HEGGIES

REPORT 10-4044-R4

Revision 1

Bamarang
Proposed Gas Turbine Power Station
Noise Assessment of Air Cooling Option

PREPARED FOR

GHD Pty Ltd
10 Bond Street
SYDNEY NSW 2000

7 AUGUST 2008

HEGGIES PTY LTD
ABN 29 001 584 612

Incorporating New Environment Graeme E. Harding & Associates Eric Taylor Acoustics

Bamarang

Proposed Gas Turbine Power Station

Noise Assessment of Air Cooling Option

PREPARED BY:

Heggies Pty Ltd
2 Lincoln Street Lane Cove NSW 2066 Australia
(PO Box 176 Lane Cove NSW 1595 Australia)
Telephone 61 2 9427 8100 Facsimile 61 2 9427 8200
Email sydney@heggies.com Web www.heggies.com

DOCUMENT CONTROL

Reference	Status	Date	Prepared	Checked	Authorised
10-4044-R4	Revision 1	7 August 2008	John Sleeman	Dick Godson	Dick Godson
10-4044-R4	Revision 0	27 March 2008	John Sleeman	Dick Godson	Dick Godson

TABLE OF CONTENTS

1 INTRODUCTION

Delta Electricity (Delta) propose to construct a gas turbine power station and associated infrastructure, including transmission connections at Bamarang, approximately 7 km southwest of Nowra, NSW. The proposal is planned to be developed in two stages:

- Stage 1:

  Installation of two open cycle gas turbines (OCGT) for a peaking facility; and

- Stage 2:

  Conversion to a combined cycle gas turbine (CCGT) power facility to meet intermediate/base load demands. The conversion essentially consists of the addition of a heat recovery steam generator to each gas generator and the addition of steam generators to form the CCGT.

GHD was originally commissioned by Delta Electricity (Delta), as part of an Environmental Assessment, to assess the acoustic impacts of the proposed gas turbine power facility. This previous assessment was conducted in December 2005 and is based on a water cooling system (cooling towers) for the plant, noting that the water cooling is required as part of the Stage 2.

Delta are now proposing replacement of the Stage 2 water cooling system with an air cooled system to inter alia reduce the operational water requirements for the facility. Heggies has been commissioned by GHD on behalf of Delta to assess the noise impact of replacing water cooling system with an air cooled system.

Accordingly, this report assesses the noise impact of the proposed gas turbine power station using an air cooled system.

2 OPERATIONAL NOISE CRITERIA

As part of the previous GHD study, an ambient noise study was conducted in order to determine design criteria in accordance with the Department of Environment and Climate Changes (DECC's) Industrial Noise Policy (INP).

The survey found at Gannet Road the Rating Background Noise Level (RBL) was 32 dBA during the daytime and 28 dBA during both the evening and night-time. At Bamarang Road the RBL was found to be 32 dBA during the daytime and 28 dBA during the evening and 27 dBA during the night-time.

In accordance with the INP when the RBL is found to be below 30 dBA, then it is set to be 30 dBA, and combining the evening/night-time period results in the following INP based criteria:

- Daytime L_{Aeq} of 37 dBA and evening/night-time L_{Aeq} of 35 dBA for Gannet Road residential receivers.
- Daytime and evening/night-time L_{Aeq} of 35 dBA for Bamarang Road residential receivers.
- L_{Aeq} of 65 dBA for commercial premises, as based on the INP amenity criteria.

3 OPERATIONAL NOISE MODELLING

In order to compute the environmental noise emission level from plant items and operations at the representative noise sensitive receptors, noise emission modelling was undertaken using the SoundPLAN noise prediction software, using the CONCAWE industrial noise algorithm.

The noise modelling algorithms account for the sound power levels of the sources, their heights, the distances to the receivers, the natural topography, noise barriers, air absorption, ground effects and meteorological conditions. The model incorporates the sound power levels of the equipment as given in the Environmental Assessment report, supplied by GHD. The topographic data used in the model was also supplied by GHD.

3.1 Operating Scenarios and Model Validation

In order to validate Heggies SoundPlan model, the same equipment, configuration and scenarios as used in the original Environmental Assessment were used and the results compared to those of the GHD report. Stage 1 and Stage 2 of the project were modelled for the same meteorological conditions as the GHD report, being neutral, a temperature inversion with a 2 m/s southeasterly wind, and a temperature inversion with a 2 m/s northwesterly wind.

The equipment used and their associated sound power levels for each stage in the model validation is presented in **Table 1**.

Table 1 Equipment and Sound Power Level used for Stage 1 and Stage 2 Validation.

