Bonney Downs Fauna Noise Impact Study

Fauna Noise Impacts

Prepared for Fortescue

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Table of Contents

Tables

Figures

Appendices

1 Introduction

1.1 Project Overview

Fortescue are proposing to construct and operate a large-scale wind farm containing up to 201 Wind Turbine Generators (WTG's), located within the Bonney Downs Pastoral Lease, approximately 130 km north of Newman in the Pilbara Region of Western Australia.

1.2 Traditional Owner Concerns

During consultation with the Palyku Traditional Owners, concerns were raised regarding the effects of WTG noise on culturally significant animals, including kangaroos, emus, and echidnas. A summary of their concerns for an operational wind farm's impact on fauna are as follows:

- The ability for grazing animals to detect approaching predators such as dingoes (i.e. the approaching predator's noise is masked by the WTG noise).

- Continuous noise from the WTG's will cause behavioural changes, including potentially driving away culturally significant animals. This would have a serious impact on the availability of species hunted for food upon which the broader Palyku and indigenous communities still relies.

1.3 Aim

The aim of this briefing note is to quantify the received noise levels and potential impacts of WTG noise levels on identified culturally significant animals (including kangaroos, emus and echidnas).

1.4 Applicable Documents

[1] Environment Protection and Biodiversity Conservation Act 1999

[2] Activity of primary auditory neurons in the cochlear ganglion of the emu Dromaius novaehollandiae: Spontaneous discharge, frequency tuning, and phase locking.

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[27] ASA S3/SC1.4 TR-2014, ‘Sound Exposure Guidelines for Fishes and Sea Turtles’, A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI.

[28] Cooper, et al, Sound production by the short-beaked echidna (Tachyglossus aculeatus). Journal of Zoology. 2023, 321, 302–308.

2 Physiological and Behavioural Effects of Noise on Fauna

2.1 Overview

Human development, such as wind farms, results in the introduction of noise sources into the environment. The impacts of these introduced noise sources on wildlife are not well studied. The studies that have been undertaken indicate that there can be impacts from noise on wildlife species at both individual and population levels.

Some of the effects of noise include the ability of fauna to communicate and reproduce. It can also result in changes in community dynamics and behaviour ([9],[13],[15]). Chronic exposure to anthropogenic noise can decrease fitness by the repeated activation of stress responses [10]. Noise exposure experiments on captive animals and humans have demonstrated negative effects on immunosuppression and reproductive function; these effects have been suggested as a possible outcome for animals living in the wild ([11], [12]). A summary of possible social behaviour and physiology effects due to noise are as follows:

- **Hearing damage (Permanent Threshold Shift).** Permanent, irreversible loss of hearing sensitivity.
- **Temporary reduction in hearing sensitivity (Temporary Threshold Shift).** Short-term loss of hearing ability following exposure.
- **Communication.** Noise can mask vocalisations or force animals to shift the frequency, timing, or amplitude of their calls, leading to reduced efficiency in mate attraction, parental care, group coordination, and alarm signalling.
- **Socialisation.** Disruption of acoustic cues may fragment groups, reduce cohesion, and increase isolation of individuals, which in turn can affect cooperative behaviours and predator avoidance.
- **Stereotypic behaviour.** Animals may exhibit repetitive, non-functional behaviours (e.g. pacing, circling) in response to chronic disturbance, indicating stress or frustration.
- **Reproduction.** Noise may reduce mating success by masking reproductive signals, increasing energetic costs during courtship, or elevating stress hormones that impair fertility and parental investment.
- **Immunology.** Chronic stress from noise exposure can suppress immune responses, increasing susceptibility to disease and lowering overall resilience of populations.
- **Additional stress.** Heightened vigilance and altered activity budgets reduce time available for feeding, resting, and caring for young, thereby lowering individual fitness.
- **Depression.** Prolonged exposure can lead to signs of behavioural depression—reduced exploration, lethargy, and withdrawal—that negatively affect survival and reproduction.

2.2 Hearing Physiology

2.2.1 Emu (Avian Ear)

Birds have an outer ear that consists of a short external passage (normally hidden under the feathers at the side of the head). Most birds have a muscle in the skin around the opening that can partially or completely close. The external passage ends at the tympanic membrane (i.e. ear drum). From the inner surface of the tympanic membrane a cartilaginous columella transmits vibrations to the cochlea (see Figure 2-1).

The avian cochlea consists of a short, slightly curved bony tube within which the basilar membrane with its sensory structures are located. At the end of the cochlea is another ending with a different function, the lagena and its macula which are receptors of the vestibular system responsible for balance and spatial orientation.

2.2.2 Mammalian Ear (Kangaroo and Echidna)

The mammalian ear has well-differentiated divisions of outer ear, middle ear, and inner ear. The outer ear consists of pinna located behind the ear opening. The pinna's purpose is to 'collect' and reflect sounds. Many mammals, including kangaroos but not echidnas, can move the pinna back and forth to determine the direction from which a sound is coming. The pinna acts as a conduit for noise to travel to the tympanic membrane.

The mammalian middle ear consists of a tympanic membrane (i.e. ear drum), an ossicular chain of three elements, and two tympanic muscles. The tympanic membrane bulges inward, unlike the usually outward-bulging membrane of reptiles and birds. The elements in the ossicular chain called the hammer, anvil, and stapes, named because of their resemblance to these objects. The hammer is attached to the tympanic membrane. It connects to the anvil, which connects in turn to the stapes, the footplate of which lies in the oval window of the cochlea (see Figure 2-1)..

One tympanic muscle extends from an attachment to the skull to an insertion on the hammer. Another muscle has its insertion on the neck of the stapes. Both muscles can contract, and they add friction and stiffness to the ossicular chain, thereby reducing its mobility and protecting the inner ear from excessive sounds. Contraction of the muscles is a reflex action and occurs in both ears at the same time in response to loud sounds.

The inner ear is called the cochlea which is a structure consisting of a complex coiled tube.[1] In mammals, the number of turns in the cochlea varies with species from a little less than one to as many as four. Extending along the inside of this coiled passage is the basilar membrane with the organ of Corti on its surface that contains the hair cells which is the sensory structure of the ear. The hair cells are connected to the auditory nerve which connects the ear to the brain. Vibratory movements of the basilar membrane causes the bodies of the hair cells to move, exciting an electrical response in the auditory nerve.

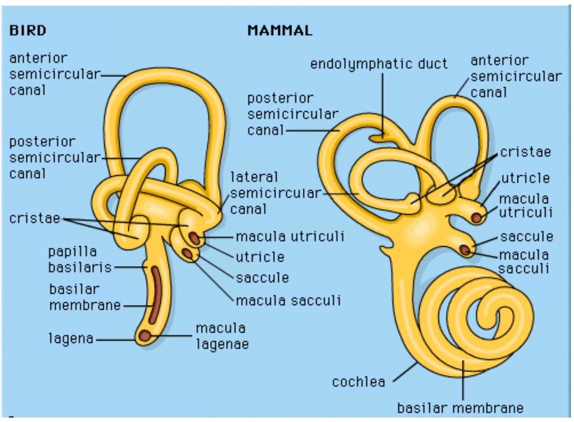

Figure 2-1: Cochlea Avarian (left) and Mammalian structures (right)

[1] The name *cochlea* has now been extended to include the auditory portion of the labyrinth in all animals, even when the structure is not coiled, as in reptiles, birds, and egg-laying mammals.

3 Hearing Bandwidths and Sensitivity

3.1 Emus

An emu audiogram based on measured data is shown in Figure 3-1 [3]. The audiogram shows emus can hear from very low frequencies up to maximum frequency of 4 kHz. Their hearing is most sensitive between 600 and 700 Hz with hearing sensitivity decreasing either side.

Conclusion: The emu's hearing bandwidth is within the spectrum of noise produced by WTGs.

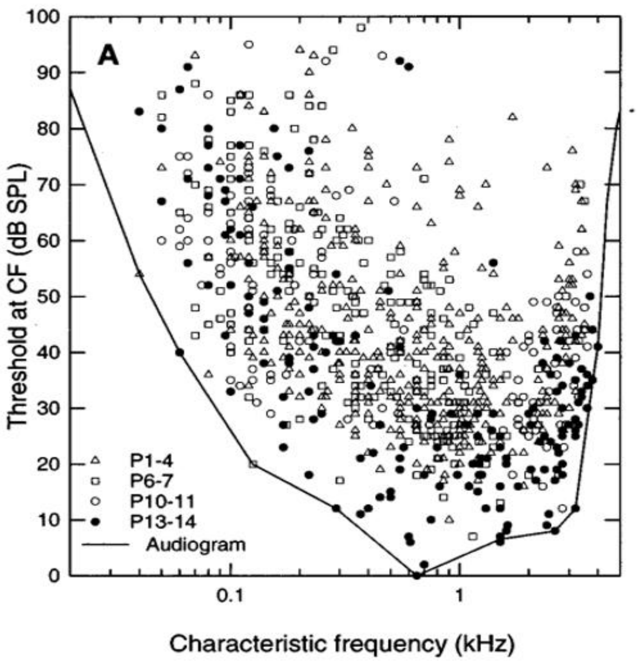

Figure 3-1: Emu scattergram thresholds for four age groups P1–P4; P6,7; P10,11; P13,14 (coded using different symbols). The continuous line is an emu "audiogram".

3.2 Kangaroos

No audiogram data could be found in the public domain for kangaroos. Data was found for a wallaby showing that wallabies (and by inference Kangaroos) have an auditory gain (Figure 3-2) and directivity (Figure 3-3) that is offered by the shape of the ears [5]. This data has been used as proxy data for a kangaroo. It has therefore been assumed that kangaroos are likely to have a hearing bandwidth between 600 Hz and 30 kHz[2] with the hearing being most sensitive between 4 and 6 kHz. The directivity patterns show that the pinna offers an additional 25 to 30 dB gain at these frequencies by making the ear able to amplify sounds in this bandwidth.

[2] **Note:** Figure 3-2 shows the gain of the pinna and is not necessary an indication of the hearing bandwidth especially at low frequencies where it is expected that the gain will be 0dB.

The assumptions are collaborated by research on kangaroo vocalisations [6]. It was found that the isolation or contact call of kangaroos[3] (i.e. provides a means for the mother to locate her offspring) consists of a series of pulses that occur in quick succession, 50-100 ms apart. Kangaroos use their ears to locate the source of a sound by comparing differences of intensity, phase and time of arrival of the sound reaching the ears (similar to humans).

The calls have a broad frequency range which provides both high frequencies for intensity comparisons and a wide range of frequencies for phase comparisons. The call is between 65-75 dB @ 1 m (the lower limit of 65 dB is like human speech, and the upper limit is similar to human shouting). In addition, the relative complexity of the call will make it more distinguishable from background noise generated from wind and wind-agitated vegetation. The dominant frequency range within the call is between 1 and 5 kHz. Based on the available information, kangaroo hearing is at least within the upper limit of wind turbine noise.

Assessing the impact of noise on the high frequency aspects of Kangaroo hearing (i.e. > 20kHz) is not possible as all noise measurement devices are limited to noise within the human range of hearing between 20 Hz and 20 kHz. As there is no noise data measured at frequencies > 20 kHz, the hearing curve assessed is limited to 20 kHz.

Conclusion: The kangaroo's hearing bandwidth is within the spectrum of noise produced by WTGs.

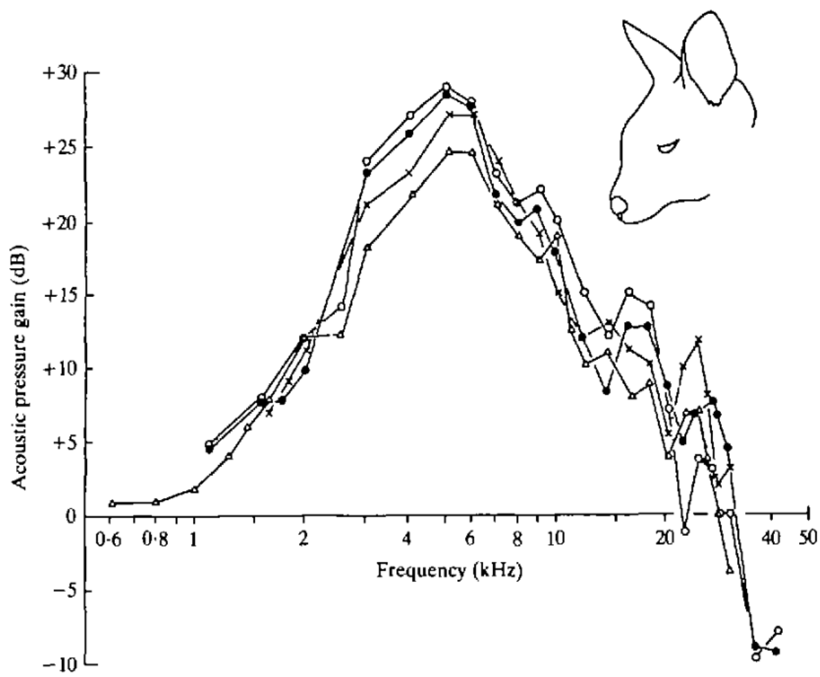

Figure 3-2 Measurement of the acoustic pressure gain (in dB) for four separate ears of the same species as a function of stimulus frequency. Inset shows 'on-axis' view of the left ear.

