Environmental Impact Assessment for the proposed Ubuntu Wind Energy Project near Jeffrey's Bay, Eastern Cape:
Final Environmental Impact Assessment Report

Chapter 9: Noise Impacts

Contents

Appendices

Tables

Figures

CHAPTER 9. IMPACT OF NOISE

This Chapter presents the Noise Specialist Study conducted by Safetrain CC (trading as Safetech) under the leadership of Mr Brett Williams, as input to the EIA being conducted by CSIR for the proposed WKN-Windcurrent Ubuntu Wind Energy Project.

9.1 INTRODUCTION & METHODOLOGY

This section presents the approach to the noise assessment. Wind Current Ubuntu is intending to construct a wind energy electricity generation project at Jeffery's Bay, Eastern Cape. The project will consist of three possible turbine types. This study only addresses the noise impact. The study was requested by the CSIR as part of the overall Environmental Impact Assessment for the project.

9.1.1 Methodology

The methodology used in the study consisted of three approaches to determine the noise impact from the proposed project and associated infrastructure:

- A desktop study to model the likely noise emissions from the site;
- Field measurements of the existing ambient noise at different locations in the vicinity of the project; and
- The identification of potential noise sensitive areas.

The desktop study was done using the available literature on noise impacts from wind turbines as well as numerical calculations of the possible noise emissions. A Danish modelling program, EMD WindPro Software Version 2.7 was used and has been developed specifically for wind turbine noise. This program is used extensively worldwide and has been developed and validated in Denmark. The method described in SANS 10357:2004 version 2.1 (The calculation of sound propagation by the Concawe method) was used a reference for further calculations where required.

WindPro uses the methods described in ISO 9613-2 (Acoustics – Attenuation of sound during propagation outdoors. Part 2 – General method of calculation). This method is very similar to SANS 10357:2004 and is used worldwide for modelling noise from various sources including wind turbine generators (Wind turbines). Where a tonal character is identified in the noise emitted from the turbines, a 5 dB(A) penalty is included in the modelling result.

The numerical results were then used to produce "noise maps" that visually indicate the extent of the noise emissions from the site. The noise emissions were modelled for various wind speeds from 4m/s to 12m/s. The direction of the wind is not taken into consideration as the wind could blow from any direction at the speeds that were modelled. The modelling is thus for worst case scenarios and takes the topography around the turbine and noise sensitive area (NSA) into account. The site elevation data was sourced from NASA and imported into WindPro. A comparison was done using the digital elevation data and the contour heights from a 1:50 000 topographical map. The comparison showed that the digital data and the map corresponded well. Furthermore, the digital data provided a better resolution.

Field Study

A number of measurements were taken by placing the noise meter on a tripod and ensuring that it was at least 1.2 m from floor level and 3.5 m from any large flat reflecting surface.

All measurement periods exceeded at least 10 minutes, except where indicated. The noise meter was calibrated before and after the survey. At no time was the difference more than one decibel (If the difference is more than 1 decibel the meter is not calibrated properly and the measurement is discarded). The weighting used was on the A scale and the meter placed on impulse correction, which is the preferred method as per Section 5 of SANS 10103:2008. No tonal correction was added to the data. Measurements were taken during the day and night-time. The meter was fitted with a windscreen, which is supplied by the manufacturer. The screen is designed so as to reduce wind noise around the microphone and not bias the measurements.

The test environment contained the following noise sources:

- Vehicular traffic that included trucks and cars;
- Birds and insects;
- Farm animals;
- Wind noise; and
- Noise from the Chicken houses fans.

The instrumentation that was used to conduct the study is as follows:

- Rion Precision Sound Level Meter (NL32) with 1/3 Octave Band Analyzer Serial No. 00151075;
- Microphone (UC-53A) Serial No. 307806; and
- Preamplifier (NH-21) Serial No. 13814.

All equipment was calibrated in October 2010 (see Appendix 9.2)

9.1.2 Terms of Reference

The Terms of Reference provided by CSIR for this noise study included the following:

Objectives of the noise study:

- Describe the affected environment covered by the scope of the noise specialist study, drawing on existing information, professional experience and limited field work;
- Contribute to the scoping process by identifying issues and concerns that need to be addressed in the specialist study, based on the experience of the specialist;
- Identify relevant protocols, legal and permit requirements (if any); and
- Assess the potential impacts of the project, and provide management actions to avoid/reduce negative impacts or enhance benefits, as well as associated monitoring requirements.

The scope of work of the noise study includes the following:

- Conduct a desktop study of available information that can support and inform the specialist noise study;
- Identify issues and potential impacts, as well as possible cumulative impacts related to the noise aspects of the project;

- Measure the existing ambient noise at the proposed site, during both the day and night time;
- Identify the components of the project that could generate significant noise levels;
- Identify the sensitive noise receptors in the vicinity of the proposed project;
- Conduct a noise study of the predicted (future) noise impacts during construction and operation of the proposed wind farm;
- Assess the potential impacts associated with the proposed project for the construction, operation and decommissioning phases; and
- Identify management and mitigation actions to enhance positive impacts and avoid/reduce negative impacts respectively.

The required EIA end-product from the noise assessment is to provide a comprehensive and detailed Noise Impact Assessment (NIA) that presents and evaluates the noise impact of the wind turbines under different operating conditions. The specialists will be required to assess impacts for the preferred layout and an alternative layout.

9.1.3 Declaration of independence

The declaration of independence by the noise specialist is provided in Box 9.1 below:

BOX 9.1: DECLARATION OF INDEPENDENCE FOR NOISE IMPACT ASSESSMENT

I **Brett Williams** declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed Wind Current Ubuntu Wind Energy Project, application or appeal in respect of which I was appointed, other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

BRETT WILLIAMS

9.2 DESCRIPTION OF THE NOISE IMPACTS

The sources of sounds emitted from operating wind turbines can be divided into two categories, firstly mechanical sounds, from the interaction of turbine components, and secondly aerodynamic sounds, produced by the flow of air over the blades.

9.2.1 Mechanical Sounds

Mechanical sounds originate from the relative motion of mechanical components and the dynamic response among them. Sources of such sounds include:

- Gearbox

- Generator
- Yaw Drives
- Cooling Fans
- Auxiliary Equipment (e.g., hydraulics)

Since the emitted sound is associated with the rotation of mechanical and electrical equipment, it tends to be tonal (of a common frequency), although it may have a broadband component. For example, pure tones can be emitted at the rotational frequencies of shafts and generators, and the meshing frequencies of the gears.

In addition, the hub, rotor, and tower may act as loudspeakers, transmitting the mechanical sound and radiating it. The transmission path of the sound can be air-borne or structure-borne. Air-borne means that the sound is directly propagated from the component surface or interior into the air. Structure-borne sound is transmitted along other structural components before it is radiated into the air.

Figure 9.1 shows the type of transmission path and the sound power levels for the individual components for a 2 MW wind turbine.

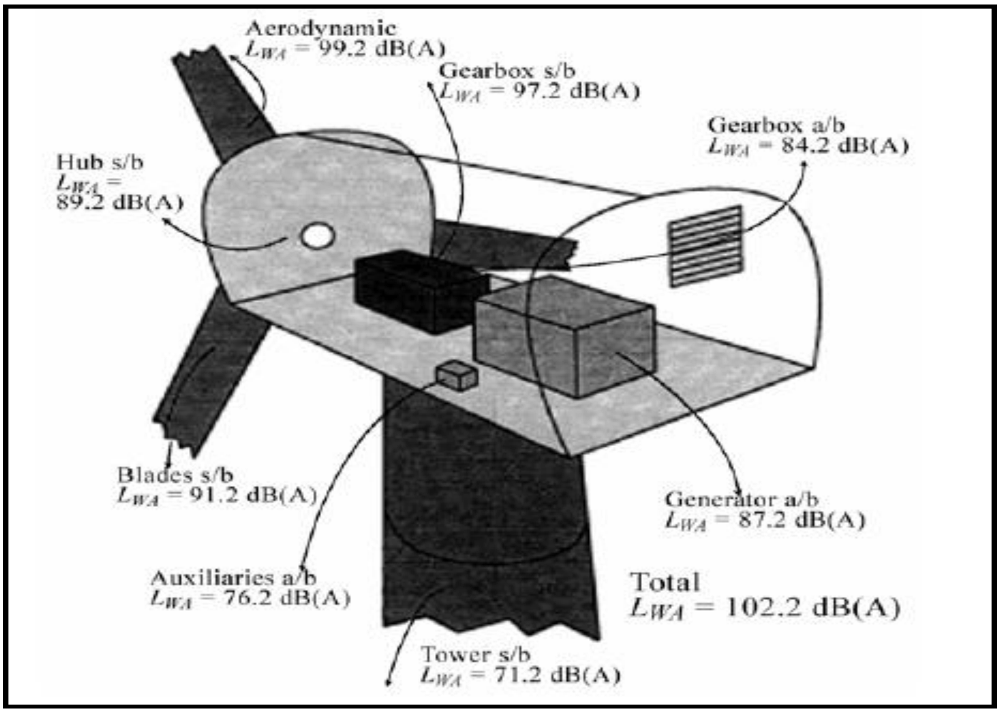

Figure 9.1: Typical Sound Power Levels of a 2 MW Turbine

9.2.2 Aerodynamic Sound

Aerodynamic broadband sound is typically the largest component of wind turbine acoustic emissions. It originates from the flow of air around the blades. A large number of complex flow phenomena occur, each of which might generate some sound (see Figure 9.2). Aerodynamic sound generally increases with rotor speed. The various aerodynamic sound generation mechanisms that have to be considered are divided into three groups:

- *Low Frequency Sound:* Sound in the low frequency part of the sound spectrum is generated when the rotating blade encounters localized flow deficiencies due to the flow around a tower, wind speed changes, or wakes shed from other blades;
- *Inflow Turbulence Sound:* Depends on the amount of atmospheric turbulence. The atmospheric turbulence results in local force or local pressure fluctuations around the blade; and
- *Airfoil Self Noise:* This group includes the sound generated by the air flow right along the surface of the airfoil. This type of sound is typically of a broadband nature, but tonal components may occur due to blunt trailing edges, or flow over slits and holes.

