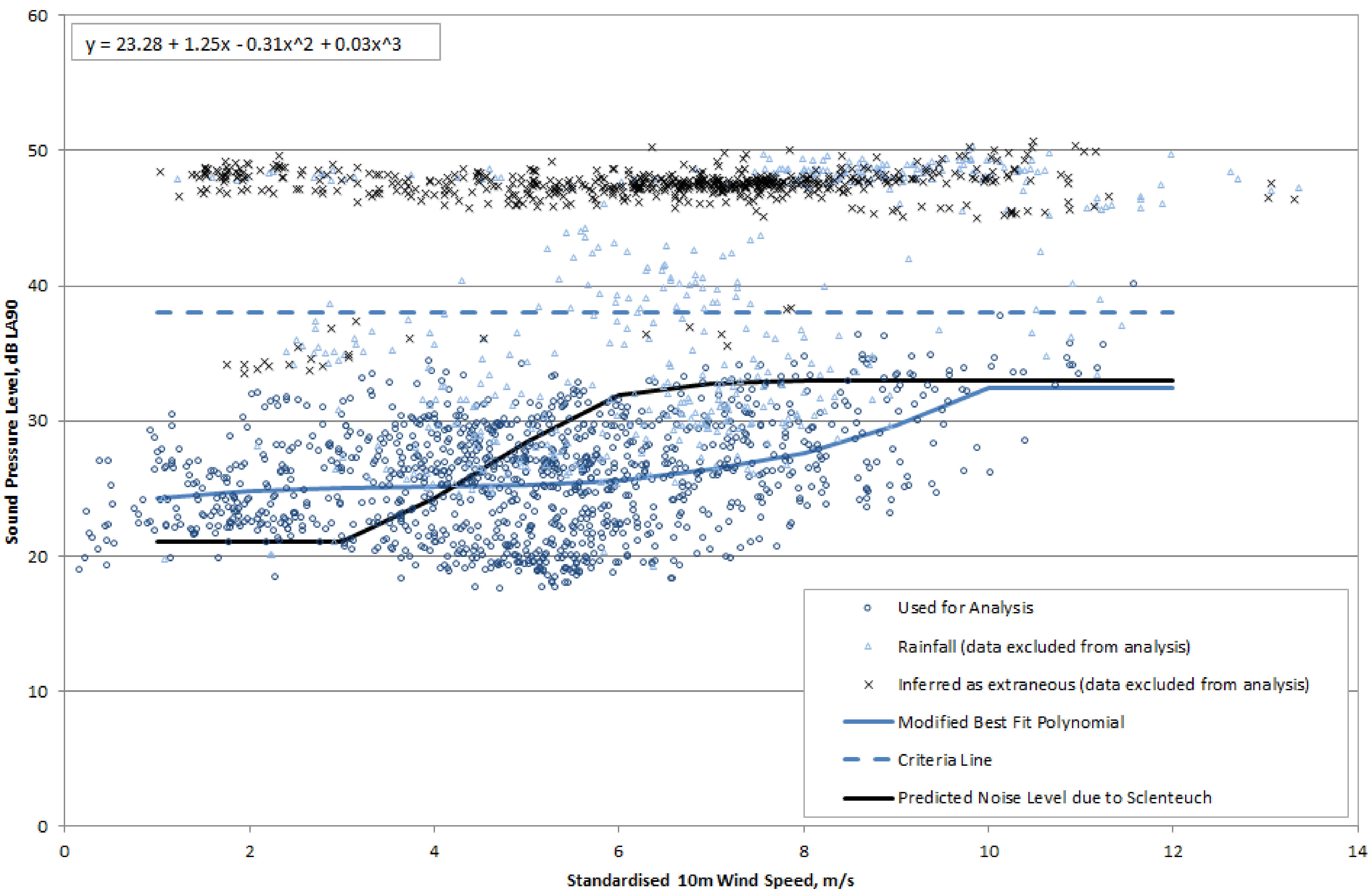


Chart 12.15: Cumulative Predicted Noise Levels and Noise Limits at H3

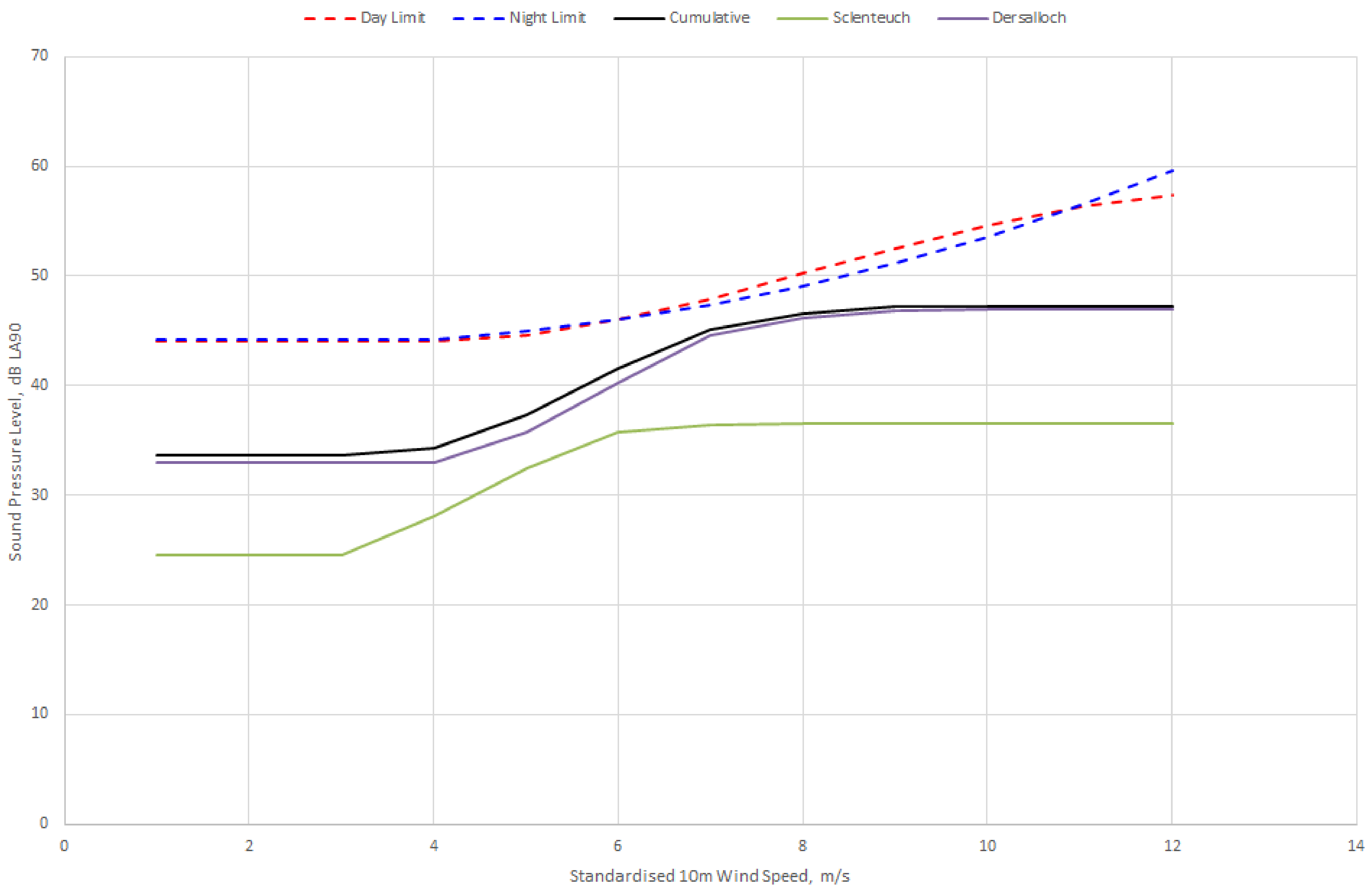
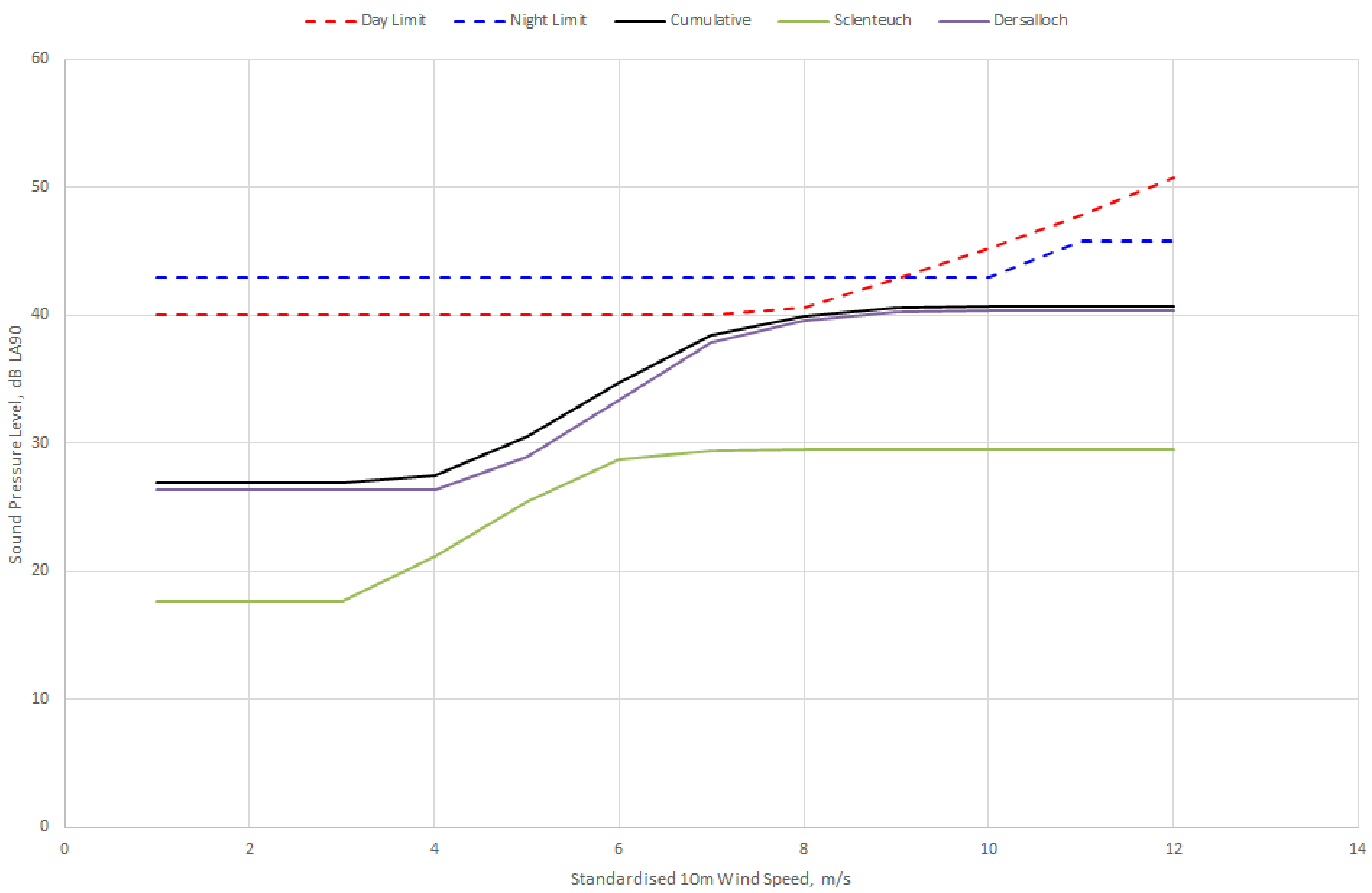


Chart 12.16: Cumulative Predicted Noise Levels and Noise Limits at H82



Technical Appendix 12.8: Suggested Planning Conditions: Noise

A12.8.1 If the wind farm was successful in its application for planning permission any resulting decision notice would likely contain appropriately worded noise conditions, written so as to be in accordance with Circular 4/1998 The Use of Conditions in Planning Permissions[1].