[3] Red and Eastern Grey Kangaroo.

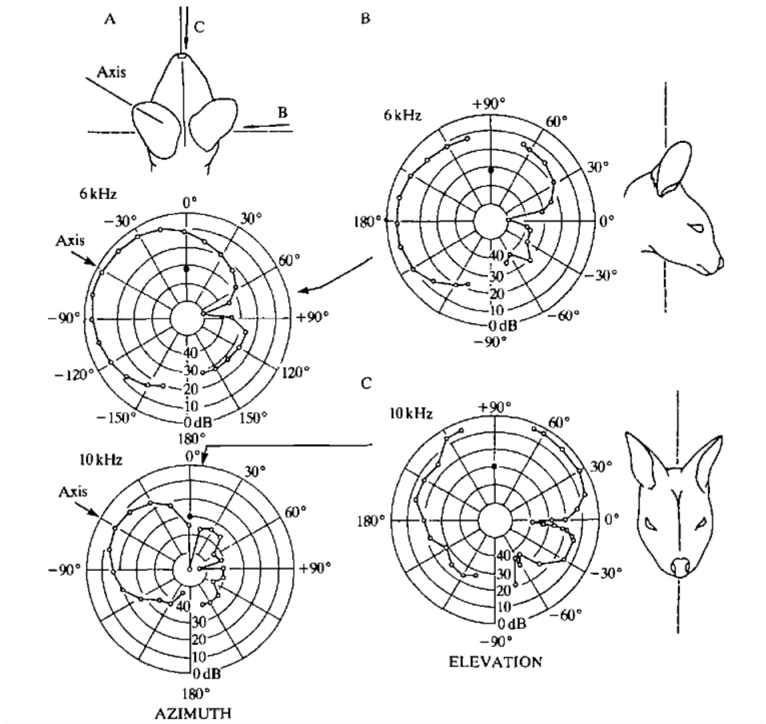

Figure 3-3 Polar response patterns based on microphone response changes (dB) to stimulus direction in azimuth (A) or elevation (B) at 6 and 10kHz. 0dB = 100dB re 20/iPa with free-field sound pressure level indicated by filled circle on polar plot.

3.3 Echidnas

An echidna's audiogram based on ABR (Audio Brain Response) data is shown in Figure 3-4 [18]. The audiogram shows that echidnas can hear from 1 kHz up to maximum frequency of 20 kHz. Their hearing is most sensitive between 4 and 8 kHz with their hearing sensitivity decreasing either side. Based on the hearing curves, their hearing isn't very sensitive (20dB at their most sensitive frequency on the hearing curve) indicating that they don't have very good hearing compared to kangaroos or humans. A study [28] has recorded echidna vocalisations between 160 Hz to 4 kHz. As the ABR indicates that echidnas do not hear well in the lower frequency ranges it can be inferred that the lower frequency vocalisations may be felt rather than heard.

Conclusion: The echidna's hearing bandwidth is within the higher frequency range of noise produced by WTGs.

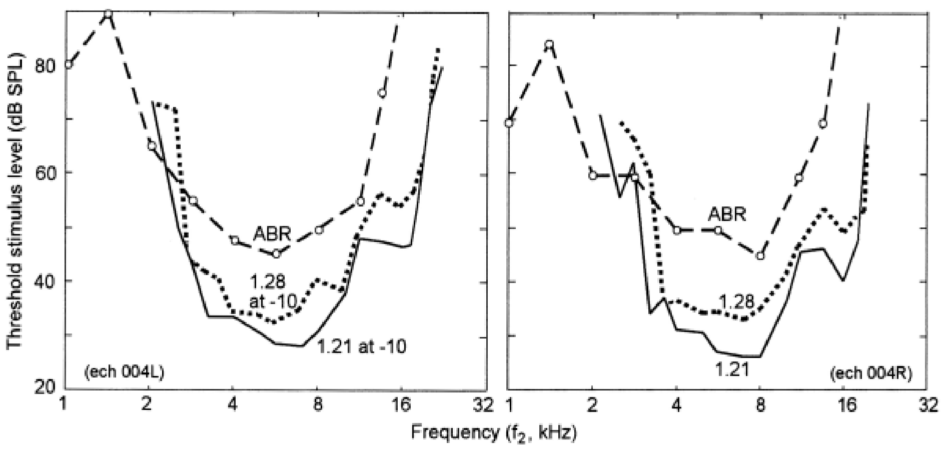

Figure 3-4 Comparison in one Echidna (both ears) of the threshold curves

3.4 Summary of Hearing Bandwidths

Table 3-1 and Figure 3-5 summarise the fauna hearing bandwidths adopted for this study[4].

Note: As high frequency noise above 20kHz is not understood or measured, the assessed bandwidths are limited to 20kHz.

Table 3-1 Hearing Bandwidths and Sensitivity

Fauna Type	Hearing Bandwidth		Notes
	Range	Most sensitive	
Kangaroo	600Hz to 30kHz	4 kHz to 6kHz	• Highly sensitive ears over a wide spectrum (25 to 30 dB gain at most sensitive frequencies)
Emu	25Hz to 4kHz	600Hz to 700Hz	• Moderate sensitivity which diminishes quickly above 2.5kHz.
Echidna	1kHz to 20kHz	4 kHz to 8kHz	• Low sensitivity, poor hearing

[4] The hearing bandwidths for kangaroos have been extrapolated to lower frequencies.

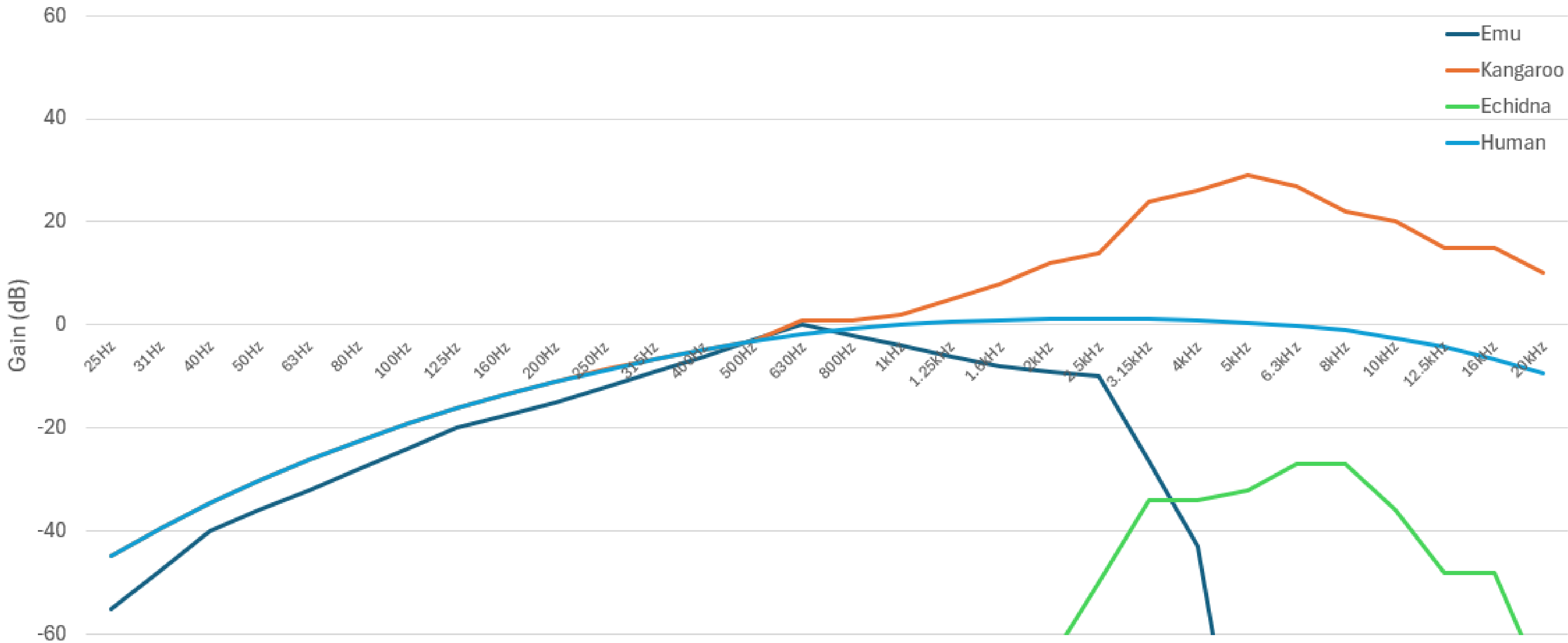

Figure 3-5 Hearing Curves

4 Disturbance

The following section summarises the evidence available in literature of noise resulting in a disturbance of each fauna type. **Note**: This is not a definitive list and is provided as examples only.

4.1 Kangaroos

The following examples are based on studies investigating kangaroo deterrents that are commonly used for scaring kangaroos from paddocks:

- Sudden or irregular sounds are more effective than steady sounds (e.g. banging metal rather than an engine), particularly in the 2-5kHz range. One study [22] found that kangaroos were startled by 2.5kHz pulses.
- Sudden impulsive noises such as clapping, metal-on-metal or explosive sounds (e.g. firecrackers) can trigger a flight response.
- Predator mimicking (e.g. dingo howls, bird-of-prey calls) can provoke fear or avoidance.
- Ultrasonic sounds (>30 kHz): Ineffective due to limited high-frequency sensitivity.
- Steady low-frequency sounds (<500 Hz): Often ignored, unless very loud or percussive.

4.2 Emus

Noises which may disturb Emus are characterised by:

- Deep, low-frequency sounds (below ~4kHz) which represents emu calls which are characterised by booms, drumming and grunts [23].
- Sudden or unfamiliar noise in a similar frequency range may alert or startle them (e.g., deep thuds, low-frequency machinery or bass sounds).
- Sounds mimicking natural threat signals - Emus use vocal warnings like hissing or grunts, as a form of deterrence [24]. Recordings of these defensive calls, or predator-related audio elements, may provoke flight responses, especially when paired with visual stimuli. A loud, low-frequency thud or boom might also act as a deterrent if it mimics a natural threat or predator cue.
- Sudden impulsive noise - While direct studies on emus are sparse, sudden impulsive noises like bangs or startling alarms are often used as effective bird deterrence.

4.3 Echidna

Given the Echidna's auditory profile, noise types that may be startling or disruptive are characterised by:

- Sharp, mid-frequency noises (4–8 kHz) fall within the echidna's most sensitive range, so sudden sounds like high-pitched snaps, clicks or machinery could prompt alertness or flight behaviour.
- Echidnas may be startled by unexpected acoustic cues such as sudden impulsive noises (e.g. metal clanks, stick snaps, abrupt vehicle sounds).
- Ground vibration - While not strictly "sound," echidnas are highly tuned to vibration - they hear through both air and ground via bone conduction to detect prey and predators [25].
- Vibrations or low-frequency noises (like heavy footsteps or machinery) could disturb them even if not easily heard.

5 Predators

Dingoes are versatile hunters, capable of hunting both alone and in packs, adapting their strategies based on prey size and local conditions. They primarily hunt at dawn, dusk, and during the night, utilizing their keen senses and agility. For smaller prey, they may stalk, chase and pounce, while larger prey like kangaroos may be hunted through group coordination, ambushes or extended pursuits.

Dingoes primarily rely on their sense of smell, hearing, and sight when hunting. Their sense of smell is highly developed, allowing them to detect prey from great distances. They also have excellent hearing and night vision, which are crucial for hunting in various conditions.