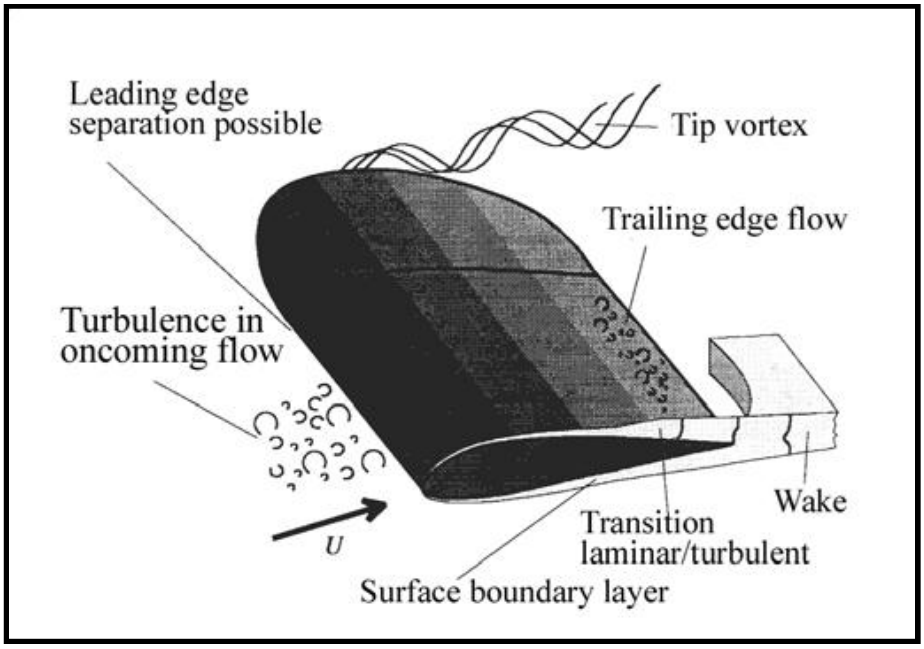

Figure 9.2: Sources of Aerodynamic Noise

Modern airfoil design takes all of the above factors into account and is generally much quieter that the first generation of bade design.

9.2.3 Ambient Sound & Wind Speed

The ability to hear a wind turbine in a given installation depends on the ambient sound level. When the background sounds and wind turbine sounds are of the same magnitude, the wind turbine sound gets lost in the background. Both the wind turbine sound power level and the ambient sound pressure level will be functions of wind speed. Thus whether a wind turbine exceeds the background sound level will depend on how each of these varies with wind speed.

The most likely sources of wind-generated sounds are interactions between wind and vegetation. A number of factors affect the sound generated by wind flowing over vegetation. For example, the total magnitude of wind-generated sound depends more on the size of the windward surface of the vegetation than the foliage density or volume.

The sound level and frequency content of wind generated sound also depends on the type of vegetation. For example, sounds from deciduous trees tend to be slightly lower and more broadband than that from conifers, which generate more sounds at specific frequencies. The equivalent A-weighted broadband sound pressure generated by wind in foliage has been shown to be approximately proportional to the base 10 logarithm of wind speed.

Sound levels from large modern wind turbines during constant speed operation tend to increase more slowly with increasing wind speed than ambient wind generated sound. As a result, wind turbine noise is more commonly a concern at lower wind speeds and it is often difficult to measure sound from modern wind turbines above wind speeds of 8 m/s because the background wind-generated sound masks the wind turbine sound above 8 m/s.

It should be remembered that average sound pressure measurements might not indicate when a sound is detectable by a listener. Just as a dog's barking can be heard through other sounds, sounds with particular frequencies or an identifiable pattern may be heard through background sounds that is otherwise loud enough to mask those sounds. Sound emissions from wind turbines will also vary as the turbulence in the wind through the rotor changes. Turbulence in the ground level winds will also affect a listener's ability to hear other sounds. Because fluctuations in ground level wind speeds will not exactly correlate with those at the height of the turbine, a listener might find moments when the wind turbine could be heard over the ambient sound.

9.2.4 Low Frequency Noise and Infrasound

Infrasound was a characteristic of some wind turbine models that has been attributed to early designs in which turbine blades were downwind of the main tower. The effect was generated as the blades cut through the turbulence generated around the downwind side of the tower. Modern designs generally have the blades upwind of the tower. Wind conditions around the blades and improved blade design minimise the generation of the effect.

Low frequency pressure vibrations are typically categorized as low frequency sound when they can be heard near the bottom of human perception (10-200 Hz), and infrasound when they are below the common limit of human perception. Sound below 20 Hz is generally considered to be infrasound, even though there may be some human perception in that range. Because the ranges of low frequency sound and infrasound overlap it is important to understand how the terms are applied in a given context.

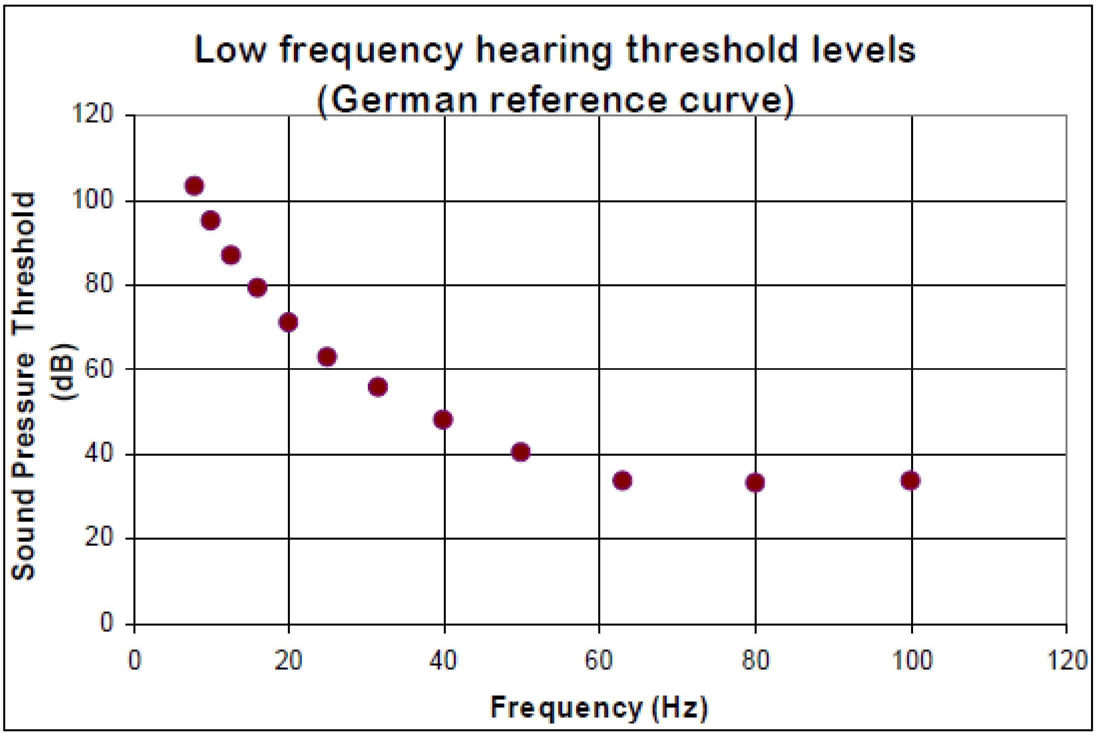

Figure 9.3: **Low frequency Hearing Threshold Levels**

Infrasound is always present in the environment and stems from many sources including ambient air turbulence, ventilation units, waves on the seashore, distant explosions, traffic, aircraft, and other machinery. Infrasound propagates farther (i.e. with lower levels of dissipation) than higher frequencies. To place infrasound in perspective, when a child is swinging high on a swing, the pressure change on its ears, from top to bottom of the swing, is nearly 120 dB at a frequency of around 1 Hz.

Some characteristics of the human perception of infrasound and low frequency sound are:

- Low frequency sound and infrasound (2-100 Hz) are perceived as a mixture of auditory and tactile sensations;
- Lower frequencies must be of a higher magnitude (dB) to be perceived, e.g. the threshold of hearing at 10 Hz is around 100 dB (see Figure 9.4 above);.
- Tonality cannot be perceived below around 18 Hz; and
- Infrasound may not appear to be coming from a specific location, because of its long wavelengths.

The primary human response to perceived infrasound is annoyance, with resulting secondary effects. Annoyance levels typically depend on other characteristics of the infrasound, including intensity, variations with time, such as impulses, loudest sound, periodicity, etc. Infrasound has three annoyance mechanisms:

- A feeling of static pressure;
- Periodic masking effects in medium and higher frequencies;
- Rattling of doors, windows, etc. from strong low frequency components.

Human effects vary by the intensity of the perceived infrasound, which can be grouped into these approximate ranges:

- 90 dB and below: No evidence of adverse effects'
- 115 dB: Fatigue, apathy, abdominal symptoms, hypertension in some humans;
- 120 dB: Approximate threshold of pain at 10 Hz; and
- 120 – 130 dB and above: Exposure for 24 hours causes physiological damage.

There is no reliable evidence that infrasound below the perception threshold produces physiological or psychological effects.

The typical range of sound power level for wind turbine generators is in the range of 100 to 105dBA – a much lower sound power level (10dB or more) than the majority of construction machinery such as bulldozers. In order for infrasound to be audible even to a person with the most sensitive hearing at a distance of, say, 300m would require a sound power level of at least 140dB at 10Hz and even higher emission levels than this at lower frequencies and at greater distances. There is no information available to indicate that wind turbine generators emit infrasound anywhere near this intensity[(2)].

Several studies have confirmed that there are no physiological effects from low frequency or infrasound from wind turbines (Bell Acoustic Consulting, 2004; DEFRA, 2003; DTI, 2006; ISO 9613-2; SANS 10103:2008 Version 6; Swedish Environmental Protection Agency, 2003 and University of Groningen, 2003).

9.3 DESCRIPTION OF THE AFFECTED ENVIRONMENT

The proposed Ubuntu wind energy project is to be constructed on farmland in an area adjacent to the N2 near Jeffrey's Bay located in the Eastern Cape Province of South Africa. The project is planned to host up to 50 turbines. Various options are modelled in this report. The topography surrounding the site is characterised by undulating hills.