A12.8.2 Such conditions would provide a degree of protection to nearby residents under planning law. To that end, presented below are a set of relevant, precise and enforceable conditions that RES suggest may be considered as appropriate. The form of condition wording suggested has been adopted at sites such as Freasdail[2], Minnygap[3], Roos[4], Solwaybank[5] and Wryde Croft[6]. Any final conditions attached to the proposal would be according to the discretion of the decision maker.

A12.8.3 The proposed noise limits are derived by subtracting the predicted noise levels due to Dersalloch wind farm from the total ETSU-R-97 limit deemed appropriate in the cumulative assessment. Prior to this the predicted noise levels for Dersalloch are scaled to the relevant conditioned noise limits using the controlling property method recommended in the IoA GPG. This results in noise limits for the proposed development alone such that the cumulative noise limit is met in combination with the existing Dersalloch wind farm.

Following the above calculation the noise limits for the proposed development have been amended so that they do not exceed the limits proposed in the assessment of the proposed development alone i.e. a lower limit of 35 dB(A) or background noise plus 5 dB(A) during the day and a lower limit of 38 dB(A) or background plus 5 dB(A) at night.

1. The level of noise immissions from the combined effects of the wind turbines (including the application of any tonal penalty) when calculated in accordance with the attached Guidance Notes, shall not exceed the values set out in the attached Table 1 or Table 2 (as appropriate). Noise limits for dwellings which lawfully exist or have planning permission for construction at the date of this consent but are not listed in the Tables attached shall be those of the physically closest location listed in the Tables unless otherwise agreed with the Local Planning Authority. The coordinate locations to be used in determining the location of each of the dwellings listed in Tables 1 and 2 shall be those listed in Table 3.
2. Within 21 days from the receipt of a written request from the Local Planning Authority and following a complaint to the Local Planning Authority from the occupant of a dwelling which lawfully exists or has planning permission at the date of this consent, the wind farm operator shall, at the wind farm operators expense, employ an independent consultant approved by the Local Planning Authority to assess the level of noise immissions from the wind farm at the complainant's property following the procedures described in the attached Guidance Notes.
3. The wind farm operator shall provide to the Local Planning Authority the independent consultant's assessment and conclusions regarding the said noise complaint, including all raw data upon which those assessments and conclusions are based. Such information shall be provided within 2 months of the date of the written request of the Local Planning Authority, with an additional 3 weeks allowed should further investigation pursuant to Guidance Note 4 be required, unless otherwise extended in writing by the Local Planning Authority.
4. Wind speed, wind direction and power generation data shall be continuously logged and provided to the Local Planning Authority at its request and in accordance with the attached Guidance Notes within 14 days of such request. Such data shall be retained for a period of not less than 24 months.
5. No development shall commence until there has been submitted to the Local Planning Authority details of a nominated representative for the development to act as a point of contact for local residents (in connection with conditions 1 - 4) together with the arrangements for notifying and approving any subsequent change in the nominated representative. The nominated representative shall have responsibility for liaison with the Local Planning Authority in connection with any noise complaints made during the construction, operation and decommissioning of the wind farm.

SCHEDULE OF NOISE GUIDANCE NOTES

These notes form part of conditions 1-5. They further explain these conditions and specify the methods to be deployed in the assessment of complaints about noise immissions from the wind farm.