Stage	Equipment		Number of Items	Sound Power Level (dBA)	Height Above ground (m)
1	Standard Packaged Combustion Turbine Generator [1]	CT inlet	2	99	15
		CT inlet Elbow & Duct	2	100	15
		CT Compartment	2	107	7.6
		GEN Compartment	2	106	7.6
		Exhaust Duct	2	101	6
		COMP Ventilation	2	92	15
		CT Fin Fan Cooler	2	99	15
	Generator Step-up Transformers	GSUT	2	105	4.5
2	Standard Packaged Combustion Turbine Generator [1]	CT inlet	2	99	15
		CT inlet Elbow & Duct	2	100	15
		CT Compartment	2	107	7.6
		GEN Compartment	2	106	7.6
		Exhaust Duct	2	101	6
		COMP Ventilation	2	92	15
		CT Fin Fan Cooler	2	99	15
	Generator Step-up Transformers	GSUT	3	105	4.5
	Cooling Tower [2]	Fan (Per cell)	6	108	11
		Inlet face (Per cell)	6	100	7.6
	Standard Packaged Heat Recovery Steam Generator	Transition Ductwork	2	111	12
		Boiler Section	2	107	18
		Stack Exit	2	115	27
	Major Pumps	Pump/Motor Assembly	1	110	1.5
	Steam Turbine [3]		1	107	7.6

Note 1 The Standard Packaged Combustion Turbine Generator sound power levels are based on a GE 9171E gas turbine.

Note 2 Whilst the current design incorporates air cooled condenser fans for Stage 2, the original design used cooling towers and these have been used in the Heggies model for comparison with the GHD model.

Note 3 As advised by GHD the sound power level for the CT Compartment of the Combustion Turbine Generator is used for the Steam Turbine of Stage 2.

Receivers

The same receivers were used in the Heggies noise model as in the original Environmental Assessment, as follows:

- Part Lot 2 DP 1040676 Yalwal Road, approximately 750 m north of the site.

  A commercial mud brick business is located at this location.

- Gannet Road, approximately 1.65 km southeast of the site.

  This location is representative of the nearest of a number of semi rural residences southeast of the site.

- 190 Bamarang Road, approximately 1.4 km northwest of the site.

  This location is representative of the nearest rural residences northwest of the site.

3.1.1 Model Validation Results

The noise modelling results are presented **Table 2**. Here the meteorological conditions corresponding to the three scenarios are:

- Scenario 1 - neutral
  (T=20 ^{0} C, RH=70%, Wind=0 m/s, Stability Class D)
- Scenario 2 - temperature inversion and southeasterly wind
  (T=20 ^{0} C, RH=70%, Wind=2 m/s, Stability Class F)
- Scenario 3 - temperature inversion and northwesterly wind
  (T=20 ^{0} C, RH=70%, Wind=2 m/s, Stability Class F)

Table 2 Comparison between GHD model and Heggies model (dBA)

Receivers	Noise Goals		Stage 1						Stage 2					
	Day	Night	Scenario 1		Scenario 2		Scenario 3		Scenario 1		Scenario 2		Scenario 3	
			GHD Model	Sound PLAN Model	GHD Model	Sound PLAN Model	GHD Model	Sound PLAN Model	GHD Model	Sound PLAN Model	GHD Model	Sound PLAN Model	GHD Model	Sound PLAN Model
Part Lot 2 DP 1040676 Yalwal Road	65	65	41	41	46	44	41	40	49	50	54	53	50	50
Gannet Road	37	35	31	27	31	27	37	35	39	38	39	37	45	43
190 Bamarang Road	35	35	27	24	32	29	27	23	35	37	41	41	35	37

Discussion

Comparison between the GHD and Heggies modelling results indicates acceptable correlation, in particular at the nearer receiver, Part Lot 2 DP 1040676 Yalwal Road. It is noted that generally, marginally higher results are predicted by the GHD model, with closer correlation for Stage 2 and also for stability class F, compared to neutral conditions. These differences are considered to arise mainly as a result of the different prediction algorithms used for the GHD (ISO 9613-2 1996) and Heggies (Concawe) noise models.

In summary, both the GHD and Heggies models are considered acceptable to predict and compare noise levels from the proposed gas turbine power station, with the result differences being in accordance with the respective model accuracies (tolerances). It is noted that ISO 9613-2 specifies a method to predict noise under "*meteorological conditions favourable to propagation from sources of known sound transmission*". Hence ISO 9513-2 would be expected to likely produce higher levels than CONCAWE.

3.2 Noise Assessment of the Power Station with Air Cooling

Delta are proposing the replacement of the Stage 2 water cooling system with an air cooled system to reduce the operational water requirements for the facility. The proposed current water cooling, provided by six cooling towers, will be replaced by an air cooled system comprising an array of nominally 36 fans.

The SoundPlan noise model as described in **Section 3.1** was modified to include the proposed air cooling system. Furthermore a residence at a similar distance to the site as 190 Bamarang Road, at 145 Bamarang Road has been identified and included as a residential receiver.