9.3.1 Site Location

The location and position of the various wind turbines are contained in the Table 9.1 and Figures 9.4 and 9.5 below.

Table 9.1: Wind Turbine Location Co-ordinates

	Vestas V90		Vestas V112	
WTG Name	X	Y	X	Y
WEA01	307 981.1044	6 242 449.8391	307 938.9502	6 242 531.4075
WEA02	308 080.8166	6 241 829.2690	308 079.1198	6 241 828.4598
WEA03	307 495.0948	6 244 557.7529	307 240.0000	6 244 683.9997
WEA04	307 370.8725	6 243 920.3476	307 323.6601	6 244 004.9575
WEA05	306 391.9497	6 242 073.9916	306 575.0000	6 243 837.9997
WEA06	306 183.1011	6 241 621.3102	306 044.0000	6 243 419.9997
WEA07	305 800.0000	6 241 231.0000	305 897.2196	6 242 754.9884
WEA08	306 999.9015	6 244 315.4135	306 353.3684	6 242 232.7870
WEA09	306 542.4556	6 242 999.3911	305 949.0000	6 241 662.9997
WEA10	306 193.6987	6 242 483.5648	305 601.4494	6 241 054.8451
WEA11	305 515.6978	6 241 752.1822	306 572.0000	6 244 775.9997
WEA12	305 198.3235	6 241 313.4211	306 041.0000	6 244 331.9997
WEA13	306 697.0000	6 244 783.0000	305 393.5238	6 243 595.9074
WEA14	306 545.0000	6 244 085.0000	305 189.6522	6 242 944.5800
WEA15	306 232.2860	6 243 462.3262	305 151.0000	6 242 273.9997
WEA16	305 967.4028	6 242 982.8257	305 139.0718	6 241 563.5391
WEA17	305 628.2354	6 242 558.5007	305 772.1883	6 244 972.6204
WEA18	305 188.6810	6 242 237.7599	305 255.5208	6 244 253.5845
WEA19	304 884.0317	6 241 764.4781	304 733.0000	6 243 435.9997
WEA20	306 134.0000	6 244 864.0000	305 197.6628	6 245 394.9803
WEA21	306 041.0000	6 244 318.0000	304 864.3631	6 244 810.9442
WEA22	305 828.9474	6 243 821.3777	304 495.0340	6 244 081.9997
WEA23	305 494.7057	6 243 256.6391	303 997.6516	6 243 484.9137
WEA24	305 130.9955	6 242 775.8074	304 716.5329	6 245 865.0531
WEA25	305 524.9905	6 244 276.1299	304 217.7385	6 245 284.1391
WEA26	305 622.0000	6 245 084.0000	303 992.0000	6 244 570.9997
WEA27	304 852.1961	6 243 262.8230	303 972.5235	6 245 904.1010
WEA28	305 234.1139	6 243 730.4498	303 491.4114	6 245 416.7417
WEA29	304 694.1775	6 243 798.3980	303 337.6936	6 244 750.6912
WEA30	305 190.4770	6 245 424.0753	303 023.3457	6 244 152.3858
WEA31	304 983.7157	6 244 927.9887	303 354.0000	6 246 149.9997
WEA32	304 707.7771	6 244 377.0725	302 827.0000	6 245 623.9997
WEA33	304 130.0000	6 243 968.0000	302 353.2313	6 245 025.1441
WEA34	303 981.1134	6 243 448.9309	-	-
WEA35	304 784.0000	6 245 816.0000	-	-
WEA36	304 538.0000	6 245 291.0000	-	-
WEA37	304 175.7907	6 244 515.4986	-	-
WEA38	303 683.2229	6 244 280.2406	-	-

	Vestas V90		Vestas V112	
WTG Name	X	Y	X	Y
WEA39	303 236.5010	6 243 801.0602	-	-
WEA40	304 220.7199	6 245 814.8370	-	-
WEA41	304 007.7686	6 245 133.4796	-	-
WEA42	303 599.2441	6 244 757.6284	-	-
WEA43	303 156.6053	6 244 328.1289	-	-
WEA44	303 649.0000	6 245 655.0000	-	-
WEA45	303 226.0000	6 245 266.0000	-	-
WEA46	303 357.0000	6 246 151.0000	-	-
WEA47	302 955.0000	6 245 761.0000	-	-
WEA48	302 557.0000	6 245 368.0000	-	-
WEA49	302 345.9603	6 244 884.2621	-	-
WEA50	302 433.4716	6 244 444.1159	-	-

	Nordex N100		Alternative (Vestas V112)	
WTG Name	X	Y	X	Y
WEA01	307 962.0000	6 242 456.0000	309 308.8803	6 242 547.6027
WEA02	308 079.0000	6 241 828.0000	308 637.2682	6 242 409.9470
WEA03	307 502.0000	6 244 332.0000	308 751.4760	6 241 728.1156
WEA04	306 903.7374	6 243 986.8508	308 561.7655	6 241 052.7479
WEA05	306 982.0000	6 244 789.0000		
WEA06	306 280.0000	6 243 969.0000		
WEA07	306 092.9451	6 243 264.5964		
WEA08	305 929.6099	6 242 658.8928		
WEA09	306 295.1745	6 241 895.0818		
WEA10	305 784.5866	6 241 481.1164		
WEA11	305 206.5567	6 241 287.2637		
WEA12	305 669.2886	6 240 883.4709		
WEA13	306 366.0000	6 244 781.0000		
WEA14	305 840.0000	6 244 433.0000		
WEA15	305 648.3059	6 243 859.9187		
WEA16	305 481.8937	6 243 270.7172		
WEA17	305 151.7507	6 242 735.4551		
WEA18	305 389.4651	6 242 137.3040		
WEA19	304 847.1313	6 241 854.4181		
WEA20	304 603.9672	6 241 305.9008		
WEA21	305 656.0000	6 245 031.0000		
WEA22	305 091.7739	6 244 479.0094		
WEA23	305 043.7455	6 243 872.5598		
WEA24	304 812.8269	6 243 314.5966		
WEA25	305 176.0000	6 245 427.0000		

WEA26	304 741.0000	6 244 977.0000
WEA27	304 485.7086	6 244 434.0209
WEA28	304 469.7160	6 243 820.9537
WEA29	303 983.4187	6 243 450.6598
WEA30	304 717.0000	6 245 865.0000
WEA31	304 198.7163	6 245 308.2102
WEA32	303 969.0000	6 244 739.0000
WEA33	303 725.9071	6 244 181.7724
WEA34	303 973.0000	6 245 904.0000
WEA35	303 491.0000	6 245 417.0000
WEA36	303 357.7480	6 244 669.1508
WEA37	303 023.0000	6 244 152.0000
WEA38	303 354.0000	6 246 150.0000
WEA39	302 827.0000	6 245 624.0000
WEA40	302 353.0000	6 245 025.0000

The positions of the turbines are shown in Figures 9.4 to 9.7 below.

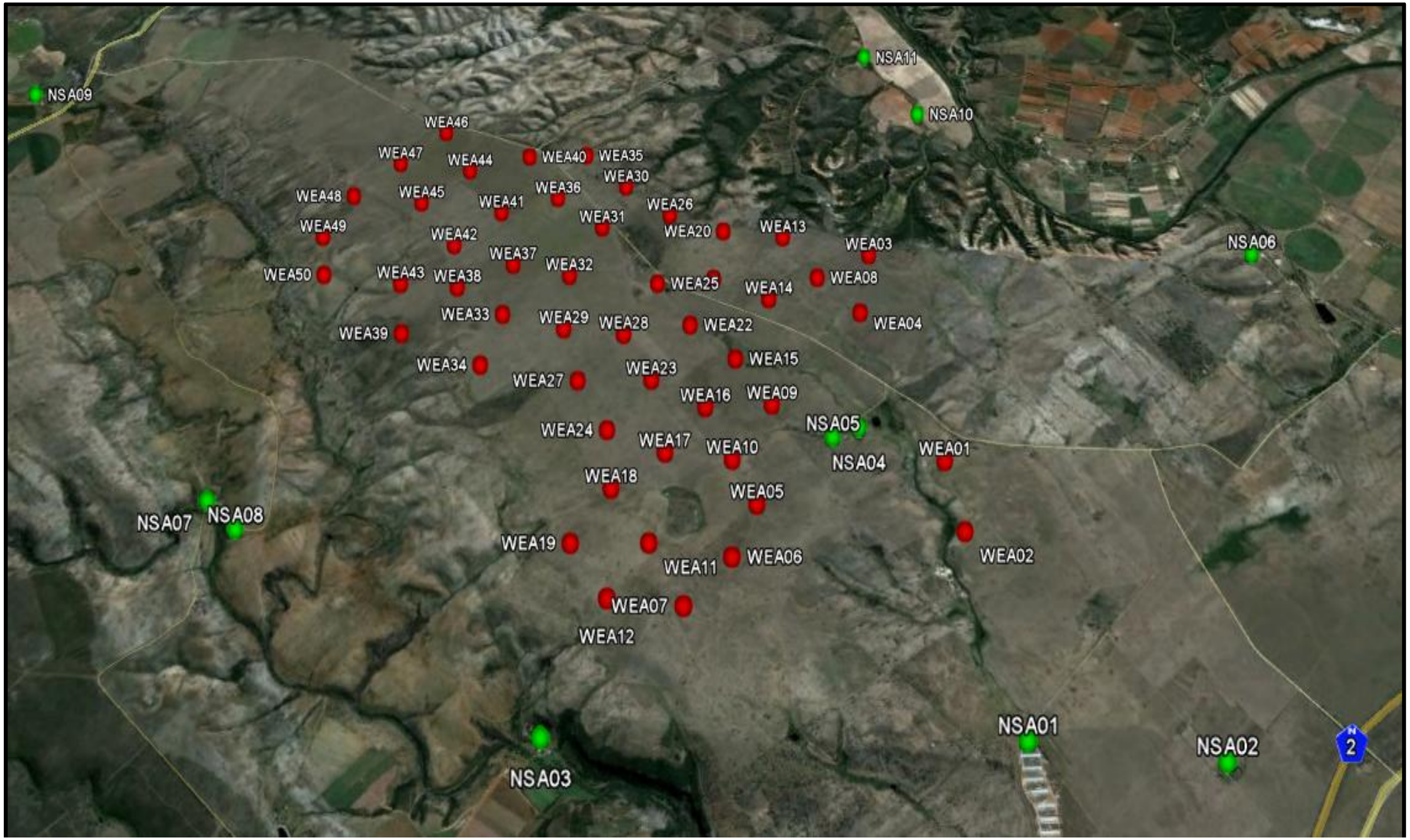

Figure 9.4: Wind turbine locations (Vestas V90)