[1] Circular 4/1998, "The Use of Conditions in Planning Permissions", Scottish Government, February 1998

[2] Directorate for Planning and Environmental Appeals, Appeal Decision Notice, Appeal Reference PPA-130-2036, Decision Date: 15 April 2014

[3] Directorate for Planning and Environmental Appeals, Appeal Decision Notice, Appeal Reference PPA-170-2055, Decision Date: 19 June 2014

[4] The Planning Inspectorate, Appeal Decision, Appeal Reference: APP/E2001/A/09/2113076, Decision Date: 21 June 2010

[5] Directorate for Planning and Environmental Appeals, Appeal Decision Notice, Appeal Reference PPA-170-2091, Decision Date: 23 September 2014

[6] The Planning Inspectorate, Appeal Decisions for Appeal References: APP/J0540/A/08/2083801 and APP/J0540/A/08/2090541, Decision Date: 1 April 2010

Reference to ETSU-R-97 refers to the publication entitled "The Assessment and Rating of Noise from Wind Farm" (1997) published by the Energy Technology Support unit (ETSU) for the Department of Trade and Industry (DTI).

Note 1

a. Values of the $L_{A90,10min}$ noise statistic shall be measured at the complainant's property using a sound level meter of EN 60651/BS EN 60804 Type 1, or EN 61672 Class 1 quality (or the replacement thereof) set to measure using a fast time weighted response as specified in BS EN 60651/BS EN 60804 or BS EN 61672-1 (or the equivalent UK adopted standard in force at the time of the measurements). This shall be calibrated in accordance with the procedure specified in BS 4142: 1997 (or the replacement thereof). These measurements shall be made in such a way that the requirements of Note 3 shall also be satisfied.

a. The microphone should be mounted at 1.2 - 1.5 m above ground level, fitted with a two layer windshield (or suitable alternative approved in writing from the Local Planning Authority), and placed outside the complainant's dwelling. Measurements should be made in "free-field" conditions. To achieve this, the microphone should be placed at least 3.5 m away from the building facade or any reflecting surface except the ground at a location agreed with the Local Planning Authority.

b. The $L_{A90,10min}$ measurements shall be synchronised with measurements of the 10-minute arithmetic mean wind speed and with operational data, including power generation information for each wind turbine, from the turbine control systems of the wind farm.

c. The wind farm operator shall continuously log arithmetic mean wind speed and arithmetic mean wind direction data in 10 minute periods on the wind farm site to enable compliance with the conditions to be evaluated. The mean wind speed at hub height shall be 'standardised' to a reference height of 10 metres as described in ETSU-R-97 at page 120 using a reference roughness length of 0.05 metres. It is this standardised 10 m height wind speed data which is correlated with the noise measurements of Note 2(a) in the manner described in Note 2(c).

Note 2

a. The noise measurements shall be made so as to provide not less than 20 valid data points as defined in Note 2 paragraph (b). Such measurements shall provide valid data points for the range of wind speeds, wind directions, times of day and power generation requested by the Local Planning Authority. In specifying such conditions the Local Planning Authority shall have regard to those conditions which were most likely to have prevailed during times when the complainant alleges there was disturbance due to noise.

b. Valid data points are those that remain after all periods during rainfall have been excluded. Rainfall shall be assessed by use of a rain gauge that shall log the occurrence of rainfall in each 10-minute period concurrent with the measurement periods set out in Note 1(c) and is situated in the vicinity of the sound level meter.

c. Data points considered valid in accordance with Note 2(b) shall be plotted against the corresponding wind speed value determined in accordance with Note 1(d). A least squares, "best fit" curve of 2nd order shall be fitted to the data. In the event that this is a poor fit to the data, a higher (maximum 4th) order polynomial or data binning can be used. The noise level at each integer speed shall be derived from this best-fit curve, or the relevant data bin, as appropriate.