- **Solitary Hunting:** Dingoes can effectively hunt small animals like rodents, rabbits, birds, and reptiles alone, relying on stealth and agility.
- **Pack Hunting:** For larger prey like kangaroos and feral pigs, dingoes usually hunt in groups, using coordinated strategies such as ambushes or extended chases to bring down their prey. Dingoes communicate through howls, growls, whines, and yelps to keep packs together, locate each other, warn others away, and signal success after a hunt. When hunting large prey like kangaroos, vocalisations can be an integral part of a dingo pack's coordinated hunting strategy.
- **Exploiting the Environment:** Dingoes are known to utilise their environment to aid in hunting. For example, they may hunt near watering holes or along shorelines, taking advantage of prey that come to drink or are caught by waves.
- **Opportunistic and Versatile:** Dingoes are opportunistic hunters, readily taking advantage of whatever food sources are available, including carrion and even some plant matter.

6 Impact Assessment Approach

There is a lack of research identifying threshold levels at which noise will impact the fauna considered in this study. As a result, a risk-based approach has been used to assess potential impacts. The risk-based approach adopted is similar to an approach taken for determining underwater noise impacts where noise impact thresholds of fauna types are not well understood.

The risk-based approach estimates the likelihood of an impact taking place [27] by using the best available data. The assessed likelihood is categorised as high (H), moderate (M), and low (L). Each of the categories are qualitative and descriptive as described in Table 6-1.

Table 6-1 also shows the risk categories considered for each impact. As injury has been determined to be highly unlikely for the Wind Farm it has been allocated only one possible risk category (i.e. L), while disturbance and masking have been allocated all three categories.

Table 6-1 Impact Risk Categories for WTG Operations

Impact	Description	Risk Catagory
Injury	Physical injury of the ear in the form of Temporary Threshold Shift (TTS) or Permanent Threshold Shift (PTS). As the WTG hub heights are 200m above ground, noise levels will be below expected TTS and PTS thresholds and are therefore not expected to result in physical injury at ground level. Injury is therefore considered low risk.	L
Disturbance	WTG noise may result in disturbance in the form of avoidance of the area (i.e. fauna moving away to other areas).	H/M/L
Masking	Masking considers the WTG noise interfering with the ability to communicate or detect predators. Masking could have long term effects on the health of the population within the area.	H/M/L

7 Noise Modelling Overview

7.1 Noise Model Software

A desktop environmental noise model was created to simulate the Project using SoundPLAN v9 software program and the Nexus noise management system. These software packages calculate sound pressure levels at nominated receiver locations and produce noise contours over a defined area of interest.

The inputs required by SoundPLAN and Nexus are noise sources, ground topographical and absorption data, meteorological data, and sensitive receiver point locations. SoundPLAN has been setup for the study to utilise ISO9613 "Acoustics - Attenuation of sound during propagation outdoors" for calculating the attenuation of sound during outside propagation and the CONCAWE[5,6] prediction algorithm. The CONCAWE algorithm is accepted by the Department of Water and Environment Regulation (DWER).

Nexus software has been used to provide noise maps using fauna hearing thresholds for WTG's at different wind speeds.

7.2 Noise Model Inputs

7.2.1 Overview

The noise model requires various inputs to make predictions. The model inputs for the fauna study were taken from the Bonney Downs noise model (see section 4 of Talis' Bonney Downs noise assessment report [26]).

WTG noise emissions increase with associated hub-height wind speeds from 5 m/s (cut-in speed) to 12 m/s (rated power and maximum noise emissions). SWLs have been calculated and allocated to the WTG's using vendor information for 6 MW WTG's, operating at increments of 1m/s wind speed increase from cut-in wind speeds to rated power (i.e. highest SWL emission). The modelling is based on a wind speed at 10m above the ground level. The hub-height wind speeds at 200 m have therefore been back-calculated to 10m for noise modelling using the wind profile law[7]. The WTG noise sources were placed at a height of 200m above the topographical ground layer, to represent the WTG hub-heights.

The model inputs can be summarised as follows:

- TN24017-2 [26] – all receptor locations, topography, ground absorption, weather conditions, WTG layout and WTG quantities are the same as the noise assessment [26].

[5] CONCAWE (Conservation of Clean Air and Water in Europe) was established in 1963 by a group of oil companies to carry out research on environmental issues relevant to the oil industry.

[6] The propagation of noise from petroleum and petrochemical complexes to neighbouring communities, CONCAWE Report 4/81, 1981.

[7] Touma, J.S., 1977, Dependence of the wind profile power law on stability for various locations, J. Air Pollution Control Association. $v2=v1*\ln(h2/z0)/\ln(h1/z0)$, where z0 is the roughness length of which 0.1 was used.

- Additional inclusions - fauna hearing bandwidths and sensitivities applied.

7.2.2 Noise Sources

Table 7-1 provides a summary of the modelled noise source SWLs for each fauna type and includes human weighted (dBA) SWLs for comparison. The spectral data for each source are provided in Appendix A.

As can be seen from Table 7-1, the level of sound that can be heard by each fauna type is different to each other and to what humans hear. This is due to the differences in frequency range and hearing sensitivity for each fauna type as shown in Figure 7-1 which shows the difference in hearing between each of the fauna (i.e. Kangaroos, Emus and Echidnas) and with humans who hear between 20Hz and 20kHz. Kangaroos can hear beyond 20 kHz (i.e. the maximum frequency audible to humans) with a maximum audible range of 30 kHz. The graph in Figure 7-1 does not extend past 20 kHz as no noise data is available for the WTG's beyond 20 kHz.

Table 7-1 WTG Sound Power Levels

WTG hub height wind speed [8]	WTG Quantity	Modelled Sound Power Level			
		Human (dBA)	Emu (L(EMU)eq)	Kangaroo (L(ROO)eq)	Echidna (L(ECH)eq)
5m/s	201	104	102	112	53
6m/s	201	108	106	116	57
7m/s	201	111	109	120	60
8m/s	201	113	111	121	62
9m/s	201	114	112	122	63
≥ 10m/s	201	114	112	122	63

[8] Hub-height wind speed 5m/s = 2.9m/s @ 10m; Hub-height wind speed 10m/s = 6m/s @ 10m; Hub-height wind speed 12m/s = 7m/s @ 10m

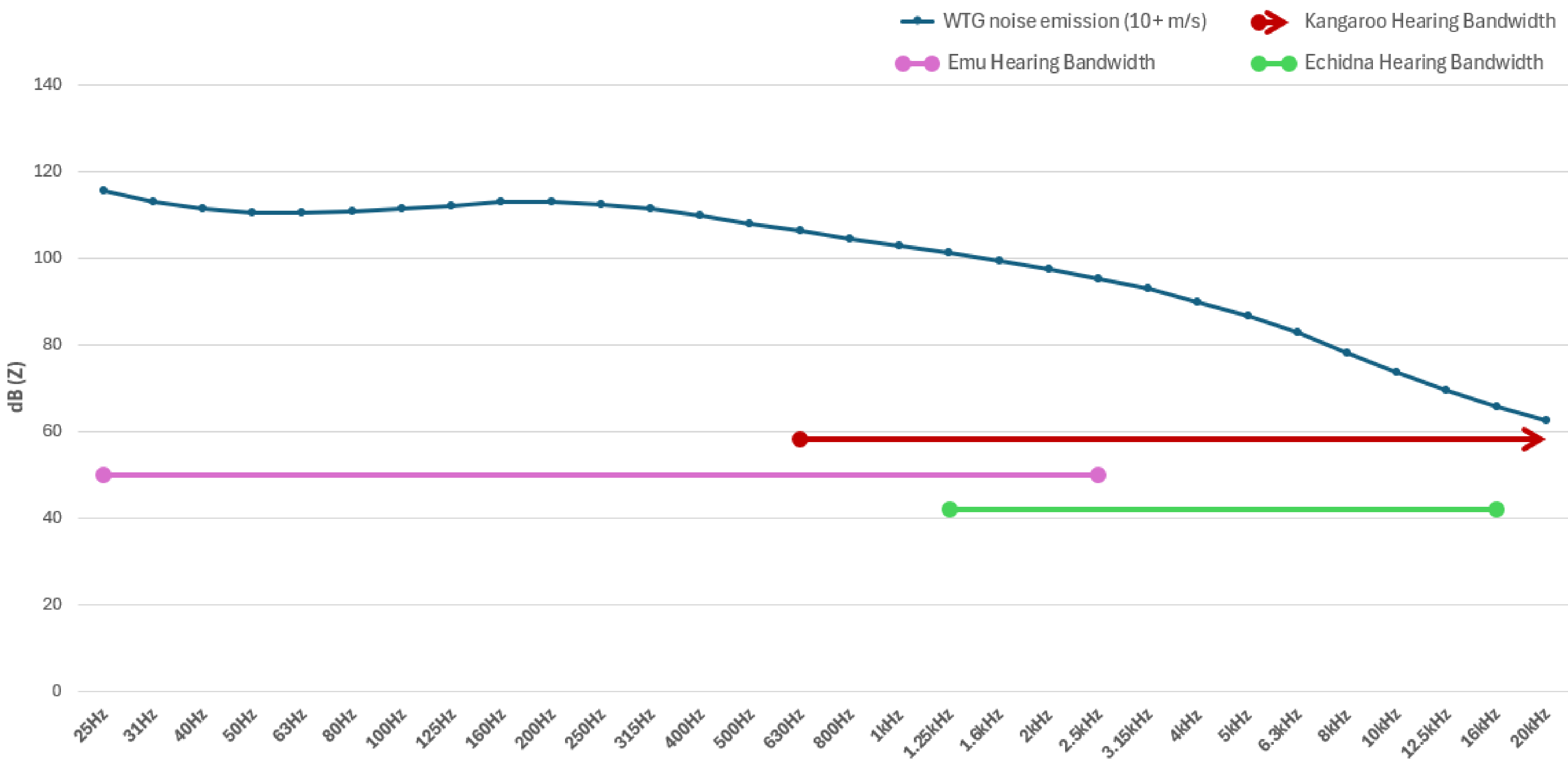

Figure 7-1 A graph showing the and the unweighted WTG noise emissions (over the audible human spectrum 20Hz to 20kHz) overlaid with audible spectrums for Kangaroos, Emu's and Echidnas.

7.3 Noise Model Layout and Scenarios

Figure 7-2 shows the windfarm layout. Receptors in the figure are shown only to provide spatial context for the reader.

The noise model has setup with all 201 WTGs operating simultaneously at 1m/s increments from 5m/s to 12m/s (note: the peak SWL emission is reached at 10m/s, and therefore model outcomes for 10m/s to 12m/s wind speeds are identical). Each fauna type has been run separately to account for their hearing curves.

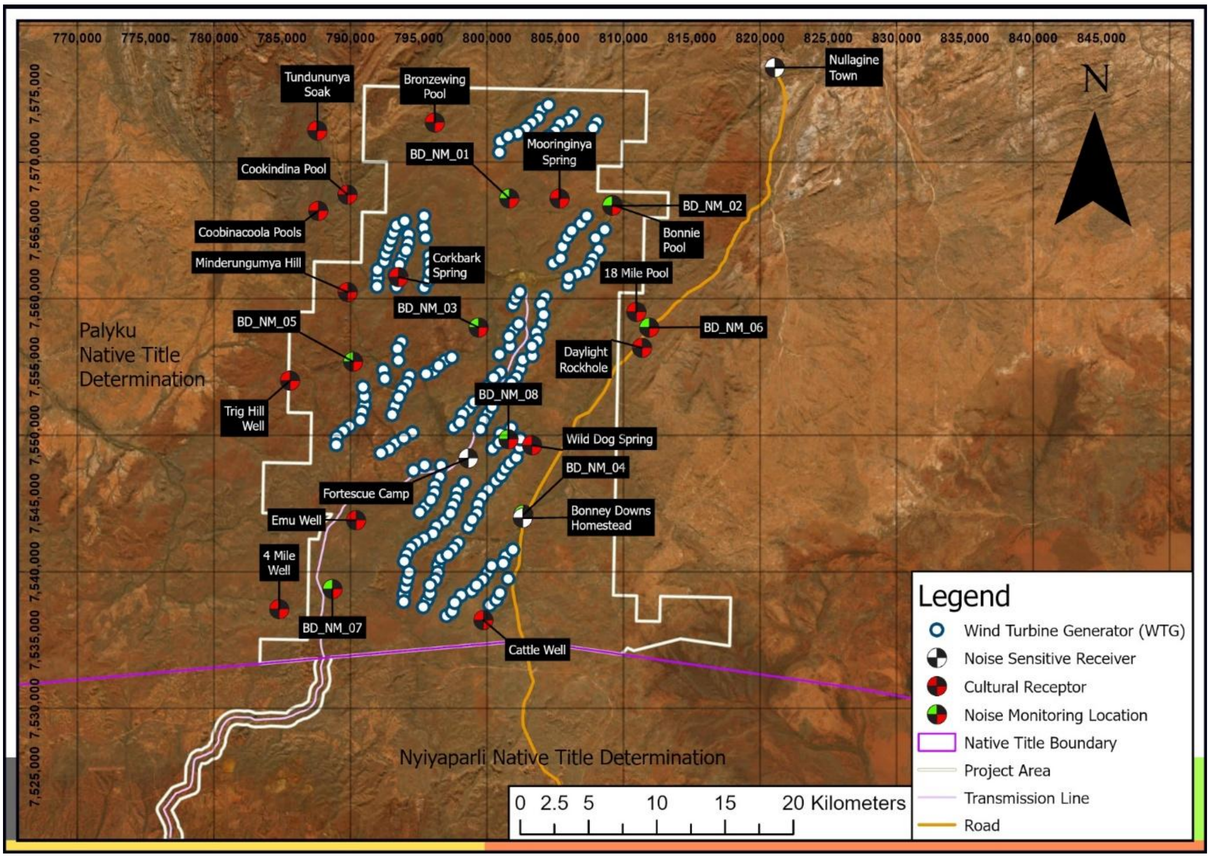

Figure 7-2 Wind Farm layout with receptor points to provide spatial context.