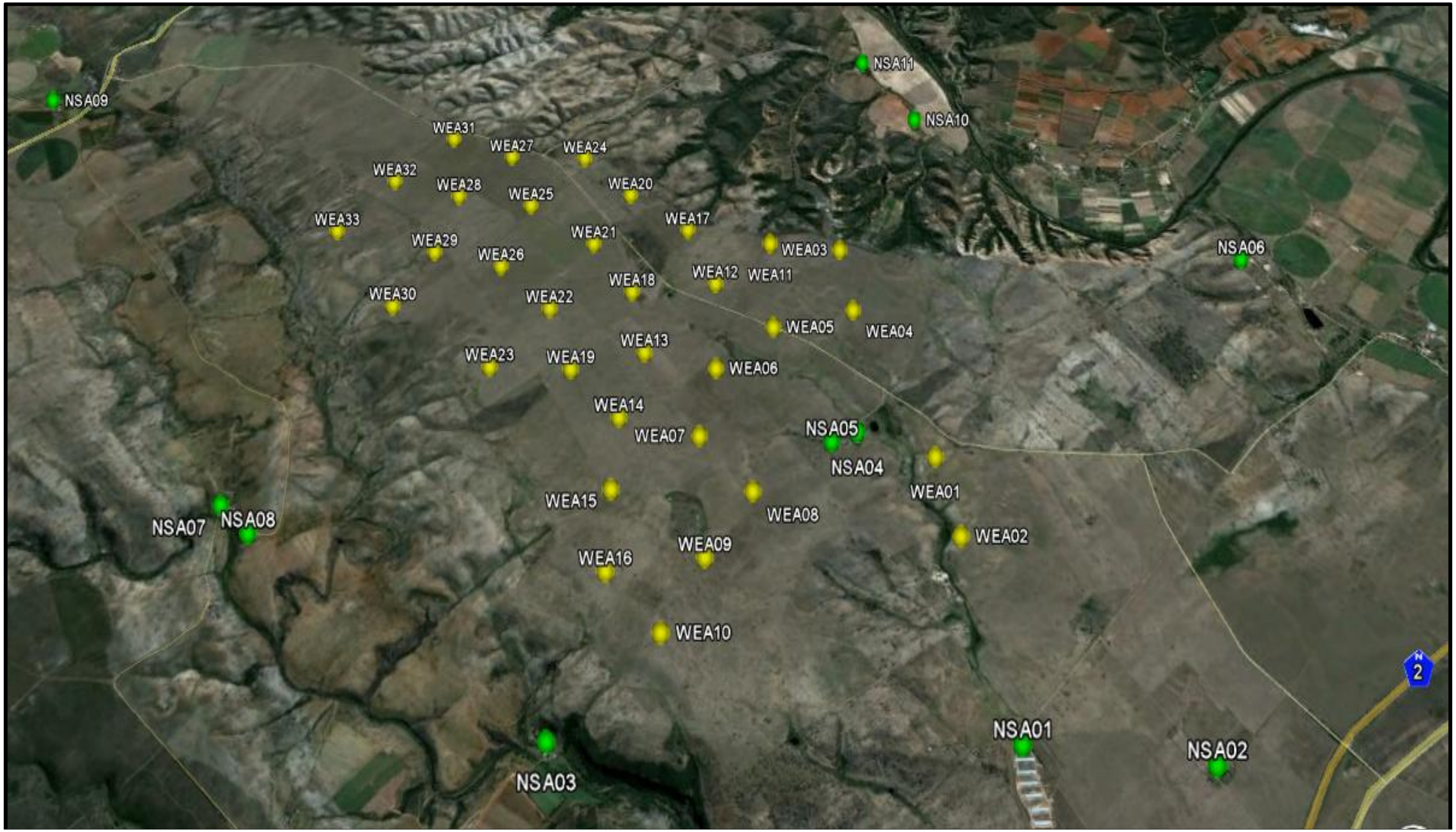

Figure 9.5: **Wind turbine locations (Vestas V112)**

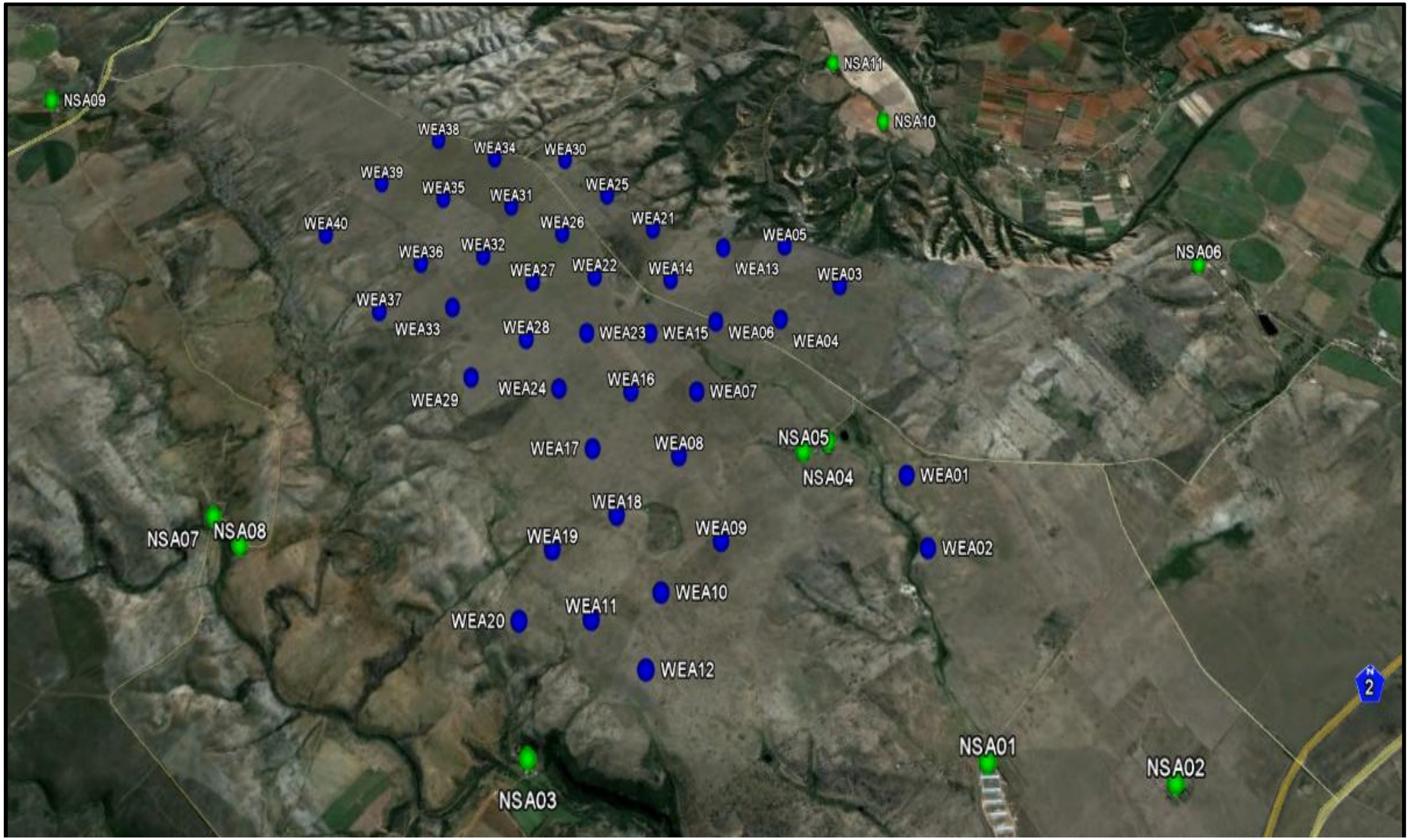

Figure 9.6: **Wind turbine locations (Nordex N100)**

Figure 9.7: Wind turbine locations (Alternative)

The potential sensitive receptors are discussed below. The main noise sensitive receptors that could be affected by noise pollution are the terrestrial fauna, the avifauna and humans. receptors.

9.3.2 Noise Sensitive Areas

Human Sensitive Receptors

The site is situated in a farming community. Several homesteads are located on the properties where the turbines will be erected as well as on neighbouring farms. The sensitive noise receptors have been recorded in Table 9.2 below.

Table 9.2: Noise Sensitive Areas (NSA)

Label	Location Description	X	Y
NSA 1	Chicken Houses	308361	6240217
NSA 2	Homestead	309810	6240044
NSA 3	Homestead	304743	6240331
NSA 4	Homestead	307279	6242780
NSA 5	Homestead	307050	6242688
NSA 6	Homestead	311145	6244610
NSA 7	Homestead	301841	6242270
NSA 8	Homestead	302128	6242012
NSA 9	Homestead	299056	6246784
NSA 10	Homestead	308155	6246537
NSA 11	Homestead	307662	6247375

Natural Environment Receptors

The vegetation around the site is characterised by grassy fynbos with thicket in areas of richer soil. The fauna includes bats, birds, commercial livestock and a variety of buck.

9.3.3 Ambient Noise at Proposed Site

The ambient noise was measured at two locations as described in the methodology and results thereof are contained in Table 9.3 below. The author is confident that this represents the ambient noise at the project site.