Note 3

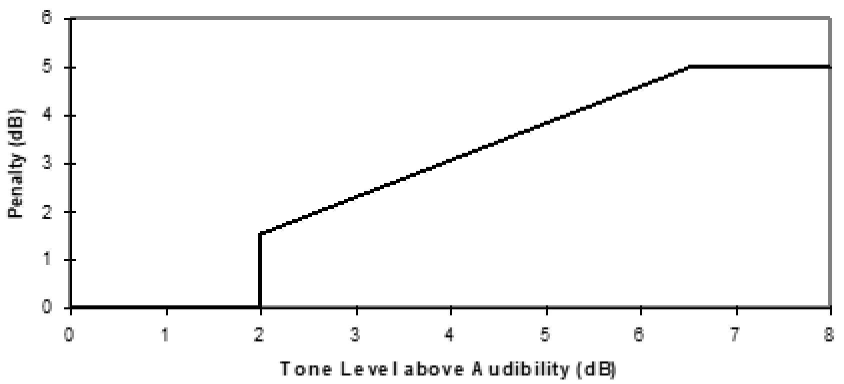
Where, in the opinion of the Local Planning Authority, noise immissions at the location or locations where assessment measurements are being undertaken contain a tonal component, the following rating procedure shall be used.

a. For each 10-minute interval for which $L_{A90,10min}$ data have been obtained as provided for in Notes 1 and 2, a tonal assessment shall be performed on noise immissions during 2-minutes of each 10-minute period. The 2-minute periods shall be regularly spaced at 10-minute intervals provided that uninterrupted clean data are available. Where clean data are not available, the first available uninterrupted clean 2 minute period out of the affected overall 10 minute period shall be selected. Any such deviations from standard procedure, as described in Section 2.1 on pages 104-109 of ETSU-R-97, shall be reported.

a. For each of the 2-minute samples the margin above or below the audibility criterion of the tone level difference, ΔL_{tm} (Delta L_{tm}), shall be calculated by comparison with the audibility criterion, given in Section 2.1 on pages 104-109 of ETSU-R-97.

b. The arithmetic average margin above audibility shall be calculated for each wind speed bin where data is available, each bin being 1 metre per second wide and centred on integer wind speeds. For samples for which the tones were below the audibility criterion or no tone was identified, a value of zero audibility shall be substituted.

c. The tonal penalty shall be derived from the margin above audibility of the tone according to the figure below. The rating level at each wind speed shall be calculated as the arithmetic sum of the wind farm noise level, as determined from the best-fit curve described in Note 2, and the penalty for tonal noise.



Note 4

If the wind farm noise level (including the application of any tonal penalty as per Note 3) is above the limit set out in the conditions, measurements of the influence of background noise shall be made to determine whether or not there is a breach of condition. This may be achieved by repeating the steps in Notes 1 & 2 with the wind farm switched off in order to determine the background noise, L_3, at the assessed wind speed. The wind farm noise at this wind speed, L_1, is then calculated as follows, where L_2 is the measured wind farm noise level at the assessed wind speed with turbines running but without the addition of any tonal penalty:

$$L_1 = 10\log\left[10^{L_2/10} - 10^{L_3/10}\right]$$

The wind farm noise level is re-calculated by adding the tonal penalty (if any) to the wind farm noise.

TABLE OF NOISE LIMITS RELATING TO CONDITION 1

- Table 1: The $L_{A90,10min}$ dB Wind Farm Noise Level Between 23:00 and 07:00 hours:

House ID	Reference Wind Speed, Standardised v_{10} (ms^{-1})											
	1	2	3	4	5	6	7	8	9	10	11	12
H1	38.0	38.0	38.0	38.0	38.0	38.0	38.6	40.6	42.7	44.8	47.0	47.0
H2	38.0	38.0	38.0	38.0	38.0	38.0	38.6	40.6	42.7	44.8	47.0	47.0
H3	38.0	38.0	38.0	38.0	38.0	38.0	38.6	40.6	42.7	44.8	47.0	47.0
H4	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H5	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H6	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H7	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H8	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H9	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H10	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H11	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H12	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H13	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H14	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H15	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H16	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H17	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H18	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H19	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H20	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H21	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H22	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H23	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H24	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H25	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H26	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H27	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H28	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H29	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H30	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H31	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H32	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H33	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H34	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H35	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H36	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0