8 Model Results

Noise contour maps representing the weighted decibel sound heard[9] by kangaroos, emus and echidnas are provided in APPENDIX B. The noise contour maps show the noise levels for the WTGs from cut-in hub height wind speed of 5m/s to maximum hub height wind speeds of 12m/s.

The results show that echidnas do not have the ability to hear the WTGs, whereas kangaroos and emus, due to their hearing sensitivity, will be able to hear the WTGs.

[9] The received noise levels shown in the table are weighted according to the hearing sensitivity of each fauna type for frequencies between 20Hz and 20kHz.

9 Risk Assessment

Risk maps for each fauna species are provided in Figure 9-1 to Figure 9-8, which are based on the factors and descriptions given in Table 9-1

Table 9-1 Risk Assessment Table

Impact	Description	Risk
Injury	• WTG noise is not expected to result in injury as the fauna will not be close enough to result in physical injury, TTS and PTS. As a result, injury is considered low risk and is not included in the table.	L
Masking	• WTG noise above background noise levels for the area (as measured during the Project Noise Assessment [26]) will impact the ability of fauna to communicate and detect predators. • The WTG noise level at which fauna will not be able to hear approaching predators, assuming the predator is present. • The level of variation in the noise emissions (i.e. from low to high) from the WTGs	H/M/L
Disturbance	• Continuously high levels of noise will result in fauna no longer using the area. • The level of variation in the noise emissions (i.e. from low to high) from the WTGs.	H/M/L

The risk assessment shows the risks profiles increase with increase in windspeed. This is due to the noise generated by the WTG's being directly correlated to wind speed. The maps indicate that emus are a lower risk than kangaroos. The kangaroo maps show that their risk profile is highest in and around the WTG's where it can result in masking or possible disturbance.

Risk maps of disturbance and masking for kangaroos and emus and echidnas are given in:

- Kangaroos - Figure 9-1 to Figure 9-4
- Emus - Figure 9-5 to Figure 9-8

This study is based on key assumptions regarding proxy data, studied hearing bandwidths, sensitivities, behavioural responses and high-level noise modelling. The risk assessment is therefore only indicative, and it is too early to develop risk mitigation strategies. A more detailed study/assessment, and potential monitoring and management measures be considered once more detailed information becomes available.

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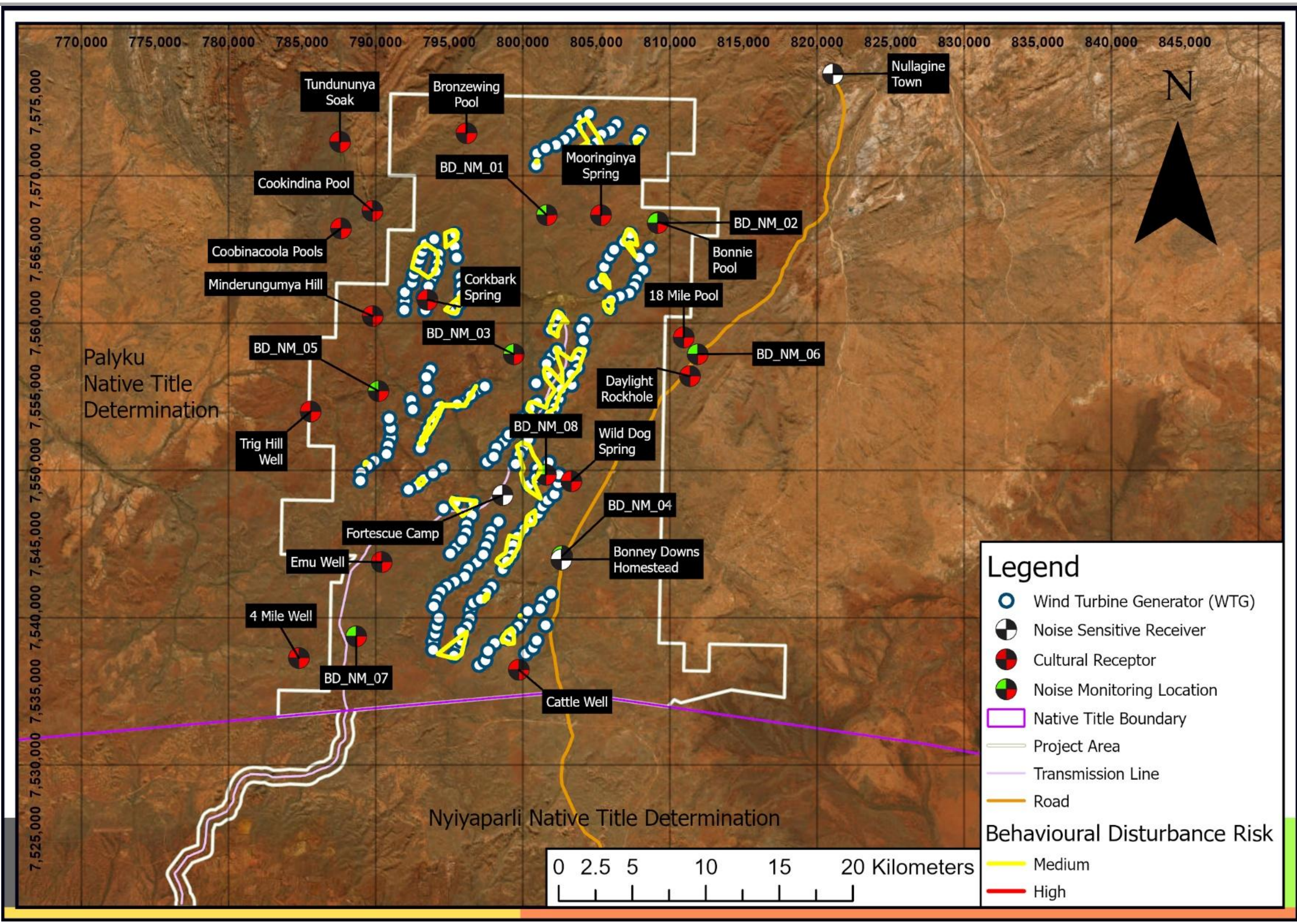