Table 9.3: Ambient Noise Results during the day – 12th April 2011

Location	Start Time	Duration (minutes)	Wind (m/s) *(At Microphone)	Temperature (° Celsius) *(At Microphone)	$L_{Req.T}$ dB(A)	Comments
Point 1 (NSA 1)	13:10	10	1.8	21.8	61.4	• Noise from chicken house fans • Vehicles in distance on N2
Point 2 (NSA 4)	14:10	10	1.8	21.1	52.3	• Dog barking • One bakkie

*Author measurements of wind speed and temperature at microphone height (1.2m).

Table 9.4: Ambient Noise Results during the night – 19th April 2011

Location	Start Time	Duration (minutes)	Wind (m/s) *(At Microphone)	Temperature (° Celsius) *(At Microphone)	$L_{Req.T}$ dB(A)	Comments
Point 1 (NSA 1)	22:15	10	2.2	15.3	51.6	• Noise from chicken house fans • Vehicles in distance on N2
Point 2 (NSA 4)	22:55	10	2.1	15.7	45.2	

*Author measurements of wind speed and temperature at microphone height(1.2m).

The general ambient noise at each location varies substantially as the ambient sound is influenced by human activities, vehicles, wind noise and animal sounds.

9.4 IDENTIFICATION OF ISSUES AND IMPACTS

The key issues regarding the noise impact are as follow:

- What is the current noise ambient noise in the vicinity of the proposed project?
- What is the likely noise impact during construction and operation of the site and associated infrastructure?
- Where are local sensitive human receptors located and how is the noise going to affect them?
- Could low frequency sound and infra sound be a problem?

9.5 APPLICABLE LEGISLATION AND STANDARDS

South Africa has noise legislation or standards that could be applied to the project. The draft scoping report has identified that the applicable environmental legislation places a general onus on the developer to ensure that the environment is not affected negatively by the development.

The following legislation and standards have been used to aid the study and guide the decision making process with regards noise pollution:

- South Africa - GNR.154 of January 1992: Noise control regulations in terms of section 25 of the Environment Conservation Act (ECA), 1989 (Act No. 73 of 1989).
- South Africa - GNR.155 of 10 January 1992: Application of noise control regulations made under section 25 of the Environment Conservation Act, 1989 (Act No. 73 of 1989).
- South Africa - SANS 10103:2008 Version 6 - The measurement and rating of environmental noise with respect to annoyance and to speech communication.
- South Africa - SANS 10210:2004 Edition 2.2 – Calculating and predicting road traffic noise.
- South Africa - SANS 10357:2004 Version 2.1 - The calculation of sound propagation by the Concawe method.
- International Finance Corporation – 2007 General EHS Guidelines: Environmental Noise.

SANS 10103:2008 provides typical rating levels for noise in various types of districts, as described in Table 9.5 below. The project is being proposed for a rural district, therefore this is the typical rating level chosen as per the SANS standard.

Table 9.5: Typical rating levels for noise in various types of districts

Type of District	Equivalent Continuous Rating Level, LReq.T for Noise					
	Outdoors (dB(A))			Indoors, with open windows (dB(A))		
	Day-night	Daytime	Night-time	Day-night	Daytime	Night-time
Rural Districts	**45**	**45**	**35**	**35**	**35**	**25**
Suburban districts with little road traffic	50	50	40	40	40	30
Urban districts	55	55	45	45	45	35
Urban districts with one or more of the following: Workshops; business premises and main roads	60	60	50	50	50	40
Central business districts	65	65	55	55	55	45
Industrial districts	70	70	60	60	60	50

SANS 10103:2008 defines Daytime as 06:00 to 22:00 hours and night time as 22:00 to 06:00 hours. The rating levels in the table above indicate that in rural districts the ambient noise should not exceed 35 dB(A) at night and 45 dB(A) during the day or a combination of 45 dB(A) for day/night. These levels can thus be seen as the maximum levels for any noise pollution sources.

Furthermore the South African noise control regulations describe a disturbing noise as **any** noise that exceeds the ambient noise by more than 7 dB. This difference is usually measured at the complainants location should a noise complaint arise. Therefore, if a new noise source is introduced into the environment, irrespective of the current noise levels, and the new source is louder than the existing ambient environmental noise by more than 7 dB, the complainant will have a legitimate complaint.

SANS 10103: 2004 also provides a guideline for expected community responses to excess environmental noise above the ambient noise. These are reflected in table below.

Table 9.6: Categories of environmental community / group response (SANS 10103:2008)

EXCESS Lr dB (A)	ESTIMATED COMMUNITY/GROUP RESPONSE	
	CATEGORY	DESCRIPTION
0 - 10	Little	Sporadic complaints
5 - 15	Medium	Widespread complaints
10 - 20	Strong	Threats of community / group action
> 15	Very Strong	Vigorous community / group action

International Standards

There are various international criteria levels for ambient sound from wind turbines. These are listed below:

- New Zealand – 40 dB(A)
- Denmark – 40 dB(A)
- United Kingdom (L_{A90}) 35 – 40 dB(A)

Australia has set the following limits that wind turbine noise should not exceed:

- 35 dB(A) at relevant receivers in localities which are primarily intended for rural living, or
- 40 dB(A) at relevant receivers in localities in other zones, or
- the background noise (L_{A90}) by more than 5 dB(A)

Germany has set the following standards

- Purely residential areas with no commercial developments 50 dBA (Day) and 35 dBA (Night)
- Areas with hospitals, health resorts, etc. 45 dBA (Day) 35 dBA (Night)

The rationale behind the criteria levels is that the design limit should be 5 dB below the natural ambient limit. This corresponds well with the South African guideline limit of 45 dB for rural districts.

9.6 ASSESSMENT OF IMPACTS AND IDENTIFICATION OF MANAGEMENT ACTIONS

9.6.1 Predicted noise levels for the Construction Phase

9.6.1.1 Construction Equipment

The construction noise at the various sites will have a local impact. Safetech has conducted noise tests at various sites in South Africa and have recorded the noise emissions of various pieces of construction equipment. The results are presented in Table 9.7 below.

Table 9.7: Typical Construction Noise

Type of Equipment	$L_{Req.T}$ dB(A)
CAT 320D Excavator measured at approximately 50 m.	67.9
Mobile crane measured at approximately 70 m	69.6
Drilling rig measured at approximately 70 m	72.6

The impact of the construction noise that can be expected at the proposed site can be extrapolated from the Tables above. As an example, if a number of pieces of equipment are used simultaneously, the noise levels can be added logarithmically and then calculated at various distances from the site to determine the distance at which the ambient level will be reached (refer to *Tables 9.8 - 9.10*).

Table 9.8: Combining Different Construction Noise Sources – High Impacts (Worst Case)

Description	Typical Sound Power Level (dB)
Overhead and mobile cranes	109
Front end loaders	100
Excavators	108
Bull Dozer	111
Piling machine (mobile)	115
Total*	**117**

*The total is a logarithmic total and not a sum of the values (at approximately 3m).

Table 9.9:Combining Different Construction Noise Sources – Low Impacts (at approximately 3m).

Description	Typical Sound Power Level (dB)
Front end loaders	100
Excavators	108
Truck	95
Total	**111**

The information in Tables 9.8 and 9.9 above can then be used to calculate the attenuation by distance. Noise will also be attenuated by topography and atmospheric conditions such as temperature, humidity, wind speed and direction etc. but this is ignored for this purpose. Therefore, the distance calculated below would be representative of maximum distances to reach ambient noise levels.

An illustration of attenuation by distance from a noise of 117 dB measured from the source is presented in Table 9.10 below

Table 9.10: Attenuation by distance for the construction phase (worst case)

Distance from noise source (metres)	Sound Pressure Level dB(A)
10	89
20	83
40	77
80	71
160	65
320	59
640	53
1280	47

What can be inferred from Table 9.10 above is that if the ambient noise level is at 45 dB(A), the construction noise will be similar to the ambient level at approximately 1280 m from the noise source, if the noise characteristics are similar. Beyond this distance, the noise level will be below the ambient noise and will therefore have little impact. The above only applies to the construction noise and light wind conditions. In all likelihood, the construction noise will have little impact on the surrounding community as it will most likely occur during the day when the ambient noise is louder and there are unstable atmospheric conditions.

9.6.2 Low frequency noise concerns

The effects of low frequency noise include sleep disturbance, nausea, vertigo etc. These effects are unlikely to impact upon residents due to the distance between the plant and the nearest communities. Sources of low frequency noise also include wind, train movements and vehicular traffic.

9.6.3 Predicted noise levels for the Wind Turbines Generators

The tables and figures below indicate the isopleths for the noise generated by the turbines at wind speeds from 4 m/s to 12 m/s. The area shaded red in the tables indicates where the recommended limit is exceeded. It must be remembered that as the wind speed increases, so too does the background noise. Therefore the predicted noise levels below 8m/s are of more concern those above 8m/s.