H37	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H38	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H39	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H40	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H41	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H42	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H43	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H44	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H45	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H46	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H47	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H48	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H49	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H50	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H51	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H52	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H53	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H54	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H55	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H56	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H57	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H58	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H59	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H60	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H61	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H62	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H63	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H64	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.3	43.3
H65	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.3	43.3
H66	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H67	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H68	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H69	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H70	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.2	43.2
H71	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.3	40.0	41.7	43.4	43.4
H72	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9	42.4	45.5	45.5
H73	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9	42.4	45.5	45.5
H74	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9	42.5	45.5	45.5
H75	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9	42.5	45.5	45.5
H76	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9	42.3	45.5	45.5
H77	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9	42.4	45.5	45.5
H78	38.0	38.0	38.0	38.0	38.0	38.0	38.4	40.5	41.4	44.9	48.3	48.3
H79	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9	40.2	44.6	44.6
H80	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9	41.5	45.1	45.1
H81	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9	41.3	45.0	45.0
H82	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.7	39.6	44.4	44.4
H83	38.0	38.0	38.0	38.5	39.1	39.6	40.2	41.0	42.2	43.0	45.4	45.4
H84	38.0	38.0	38.0	38.5	39.1	39.6	40.2	41.0	42.2	43.1	45.4	45.4
H85	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
H86	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0

- Table 2: $L_{A90,10min}$ dB Wind Farm Noise Level at all other times:

House ID	Reference Wind Speed, Standardised v_{10} (ms^{-1})											
	1	2	3	4	5	6	7	8	9	10	11	12
H1	35.0	35.0	35.0	35.0	36.3	38.4	40.8	43.3	46.2	49.6	53.5	57.0
H2	35.0	35.0	35.0	35.0	36.3	38.4	40.8	43.3	46.2	49.6	53.5	57.0
H3	35.0	35.0	35.0	35.0	36.3	38.4	40.8	43.3	46.2	49.6	53.5	57.0
H4	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H5	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H6	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H7	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H8	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	38.5	38.5	38.5	38.5
H9	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	38.4	38.4	38.4	38.4
H10	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.0	39.0	39.0	39.0
H11	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.0	39.0	39.0	39.0
H12	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.0	39.0	39.0	39.0
H13	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.0	39.0	39.0	39.0
H14	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.0	39.0	39.0
H15	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.0	39.0	39.0	39.0
H16	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	38.9	38.8	38.8	38.8