Figure 9-1 – Risk Map –Behavioural – 5m/s KANGAROO

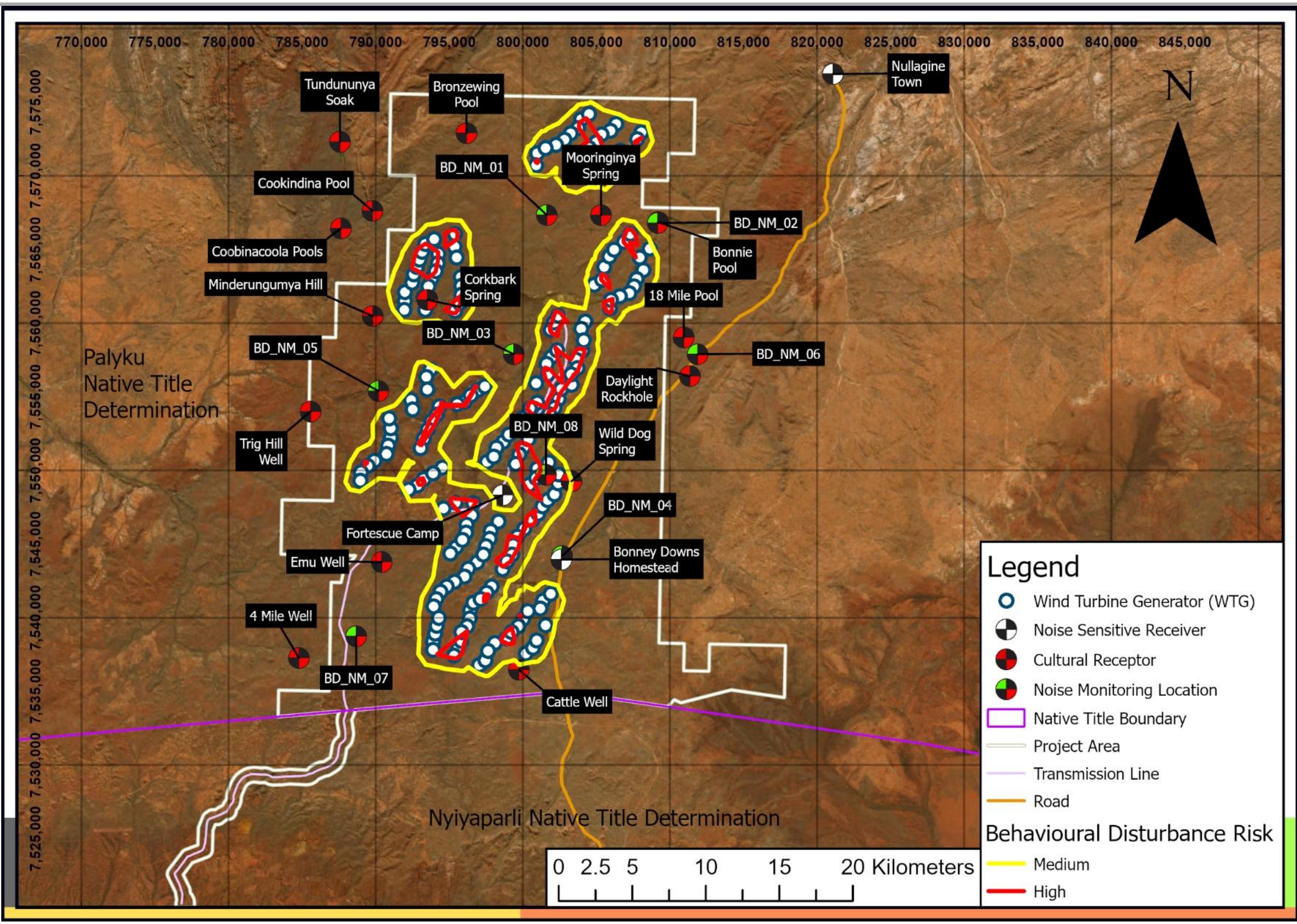

Figure 9-2 – Risk Map – Behavioural – 12m/s KANGAROO

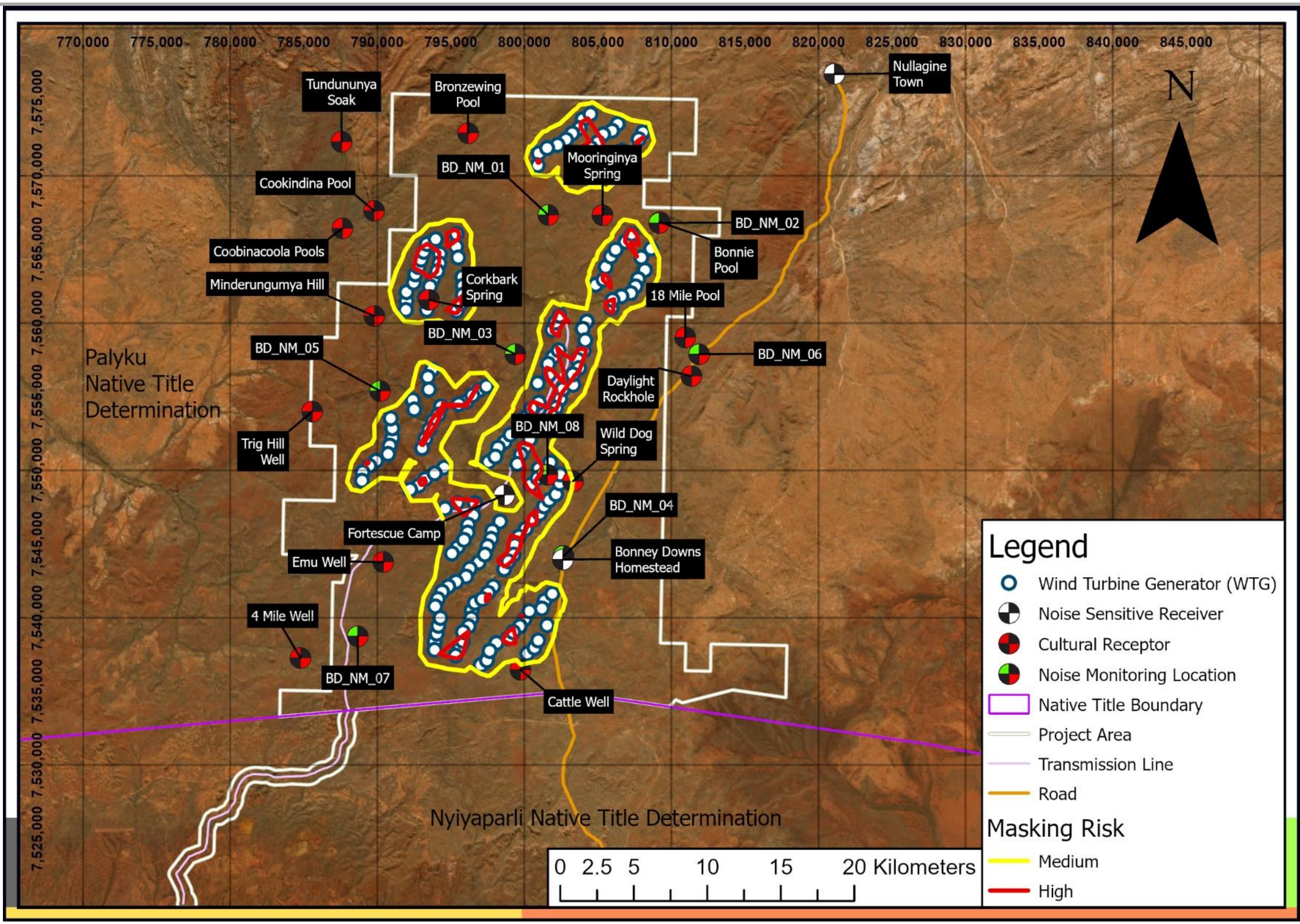

Figure 9-3 – Risk Map – Masking – 5m/s KANGAROO

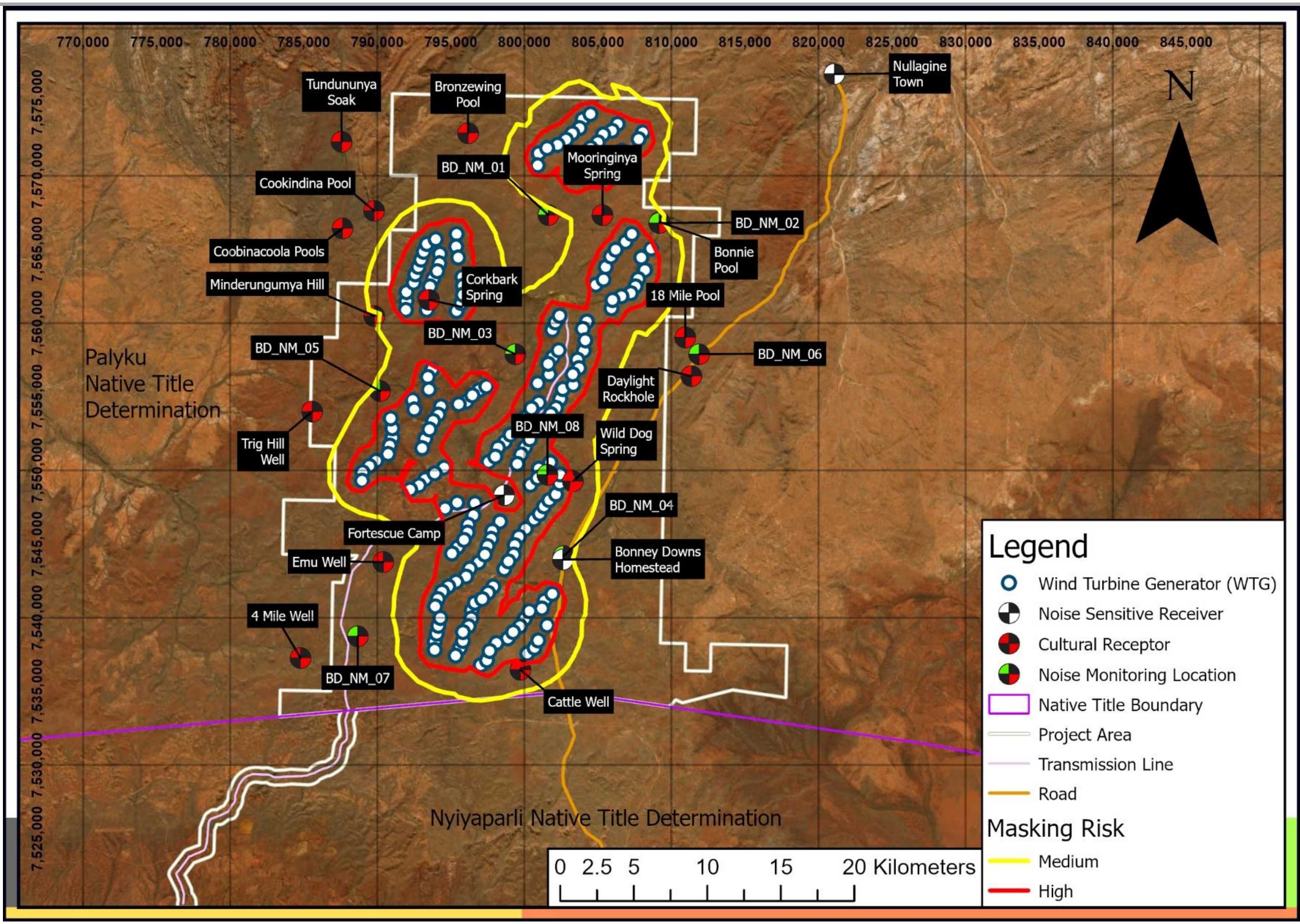

Figure 9-4 – Risk Map – Masking – 12m/s KANGAROO

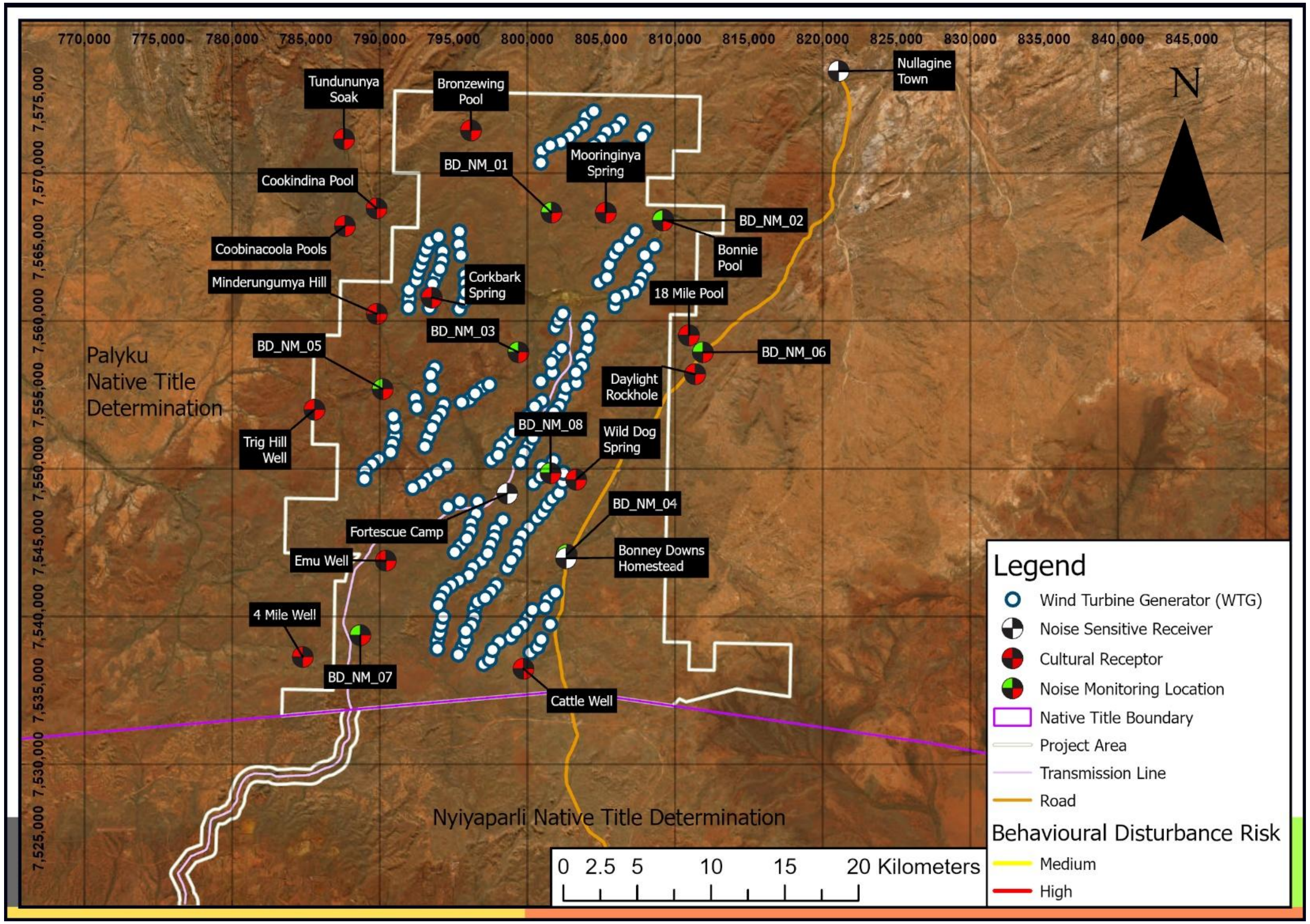

Figure 9-5 – Risk Map – Behavioural – 5m/s EMU

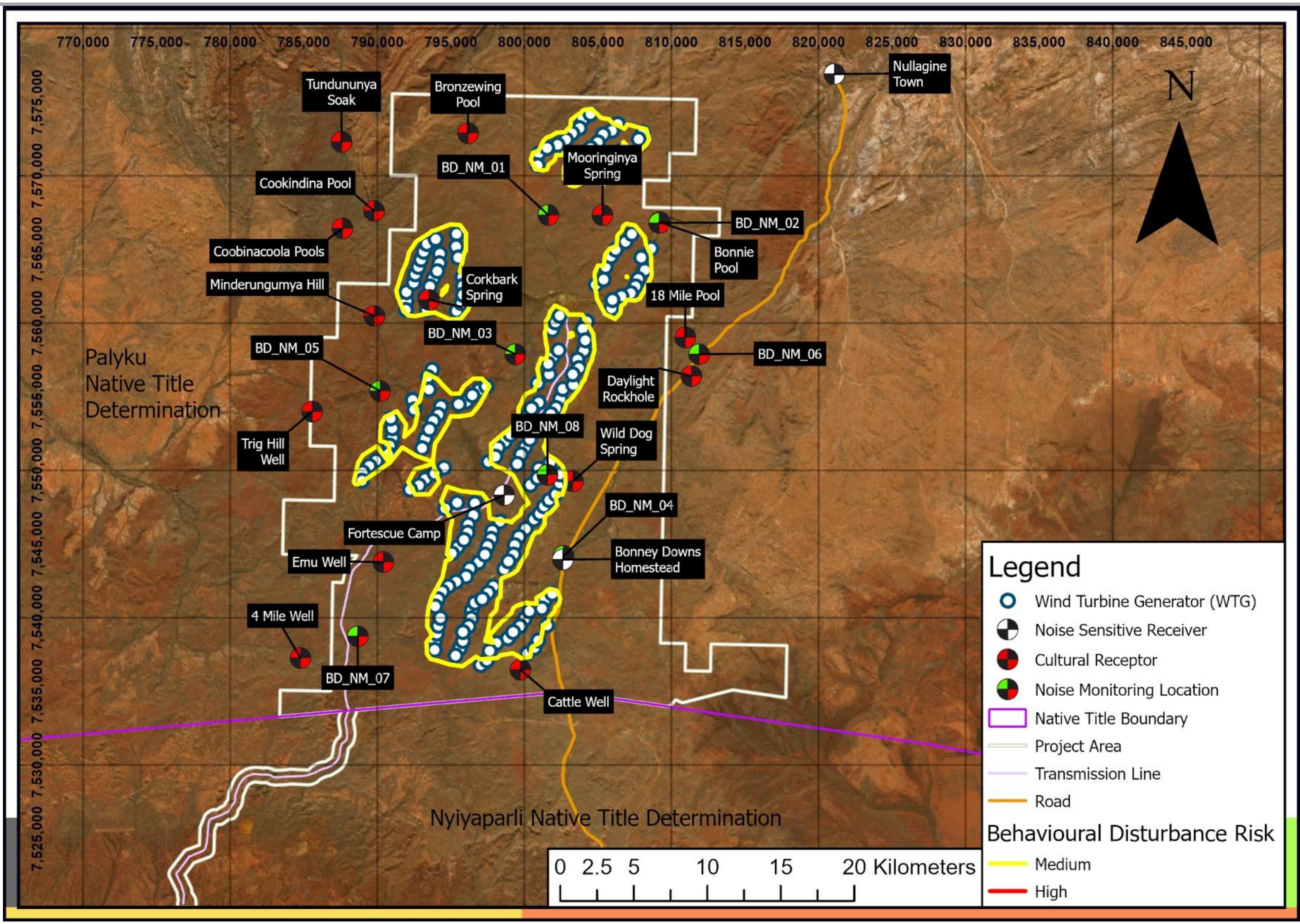

Figure 9-6 – Risk Map– Behavioural – 12m/s EMU

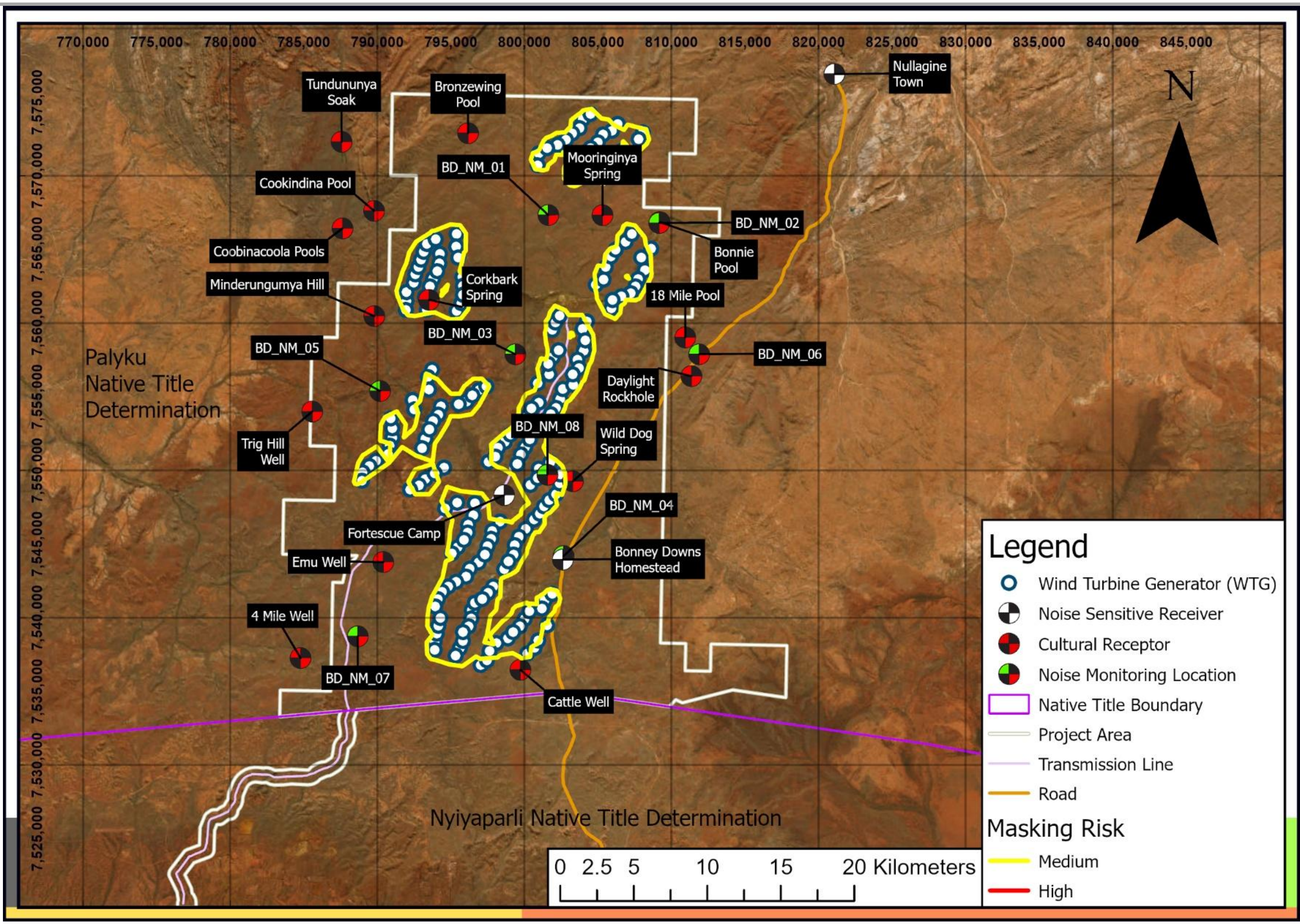

Figure 9-7 – Risk Map– Masking – 5m/s EMU

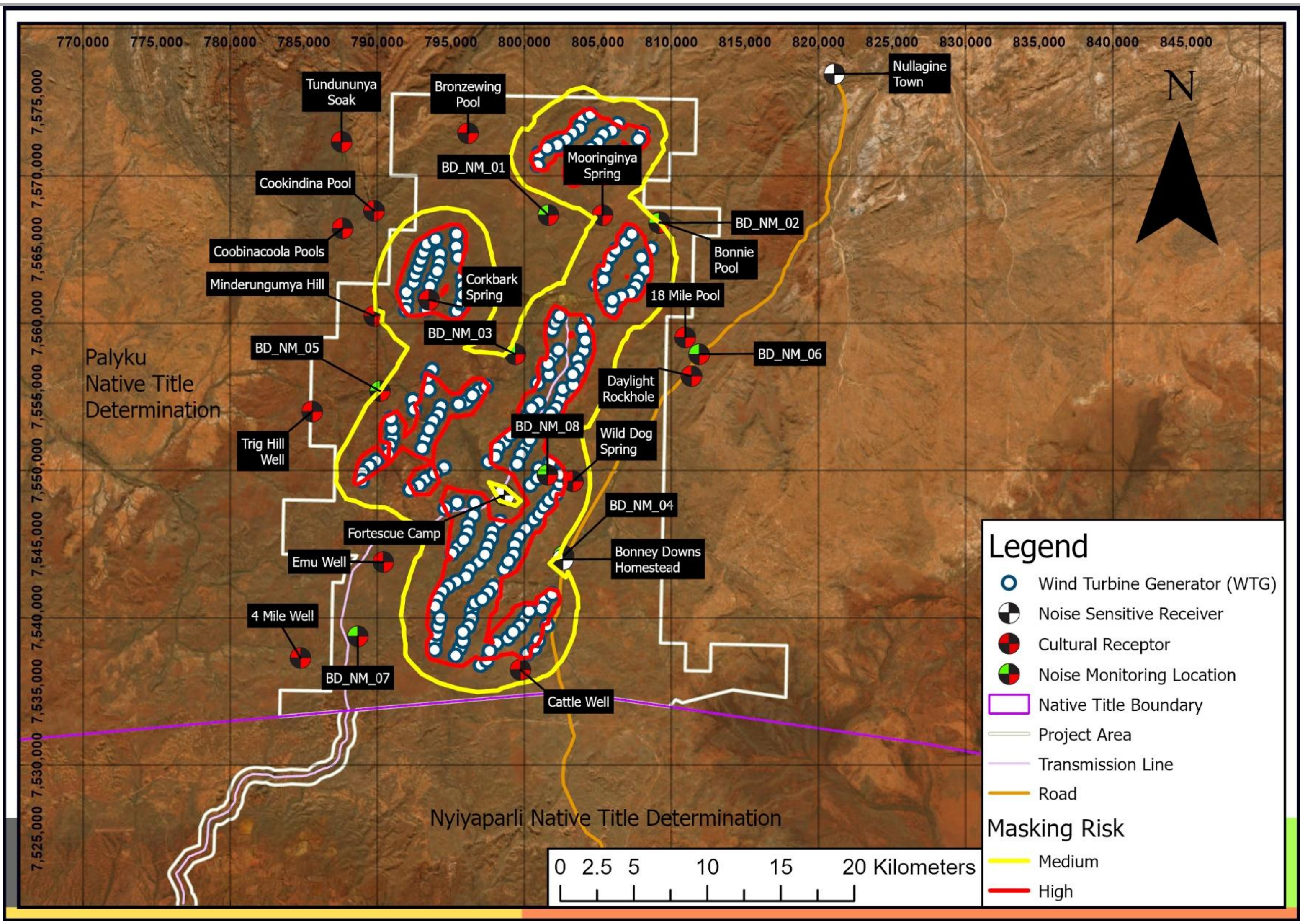

Figure 9-8 – Risk Map– Masking – 12m/s EMU

10 Findings and Uncertainties

10.1 Findings

There are no Regulations or Standards which define noise assessment criteria for the fauna of interest (kangaroos, emus and echidnas). As a result, a risk-based approach has been taken.

The study concludes that the likelihood of direct injury (TTS, PTS) is low, however there may be potential for disturbance and masking risk in high-risk areas such as Corkbark Spring and as shown in the risk maps.

The studies risk assessment is high-level and only indicative. Risk mitigation strategies require detailed long-term studies to determine the likelihood of the identified risks.

10.2 Uncertainties

The study has used the best information available. As the impacts are not well studied there is some uncertainty due to the following:

- Unlike emus and echidnas no research could be found regarding kangaroo hearing bandwidths and threshold levels. Data for species within the same family has been used but this is indicative only and may not correlate exactly.
- WTG noise levels and the sustained duration of noise at which disturbance or physiological effects of population health for all three species is not well understood.
- Vibration levels may impact echidnas. At this stage vibration levels from the WTG's is not well understood and the vibration sensitivity of echidnas has not been measured.

As a result, the risks identified in the assessment should be treated as indicative of potential impacts.