The results below are modelled as follows:

Table 9.11: Table of Results of the Noise Impacts at the Noise Sensitive Areas (NSAs)

NSA 1						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	20.2	22.0	25.0	27.8	Yes
6	45	28.3	29.0	30.4	34.8	Yes
8	45	29.8	31.0	31.6	36.8	Yes
10	45	29.8	31.0	31.6	36.8	Yes
12	45	29.8	31.0	31.6	36.8	Yes

NSA 2						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	16.1	17.9	21.0	22.5	Yes
6	45	24.2	24.9	26.1	29.5	Yes
8	45	25.7	26.9	27.4	31.5	Yes
10	45	25.7	26.9	27.4	31.5	Yes
12	45	25.7	26.9	27.4	31.5	Yes

NSA 3						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	24.2	25.6	30.9	25.7	Yes
6	45	32.3	32.6	36.5	32.7	Yes
8	45	33.8	34.6	37.6	34.7	Yes
10	45	33.8	34.6	37.6	34.7	Yes
12	45	33.8	34.6	37.6	34.7	Yes

NSA 4						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	30.6	32.2	34.2	32.7	Yes
6	45	38.7	39.2	39.8	39.6	Yes
8	45	40.2	41.2	40.9	41.6	Yes
10	45	40.2	41.2	40.9	41.6	Yes
12	45	40.2	41.2	40.9	41.6	Yes

NSA 5						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	31.7	32.1	34.1	32.4	Yes
6	45	39.8	39.1	39.7	39.4	Yes
8	45	41.3	41.1	40.8	41.4	Yes
10	45	41.3	41.1	40.8	41.4	Yes
12	45	41.3	41.1	40.8	41.4	Yes

NSA 6						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	14.6	16.0	19.1	18.0	Yes
6	45	22.7	23.0	24.0	25.0	Yes
8	45	24.2	25.0	25.4	27.0	Yes
10	45	24.2	25.0	25.4	27.0	Yes
12	45	24.2	25.0	25.4	27.0	Yes

NSA 7						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	21.0	21.8	25.3	21.9	Yes
6	45	29.1	28.8	30.6	28.8	Yes
8	45	30.6	30.8	31.8	30.8	Yes
10	45	30.6	30.8	31.8	30.8	Yes
12	45	30.6	30.8	31.8	30.8	Yes

NSA 8						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	21.1	22.0	25.6	22.1	Yes
6	45	29.2	29.0	30.9	29.1	No
8	45	30.7	31.0	32.1	31.1	No
10	45	30.7	31.0	32.1	31.1	No
12	45	30.7	31.0	32.1	31.1	No

NSA 9						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	14.0	15.3	18.3	15.4	Yes
6	45	22.1	22.3	23.3	22.3	Yes
8	45	23.6	24.3	24.6	24.3	Yes
10	45	23.6	24.3	24.6	24.3	Yes
12	45	23.6	24.3	24.6	24.3	Yes

NSA 10						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	20.3	21.8	24.8	22.1	Yes
6	45	28.3	28.8	30.1	29.1	Yes
8	45	29.8	30.8	31.4	31.1	Yes
10	45	29.8	30.8	31.4	31.1	Yes
12	45	29.8	30.8	31.4	31.1	Yes

NSA 11						
Wind Speed [m/s]	Maximum Noise Allowed [dB(A)]	Vestas V90	Vestas V112	Nordex N100	Alternative plus V112	Noise Demand Fulfilled?
4	45	18.9	20.5	23.6	20.7	Yes
6	45	27.0	27.5	28.8	27.7	Yes
8	45	28.5	29.5	30.1	29.7	Yes
10	45	28.5	29.5	30.1	29.7	Yes
12	45	28.5	29.5	30.1	29.7	Yes

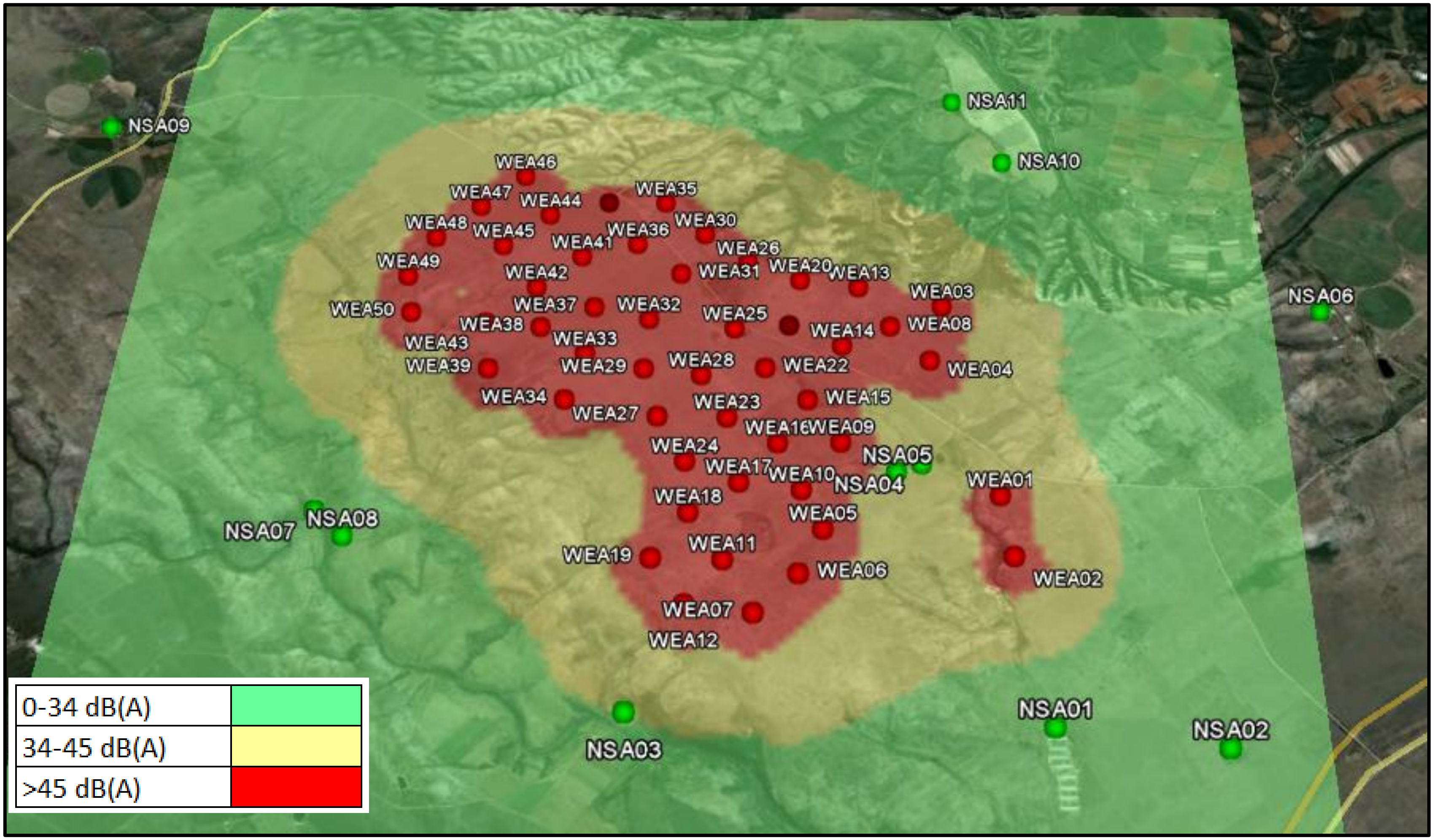

Figure 9.8: **Raster Image of Noise Isopleths & Noise Sensitive Areas (Vestas V90 at 8m/s)**

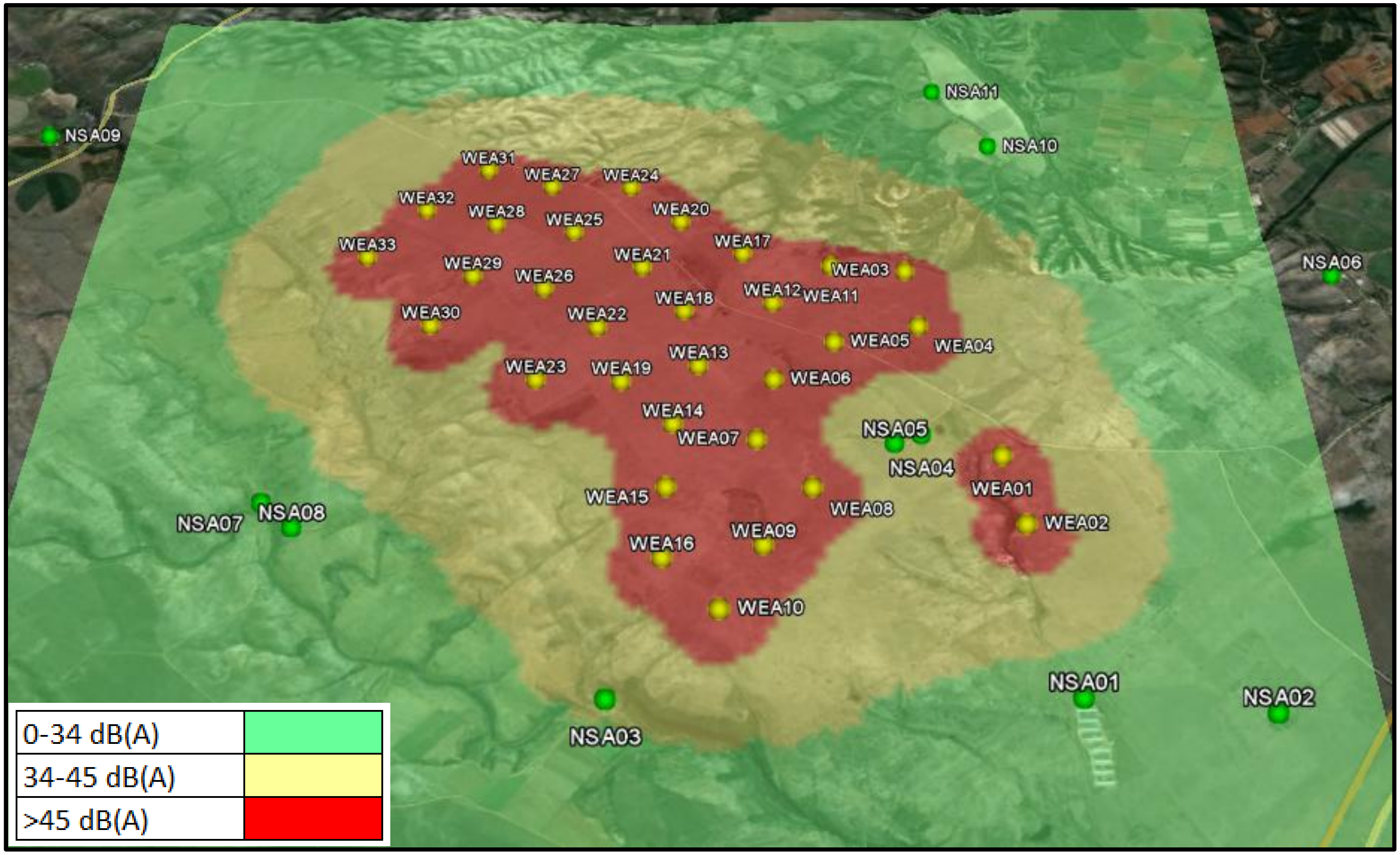

Figure 9.9: Raster Image of Noise Isopleths & Noise Sensitive Areas (Vestas V112 at 8m/s)