H17	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H18	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H19	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.0	39.0	39.0	39.0
H20	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H21	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.0	39.0	39.0	39.0
H22	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H23	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H24	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H25	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H26	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H27	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H28	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H29	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H30	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H31	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H32	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H33	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H34	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H35	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H36	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H37	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H38	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H39	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H40	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H41	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H42	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H43	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H44	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H45	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H46	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H47	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H48	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H49	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H50	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H51	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H52	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H53	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1
H54	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.1	43.3	45.9	48.4	48.4
H55	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.3	45.8	48.4	48.4
H56	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.1	43.3	45.9	48.4	48.4
H57	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.1	43.3	45.9	48.4	48.4
H58	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.1	43.3	45.9	48.4	48.4
H59	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.1	43.3	45.8	48.4	48.4
H60	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.3	45.8	48.4	48.4
H61	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.1	43.3	45.9	48.4	48.4
H62	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.1	43.3	45.8	48.4	48.4
H63	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.3	45.8	48.4	48.4
H64	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.2	45.8	48.3	48.3
H65	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.2	45.8	48.3	48.3
H66	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.3	45.8	48.4	48.4
H67	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.3	45.8	48.4	48.4
H68	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.3	45.8	48.4	48.4
H69	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.3	45.8	48.4	48.4
H70	35.0	35.0	35.0	35.0	35.6	37.2	39.1	40.8	43.1	45.7	48.3	48.3
H71	35.0	35.0	35.0	35.0	35.6	37.2	39.1	41.0	43.3	45.8	48.4	48.4
H72	35.0	35.0	35.0	35.0	35.0	36.7	38.6	39.7	42.2	44.8	47.6	50.7
H73	35.0	35.0	35.0	35.0	35.0	36.7	38.6	39.7	42.2	44.8	47.6	50.7
H74	35.0	35.0	35.0	35.0	35.0	36.7	38.6	39.8	42.3	44.9	47.6	50.7
H75	35.0	35.0	35.0	35.0	35.0	36.7	38.6	39.8	42.2	44.9	47.6	50.7
H76	35.0	35.0	35.0	35.0	35.0	36.7	38.6	39.6	42.1	44.8	47.6	50.7
H77	35.0	35.0	35.0	35.0	35.0	36.7	38.6	39.6	42.1	44.8	47.6	50.7
H78	35.0	35.0	35.0	35.6	37.6	39.4	40.5	42.6	44.7	46.4	47.7	47.7
H79	35.0	35.0	35.0	35.0	35.0	36.7	36.6	35.5	39.9	43.7	47.1	50.4
H80	35.0	35.0	35.0	35.0	35.0	36.7	38.3	38.2	41.3	44.4	47.4	50.6
H81	35.0	35.0	35.0	35.0	35.0	36.7	38.0	37.8	41.0	44.2	47.3	50.6
H82	35.0	35.0	35.0	35.0	35.0	36.7	35.9	34.0	39.3	43.5	46.9	50.4
H83	37.4	37.4	37.7	38.3	39.2	40.1	41.2	42.8	44.7	47.0	49.3	51.7
H84	37.4	37.4	37.7	38.3	39.2	40.1	41.2	42.8	44.8	47.0	49.3	51.7
H85	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	38.9	38.9	38.9	38.9
H86	35.0	35.0	35.0	35.0	35.5	36.4	37.3	38.3	39.1	39.1	39.1	39.1

TABLE OF COORDINATE LOCATIONS OF PROPERTIES

Note to Table 3: The geographical co-ordinates references are provided for the purpose of identifying the general location of dwellings to which a given set of noise limits applies

Table 3: Coordinate locations of the properties listed in Table 1 & 2.

House ID	Co-ordinates	
	X (m)	Y (m)
H1	241069	605637
H2	241176	605676
H3	241216	605634
H4	244706	606400
H5	244742	606304
H6	244698	606235
H7	245184	606134
H8	246254	607361
H9	245847	607678
H10	244390	608119
H11	243918	608517
H12	243691	608590
H13	243825	608632
H14	243588	608680
H15	243811	608691
H16	243831	608719
H17	243657	608786
H18	243620	608813
H19	243598	608878
H20	243527	608940
H21	243424	609110
H22	242828	609536
H23	242564	609551
H24	242537	609575
H25	242468	609604
H26	241962	609281
H27	241932	609378
H28	241879	609388
H29	241827	609431
H30	241810	609468
H31	241793	609520
H32	241771	609557
H33	241711	609636
H34	241707	609654
H35	241698	609689
H36	241667	609718
H37	241623	609770
H38	241623	609836
H39	241561	609938
H40	241411	610086
H41	241522	610000
H42	241418	610185
H43	241385	610247
H44	241324	610435
H45	241272	610451
H46	241240	610493
H47	241216	610547
H48	241174	610606
H49	241165	610657
H50	241123	610666
H51	241048	610741
H52	241090	610754
H53	240062	609994
H54	238625	610696
H55	237659	610874
H56	237755	610001
H57	236885	609477
H58	236942	609426
H59	237548	609201
H60	237479	608915
H61	236507	609296
H62	236516	608629
H63	236196	608648
H64	235977	608016
H65	235948	607992
H66	235901	607851

H67	235979	607787
H68	236139	607710
H69	235944	607700
H70	236320	607472
H71	235814	607555
H72	237363	606687
H73	237419	606668
H74	236905	606433
H75	237813	606067
H76	237951	605922
H77	238012	605847
H78	238700	605583
H79	239181	605501
H80	238599	605369
H81	238795	605048
H82	239300	605093
H83	242959	608133
H84	243039	608066
H85	243315	608463
H86	241468	609442