APPENDIX A

Fauna weighted noise source spectral data

Element name	25Hz	31Hz	40Hz	50Hz	63Hz	80Hz	100Hz	125Hz	160Hz	200Hz	250Hz	315Hz	400Hz	500Hz	630Hz	800Hz	1kHz	1.25kHz	1.6kHz	2kHz	2.5kHz	3.15kHz	4kHz
L(EMU)eq 5m/s	50	55	61	64	68	73	77	82	85	88	90	92	94	95	96	92	89	85	81	78	75	56	37
L(EMU)eq 6m/s	54	59	65	68	72	77	81	86	89	92	94	96	98	99	100	96	93	89	85	82	79	60	41
L(EMU)eq 7m/s	58	63	69	72	75	80	84	89	93	95	97	99	101	102	103	100	96	92	88	86	82	64	44
L(EMU)eq 8m/s	59	64	70	73	77	82	86	91	94	97	99	101	103	104	105	101	98	94	90	87	84	65	46
L(EMU)eq 9m/s	60	65	71	74	78	82	87	92	95	98	100	102	103	105	106	102	98	95	91	88	85	66	46
L(EMU)eq 10m/s +	61	65	71	74	78	83	87	92	95	98	100	102	104	105	106	102	99	95	91	88	85	66	47
L(ROO)eq 5m/s	61	63	67	70	74	78	82	86	89	92	94	95	95	95	97	95	95	96	97	99	99	107	106
L(ROO)eq 6m/s	65	67	71	74	78	82	86	90	93	96	98	99	99	99	101	99	99	100	101	103	103	111	110
L(ROO)eq 7m/s	68	71	74	77	81	85	89	93	97	99	101	102	102	102	104	103	102	103	104	107	106	114	113
L(ROO)eq 8m/s	70	72	76	79	83	87	91	95	98	101	103	104	104	104	106	104	104	105	106	108	108	116	115
L(ROO)eq 9m/s	70	73	76	80	84	88	92	96	99	102	103	104	105	104	107	105	104	106	107	109	109	116	115
L(ROO)eq 10m/s +	71	74	77	80	84	88	92	96	99	102	104	105	105	105	107	105	105	106	107	109	109	117	116
L(ECH)eq 5m/s	6	4	2	1	1	2	2	3	4	4	3	2	1	-1	-3	-5	13	6	-1	22	35	49	46
L(ECH)eq 6m/s	10	8	6	5	5	6	6	7	8	8	7	6	5	3	1	-1	17	10	3	26	39	53	50
L(ECH)eq 7m/s	14	11	10	9	8	9	9	10	11	11	10	9	8	6	4	3	20	13	6	30	42	56	53
L(ECH)eq 8m/s	15	13	11	10	10	11	11	12	13	13	12	11	10	8	6	4	22	15	8	31	44	58	55
L(ECH)eq 9m/s	16	14	12	11	11	11	12	13	14	14	13	12	10	9	7	5	22	16	9	32	45	58	55
L(ECH)eq 10m/s +	17	14	12	11	11	12	12	13	14	14	13	12	11	9	7	5	23	16	9	32	45	59	56