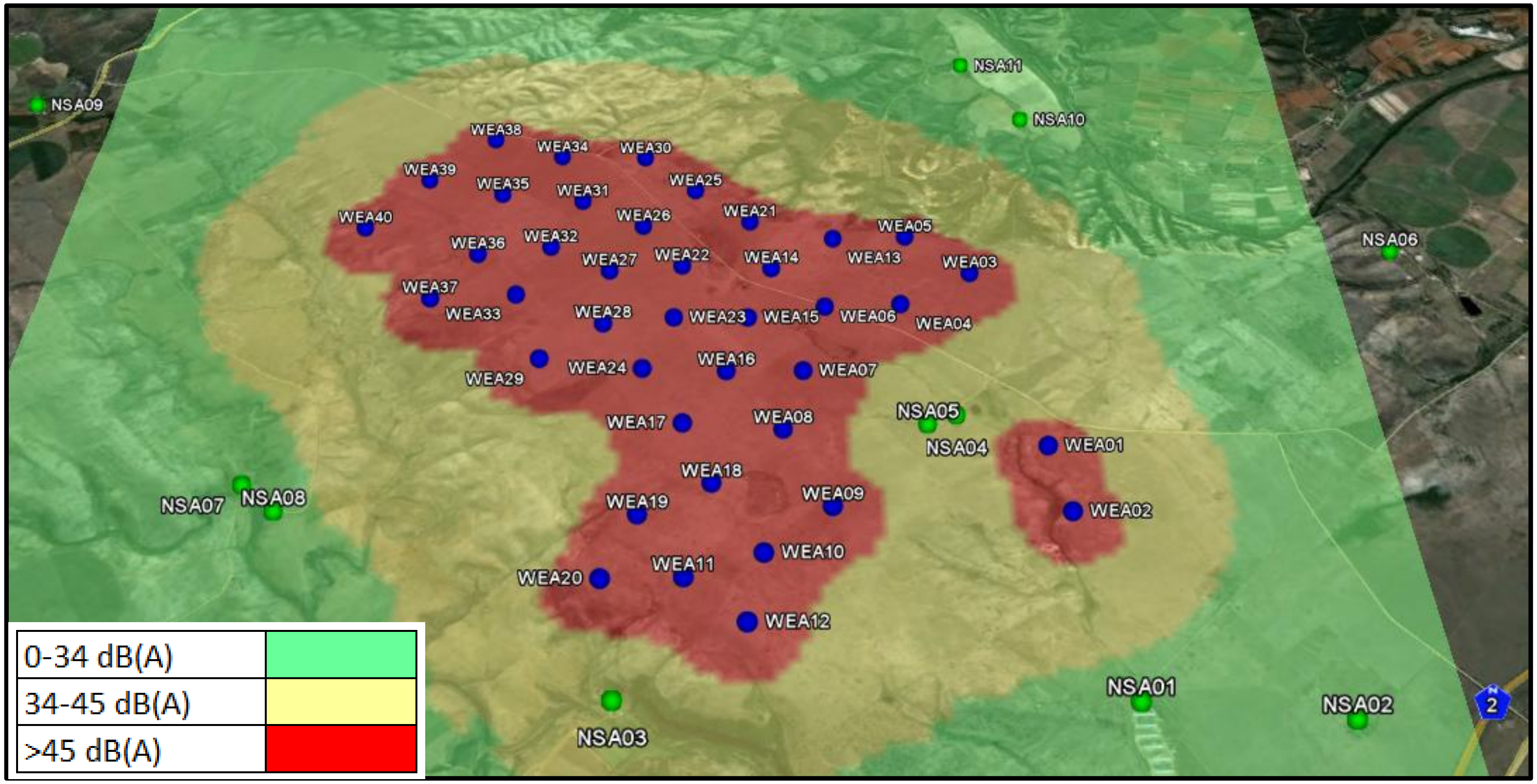

Figure 9.10: Raster Image of Noise Isopleths & Noise Sensitive Areas (Nordex N100 at 8m/s)

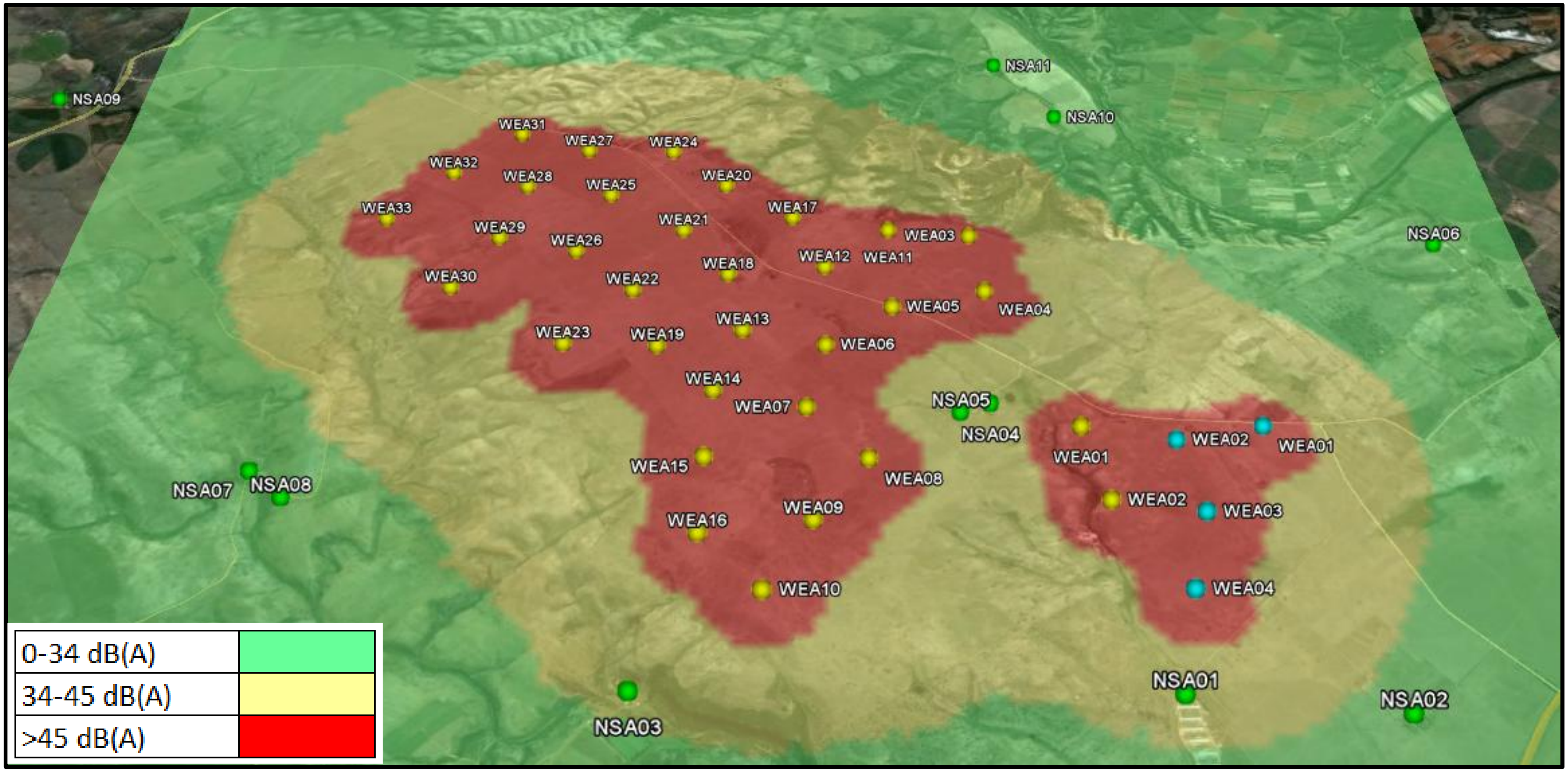

Figure 9.11: **Raster Image of Noise Isopleths & Noise Sensitive Areas (Alternative WTG's at 8m/s)**

9.6.4 Assessment of Noise Impacts

The impact of the noise pollution that can be expected from the site during the construction and operational phases is presented below. A summary of the noise impact assessment using the standard assessment criteria is provided in Tables 9.12 – 9.14.

9.6.4.1 Assessment and mitigation for Construction Phase

1) There will be an impact on the immediate surrounding environment from the construction activities, especially if pile driving is to be done. This, however, will only occur if the underlying geological structure requires piling.
2) The area surrounding the construction site will be affected for a short periods of time in all directions by construction noise impacts, should several pieces of construction equipment be used simultaneously.
3) The number of construction vehicles that will be used in the project will add to the existing ambient levels and will most likely cause a disturbing noise, albeit for a short period of time.

In conclusion, there will be a short term increase in noise in the vicinity of the site during the construction phase as the ambient noise level will be exceeded. The impact during the construction phase will be difficult to mitigate. The significance of the construction noise impact is predicted to be ***low*** (without mitigation).

The following **mitigation measures** are recommended for construction activities:

- All construction operations should only occur during daylight hours, if possible.
- No construction piling should occur at night. Piling should only occur during the hottest part of the day to take advantage of unstable atmospheric conditions.
- Construction staff should be given “noise sensitivity” training in order to mitigate the noise impacts caused during construction.

9.6.4.2 Assessment and mitigation for Operational Phase

The ambient noise increases as the wind speed increases. Under very stable atmospheric conditions, a temperature inversion or a light wind, the turbines will in all likelihood not be operational as the cut-in speed is 4 m/s. As the wind speed increases above the cut-in speed the ambient noise will also increase. If the atmospheric conditions are such that the wind is very light (<4 m/s) at ground level but exceeds the cut-in speed at hub height i.e. the turbines will begin to operate, it is feasible that little ambient noise masking will occur. As the wind speed increases, the ambient noise also increases and masks the wind turbine noise. The critical wind speeds are thus between 4-6 m/s when there is little possibility of masking. Above 8m/s the wind noise starts masking the wind turbine noise. The noise modelling indicates that, in general, noise from the turbines will be below the SANS10103 limits for rural areas at a distance of approximately 500 m from the turbines.

The results indicate the following:

Table 9.12: Summary of Noise Impacts (Vestas V90)

Wind Speed	NSA 1	NSA 2	NSA 3	NSA 4	NSA 5	NSA 6	NSA 7	NSA 8	NSA 9	NSA 10	NSA 11
4m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

NSA = Noise Sensitive Area
✓ = Within Recommended Noise Limits
X = Exceeds 45 dB (A) Rural Recommended Limit

Table 9.13: Summary of Noise Impacts (Vestas V112)

Wind Speed	NSA 1	NSA 2	NSA 3	NSA 4	NSA 5	NSA 6	NSA 7	NSA 8	NSA 9	NSA 10	NSA 11
4m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

NSA = Noise Sensitive Area
✓ = Within Recommended Noise Limits
X = Exceeds 45 dB (A) Rural Recommended Limit

Table 9.14: Summary of Noise Impacts (Nordex N100)

Wind Speed	NSA 1	NSA 2	NSA 3	NSA 4	NSA 5	NSA 6	NSA 7	NSA 8	NSA 9	NSA 10	NSA 11
4m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

NSA = Noise Sensitive Area
✓ = Within Recommended Noise Limits
X = Exceeds 45 dB (A) Rural Recommended Limit

Table 9.15: Summary of Noise Impacts (Alternative layout plus All Vestas V112 Turbines)

Wind Speed	NSA 1	NSA 2	NSA 3	NSA 4	NSA 5	NSA 6	NSA 7	NSA 8	NSA 9	NSA 10	NSA 11
4m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12m/s	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

NSA = Noise Sensitive Area
✓ = Within Recommended Noise Limits
X = Exceeds 45 dB (A) Rural Recommended Limit

The results indicate the following:

- The Vestas V90 did not exceed the 45 dB(A) guideline at any of the identified noise sensitive sources.
- The Vestas V112 did not exceed the 45 dB(A) guideline at any of the identified noise sensitive sources.
- The Nordex N100 did not exceed the 45 dB(A) guideline at any of the identified noise sensitive sources.
- The Vestas V112 and the additional 4 turbines known as the alternative layout did not exceed the 45 dB(A) guideline at any of the identified noise sensitive sources.

All the turbine positions met the required 500m setback distance.

9.6.5 Recommendations

The results of the study indicate that the following conclusions can be drawn:

- There will be a short term increase in noise in the vicinity of the site during construction as the ambient level will be exceeded. The impact during construction will be difficult to mitigate.
- The impact of low frequency noise and infra sound will be negligible and there is no evidence to suggest that adverse health effects will occur as the sound power levels generated in the low frequency range are not high enough to cause physiological effects.

The following is recommended:

9.6.5.1 Construction Activities

- All construction operations should only occur during daylight hours if possible.
- No construction piling should occur at night. Piling should only occur during the hottest part of the day to take advantage of unstable atmospheric conditions.
- Ensuring that construction staff is given "noise sensitivity" training.

9.6.5.2 Operational Activities

Ambient noise monitoring is recommended at all noise sensitive areas once the turbines are erected. This is to determine whether or not the noise rating limits are being exceeded.

9.7 IMPACT ASSESSMENT RATING TABLE

Table 9.16: Table of impact assessment rating

Nature of impact	Status (Negative or positive)	Extent	Duration	Intensity	Probability	Significance (no mitigation)	Mitigation/Management Actions	Significance (with mitigation)	Confidence level
Construction Phase									
1.1 Impact of the construction noise on the Noise Sensitive Areas (NSAs)	Negative	**Local**, given impact is limited to one NSA at a time.	**Short**, only for the duration of the construction (approx 22 months**)**	**Low** no change in the environment is expected	**Improbable,** based on calculations	**Low**	Staff to receive noise sensitivity training; Monitoring of noise; Limit high noise activities to daytime operations when possible, noting that operational requirements might not allow this due to various factors e.g. Crane use optimization, weather conditions etc.	**Low**	**High**, since based on actual measurements
Operational Phase									
1.1 Impact of the operational noise on the Noise Sensitive Areas (NSAs) using the Vestas V90, Vestas V112, Nordex N100 and the alternative lyout.	Negative	**Local**, given impact is limited to a one NSA at a time.	**Long Term**	**Low** – no change in the environment is not expected	**Probable**, based on calculations	**Low**	Ensure that noise monitoring is conducted during the commissioning phase to determine the actual noise impact during operation.	**Low**	**High**, since based on modelling and ambient measurements

9.8 MONITORING ACTIONS

Table 9.17: Table of monitoring actions (Construction)

Impact	Mitigation/Management action	Monitoring		
		Methodology	Frequency	Responsibility
Reduce construction noise	Conduct noise sensitivity training for all construction staff	Training	Before construction commences	Contractor
Monitor construction noise	Ambient noise monitoring to be conducted at the 11 NSAs as well as any other areas the specialist bird study will identify.	As per the requirements of SANS 10103	Four times during the construction phase	Specialist noise consultant

Table 9.18: Table of monitoring actions (Operation)

Impact	Mitigation/Management action	Monitoring		
		Methodology	Frequency	Responsibility
Reduce operational noise	Ambient noise monitoring to be conducted at the 11 NSAs when operations commence to verify the noise emissions meet the noise rating limit.	As per the requirements of SANS 10103	During project commissioning	Specialist noise consultant
Reduce operational noise	Confirm the noise impact by conducting monitoring.	As per the requirements of SANS 10103	Monitoring to be done at three NSA's per year over a 3 year period to confirm that the actual noise complies with the predicted noise levels in the EIA. The monitoring to be done in the first year in the month that shows the most wind production from the historical data available. The monitoring to be done in the second year in the month that shows the least wind production from the historical data available. The monitoring to be done in the third year in the month that shows the "average" wind production from the historical data available.	Specialist noise consultant

a) Ambient noise monitoring to be conducted at the 11 NSAs when operations commence to verify the noise emissions meet the noise rating limit.

9.9 CONCLUSIONS

Provided that the mitigation measures presented in the noise specialist study are implemented effectively, the noise from the turbines at the identified noise sensitive areas is predicted to be less than the 45 dB(A) limit for rural areas presented in SANS 10103:2008. The overall noise impact with recommended mitigation is expected to be negative and of **Low** significance.

9.10 APPENDICES

Appendix 9.1: AIA Approval Certificate

DEPARTMENT
OF LABOUR

Certificate

This is to certify that

SAFETRAIN CC
TRADING AS T\A SAFETECH

has been approved as an

APPROVED INSPECTION AUTHORITY

in terms of the Occupational Health and Safety Act, 1993, for the monitoring of

Physical Stress Factors and Chemical Stress Factors (including Lead and Asbestos, Ergonomic hazards and Ventilation Installation) and Biological Factors

2009-08-27

DATE

CI 049 OH

CERTIFICATE NUMBER

CHIEF INSPECTOR

Appendix 9.2: Calibration Certificate

sanas
Calibration Laboratory
148 1302

M AND N ACOUSTIC SERVICES CC
VAT NO: 4300255876
P.O. Box 61773
Pierre van Ryneveld
0045
Co. Reg. No: 2009/079193/23
Tel: 012 689 2007/8
Fax: 086 211 4690
E-mail: calservice@mweb.co.za

CERTIFICATE OF CALIBRATION

CERTIFICATE NUMBER	2010-1352
ORGANISATION	SAFETRAIN T/A SAFETECH
ORGANISAION ADDRESS	P.O. BOX 27607, GREENACRES, PORT ELIZABETH, 6057
CALIBRATION OF	INTEGRATING SOUND LEVEL METER, ½" MICROPHONE and ⅓-OCTAVE/OCTAVE FILTER CARD
CALIBRATED BY	M.W. DE BEER
MANUFACTURER	RION
MODEL NUMBERS	NL-32, UC-53 and NX-22RT
SERIAL NUMBERS	00151075, 12930 and 00150957 V2.2
DATE OF CALIBRATION	19 OCTOBER 2010
RECOMMENDED DUE DATE	OCTOBER 2011
PAGE NUMBER	PAGE 1 OF 4

This certificate is issued in accordance with the conditions of approval granted by the South African National Accreditation System (SANAS). This Certificate may not be reproduced without the written approval of SANAS and M and N Acoustic Services.

Calibrations performed by this laboratory are in terms of standards, the accuracies of which are traceable to national measuring standards as maintained by NMISA

The measurement results recorded in this certificate were correct at the time of calibration. The subsequent accuracy will depend on factors such as care, handling, frequency of use and the amount of different users. It is recommended that re-calibration should be performed at an interval, which will ensure that the instrument remains within the desired limits and/or manufacturer's specifications.

The South African National Accreditation System (SANAS) is member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). This arrangement allows for mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org

20 October 2010

M.W. DE BEER (SANAS TECHNICAL SIGNATORY) DATE OF ISSUE

Only Member : Marianka Naudé

Appendix 9.3: Typical Sound Power and Sound Pressure Levels

Acoustic Power	Degree		Pressure Level	Source
32 GW	Deafening		225 dB	12" Cannon @ 12ft in front and below
25 to 40 MW			195 dB	Saturn Rocket
100 Kw			170 dB	Turbojet engine with afterburner
10 Kw			160 dB	Turbojet engine, 7000lb thrust
1 kW			150 dB	4 Propeller Airliner
100 W			140 dB	Artillery Fire
10 W	Threshold of pain		130 dB	Pneumatic Rock Drill
				130 dB causes immediate ear damage
3 W			125 dB	Small aircraft engine
1.0 W			120 dB	Thunder
100 Mw			110 dB	Close to train
10 mW	Very Loud		100 dB	Home lawn mower
1 mW			90 dB	Symphony or a Band
				85 dB regularly can cause ear damage
100 uW	Loud		80 dB	Police whistle
10 uW			70 dB	Average radio
1 uW	Moderate		60 dB	Normal conversational voice
100 nW			50 dB	Quiet stream
10 nW	Faint		40 dB	Quiet conversation
1 nW			30 dB	Very soft whisper
100 pW	Very faint		20 dB	Ticking of a watch
10 pW	Threshold of hearing		10 dB	
1 pW			0 dB	Absolute silence

Sound Perception

Change in Sound Level	Perception
3 dB	Barely perceptible
5 dB	Clearly perceptible
10 dB	Twice as loud