APPENDIX B

Noise Contour Maps

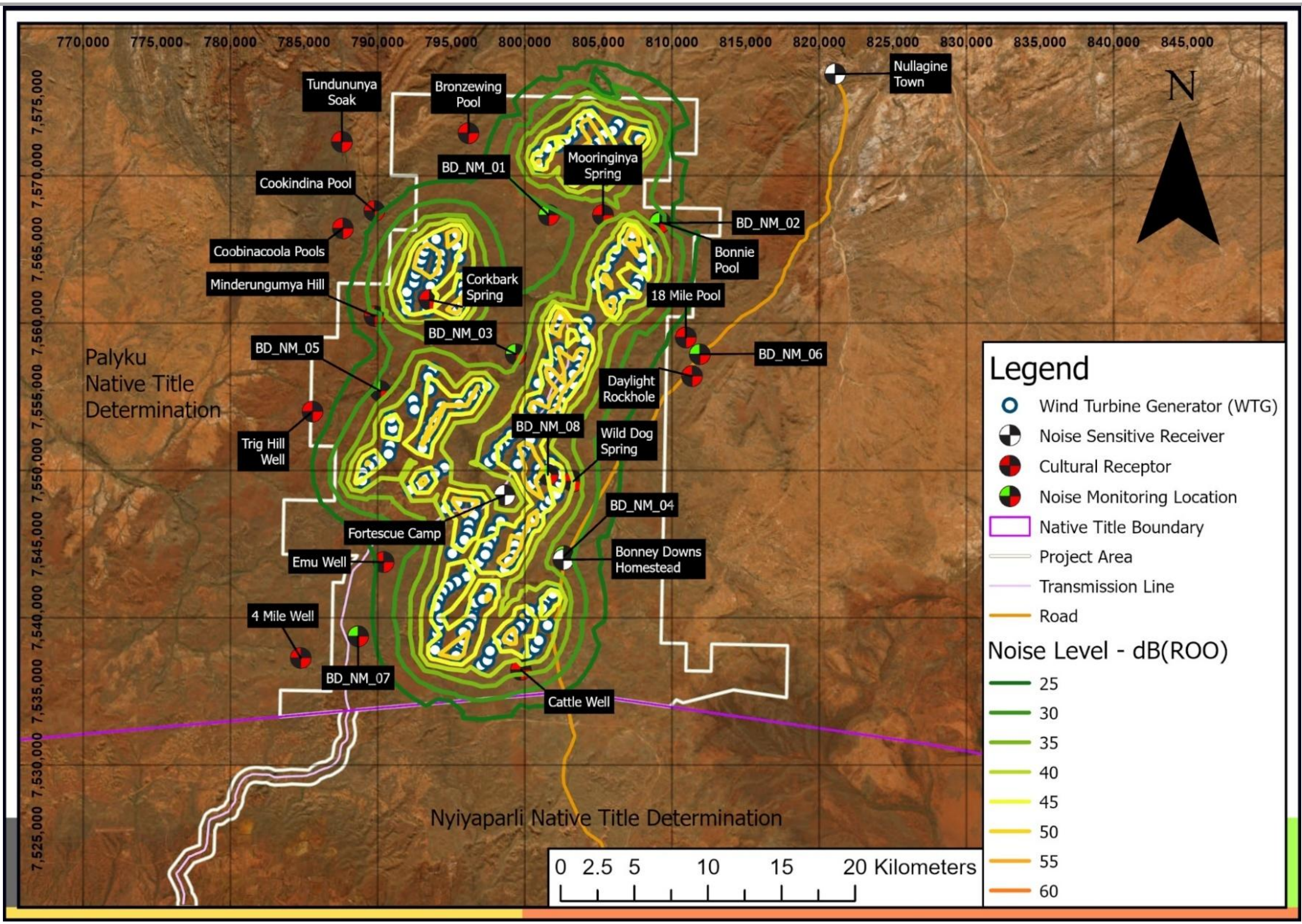

Figure B 1 Noise Contour Map – Wind Farm Operations 5m/s KANGAROO

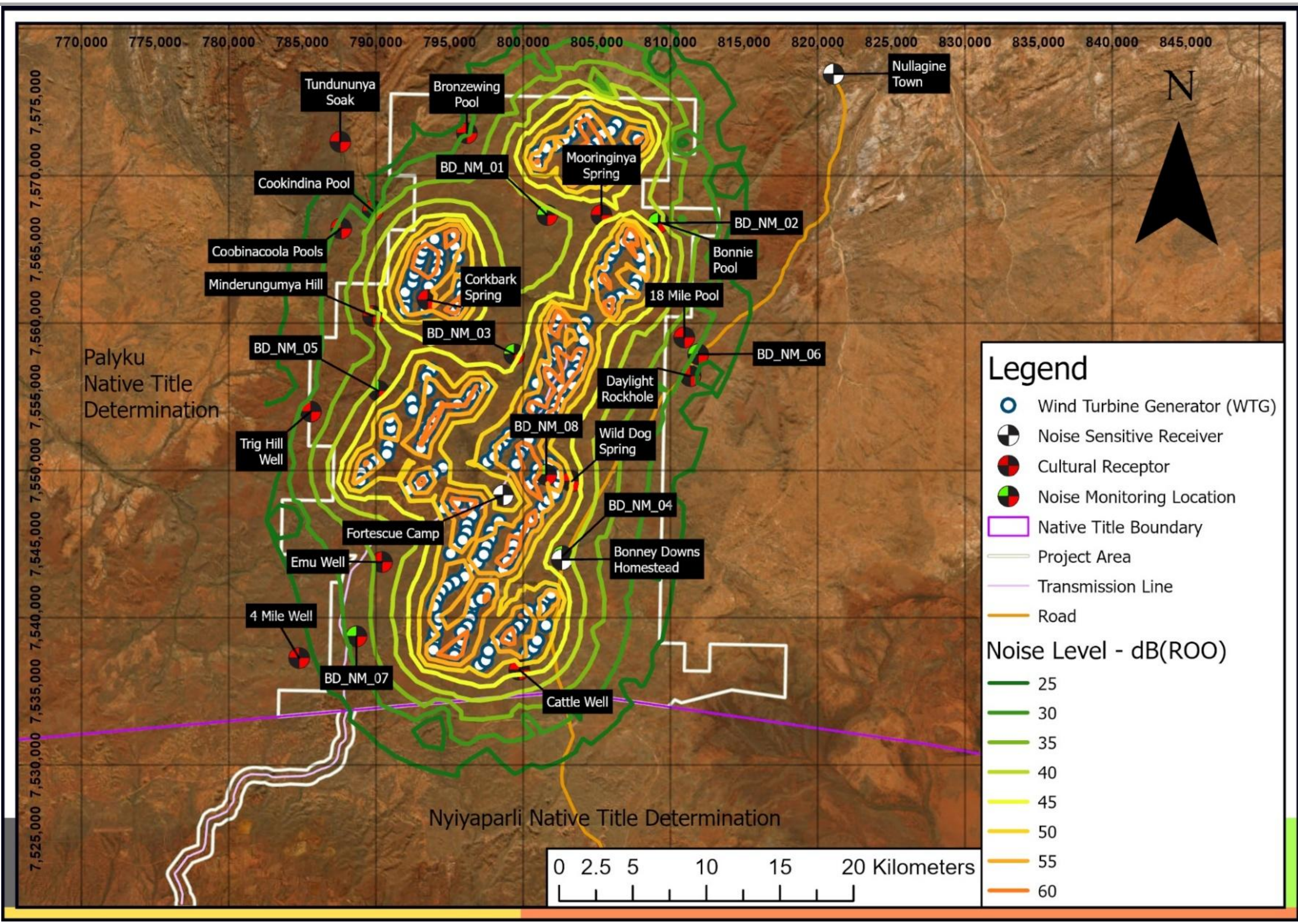

Figure B 2 Noise Contour Map – Wind Farm Operations 12m/s KANGAROO

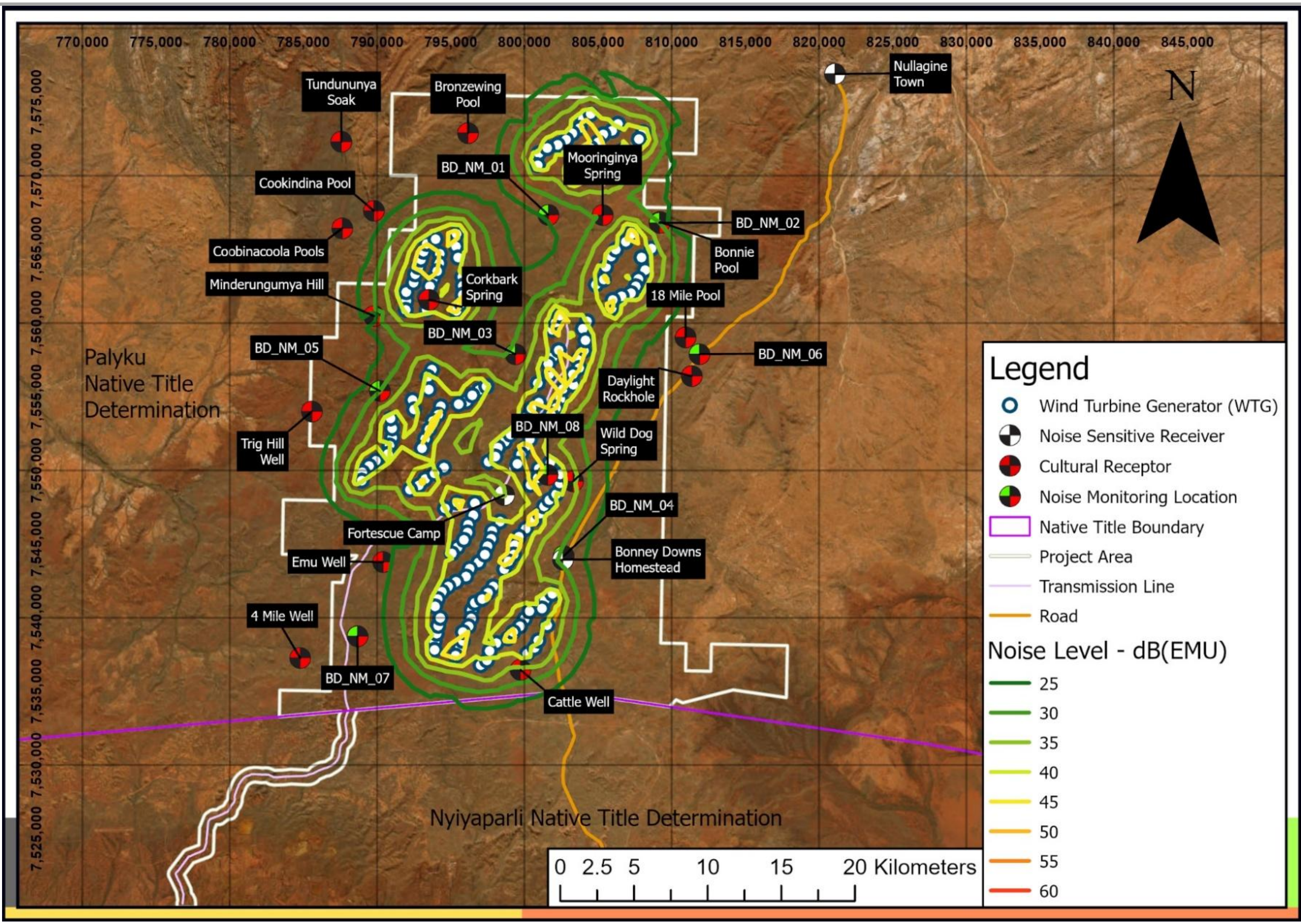

Figure B 3 Noise Contour Map – Wind Farm Operations 5m/s EMU

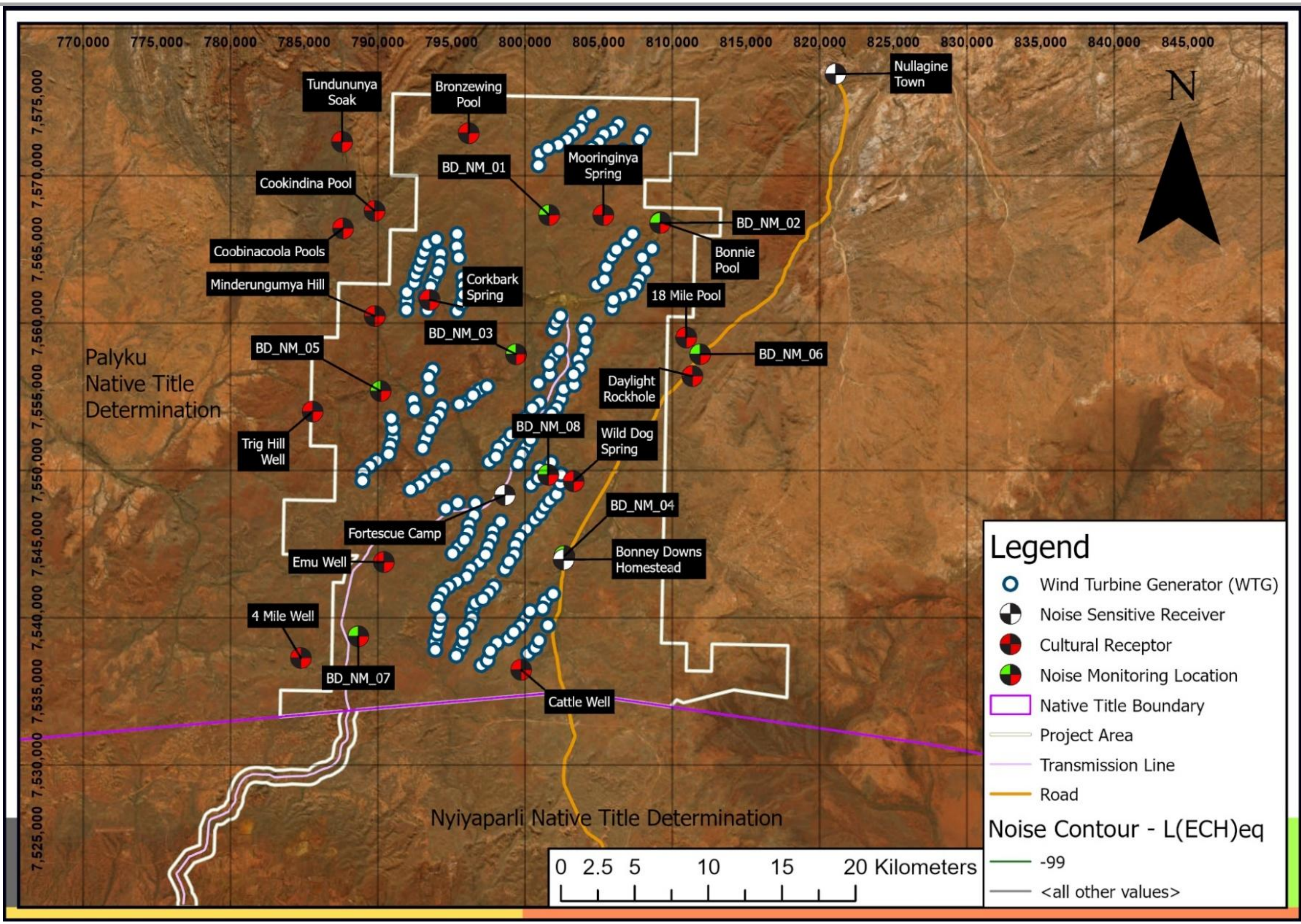

Figure B 4 Noise Contour Map – Wind Farm Operations 5m/s ECHIDNA

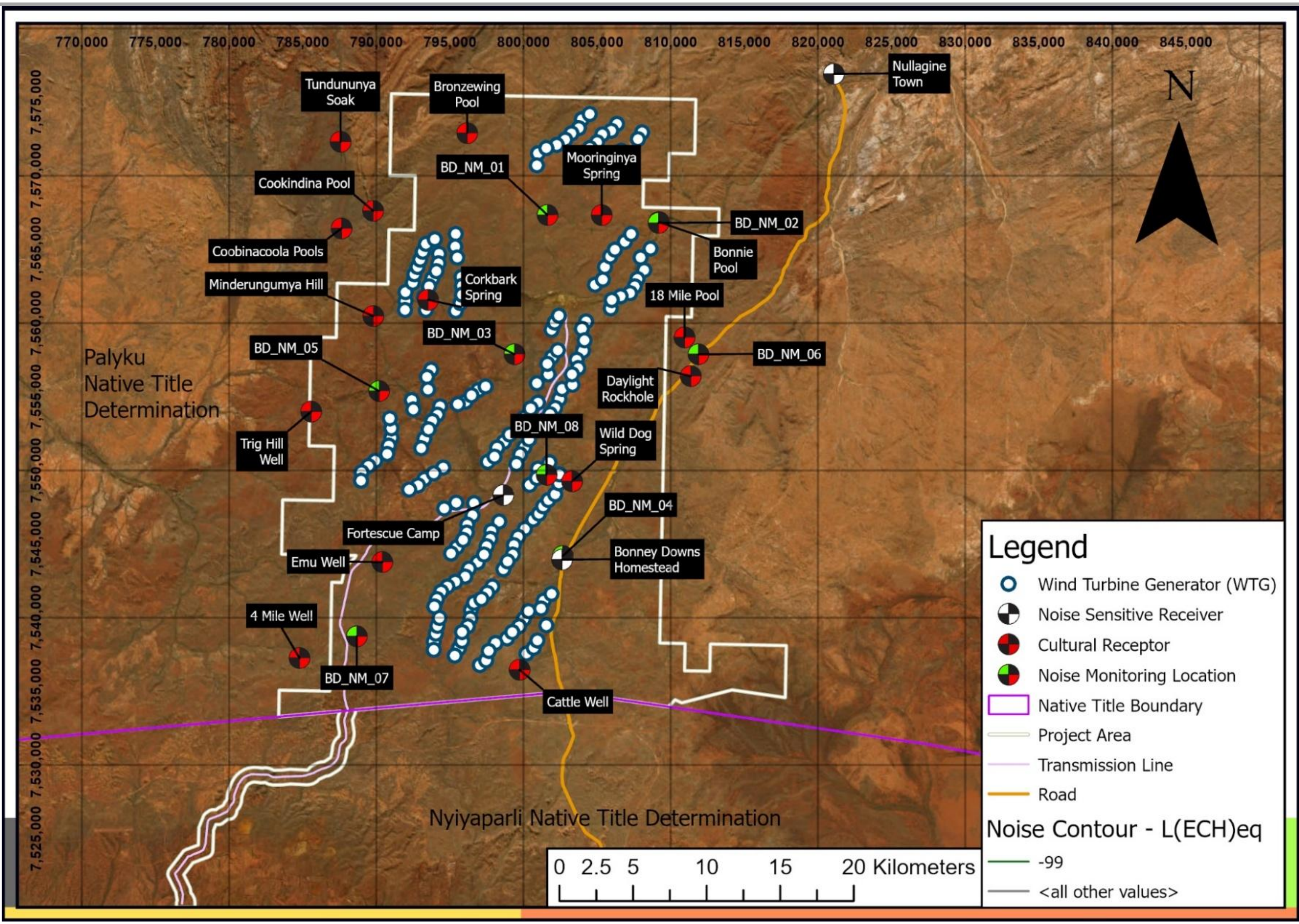

Figure B 5 Noise Contour Map – Wind Farm Operations 12m/s ECHIDNA

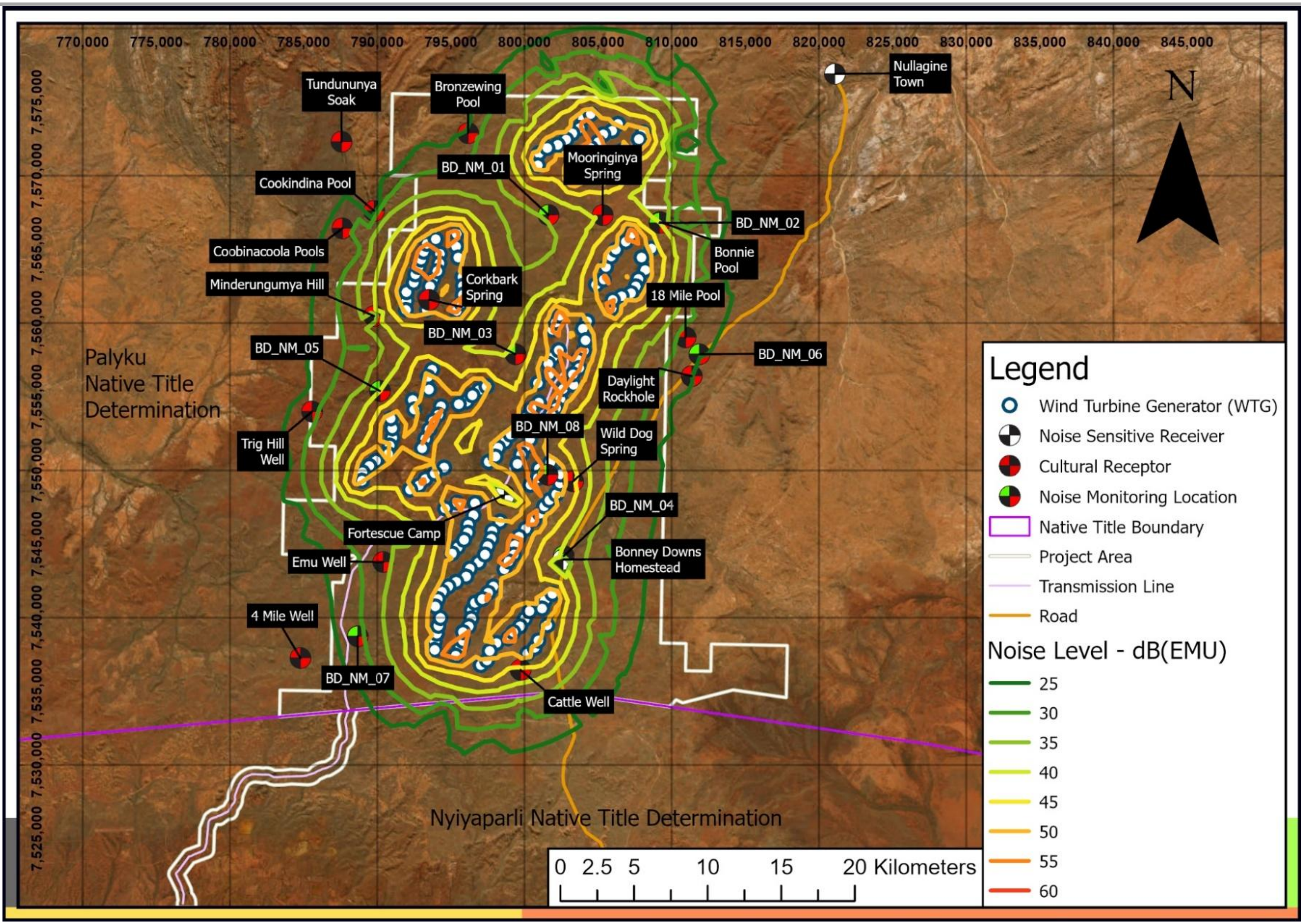

Figure B 6 Noise Contour Map – Wind Farm Operations 12m/s EMU

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