Sound power levels used in the modelling, as presented in **Table 1**, remain unchanged with the exception of the water cooled elements (cooling towers). These have been replaced by air cooled condenser fans, as manufactured by Hudson, with the relevant modelling parameters presented in **Table 3**.

Table 3 Hudson Air Cooled Condenser Fan Options for Stage 2

Stage	Equipment	Number of Items	Sound Power Level (dBA)	Height above Ground (m)
2	Hudson Fans[1]	36 fans	112 dBA (total)	30 [2]

Note 1 The Hudson fan sound power levels are based on a low noise design.

Note 2 The fans are located at 22 m above ground with the cooling fins extending a further 8 m above the fans.

3.2.1 Predicted Noise Level Results

Noise levels have been predicted for the air cooled option and are presented in **Table 4**. The same three meteorological conditions used for the model validation were used in the calculations (refer to **Section 3.1.1**).

Table 4 Predicted Power Station Noise Levels for Stage 2 with the Hudson Air Cooled Condenser Option

Receivers	Noise Goals (dBA)		Predicted Noise levels in dBA		
	Daytime	Night	Scenario 1	Scenario 2	Scenario 3
Part Lot 2 DP 1040676 Yalwal Rd	65	65	50	52	50
Gannet Road	37	35	38	37	42
145 Bamarang Road	35	35	25	28	25
190 Bamarang Road	35	35	38	42	37

Noise Contours for the three scenarios for the air cooled condenser option are also presented in **Appendix B**.

Discussion

Analysis of the predicted noise levels at the nominated receiver locations is summarised in the following points:

- At the distant receivers of 190 Bamarang Road (to the north) and Gannet Road (to the southeast), which are representative of the residential receivers in these areas, the design criterion is exceeded by 3 dBA under neutral conditions and by up to 7 dBA for meteorologically enhanced conditions.
- At the single isolated commercial receiver Part Lot 2 DP 1040676 Yalwal Rd (to the north), the design criterion is complied with.

3.3 Noise Mitigation

Concept mitigation (not detailed design) is discussed in this section which achieves reductions that will result in compliance of the design criterion.

As discussed in the analysis of results moderate exceedances of the design criterion is predicted at the distant receivers and mitigation was investigated to achieve a nominal reduction of 7 dBA.

The noise model was used to rank the contribution of the various sources to determine those sources requiring mitigation.

3.3.1 Design of Noise Mitigation

Under meteorologically enhanced conditions, significant contributions to the received noise levels are produced at the distant receivers by the by the stack exits, followed by the 36 Hudson fans and transition ductwork, boiler section and pumps. Providing a noise reduction of 15 dBA to the stack exits, 10 dBA to the 36 Hudson fans, transition ductwork, and boiler section, and 5 dBA to the pumps is expected to result in compliance of the design criterion at all receivers.

Indicatively, this could be achieved as follows:

- Stack exit attenuators.
  A silencer with splitters would be installed at the base of the discharge stack of the standard packaged heat recovery steam generator. The splitter length is likely to be required to be several diameters in length and cladding of the stack may be required to reduce radiated noise. Octave band noise reductions similar to those for a simple two diameter long conventional silence were assumed in the modelling, which is considered conservative.

- 36 Hudson fan array.
  Given the fans are of a “low noise” design, options for the mitigation of fan noise are generally limited to attenuators to the fan inlet and outlet, or shielding by a perimeter noise barrier for the fan array. Noting there are technical issues with the use of silencers (ie fan static pressure constraints, mounting above cooling fins) a noise barrier has been assumed and modelled to be continuous from a height of 8 m below the fan to 8 m above the fans. The barrier is also assumed to be internally lined with acoustic absorption to reduce reflections.
- Transition Duckwork
  The transition ductwork would be lagged and shrouded including thermal expansion joints.
- Boiler Section
  The boiler section would be total enclosed in a building nominally of standard sheet metal construction and internally lined with acoustic insulation (both walls and roof).
- Pumps
  The pumps have been enclosed in a 2.5 m high noise barrier internally lined with acoustic absorption to reduce reflections.

The noise model was modified to include the noise barriers described in dot points 2 and 5, and the octave band noise reductions expected from the stack exit attenuators ,duckwork lagging and boiler enclosure. Noise levels have been predicted with these mitigation measures implemented and the results are presented in **Table 5** at the nominated receivers.

Table 5 Predicted Power Station Noise Levels for Stage 2 with the Hudson Air Cooled Condenser Option and Noise Mitigation.

Receivers	Noise Goals (dBA)		Predicted Noise levels in dBA		
	Daytime	Night	Scenario 1	Scenario 2	Scenario 3
Part Lot 2 DP 1040676 Yalwal Rd	65	65	43	47	43
Gannet Road	37	35	28	28	33
145 Bamarang Road	35	35	19	23	19
190 Bamarang Road	35	35	28	32	28

With the noise mitigation measures implemented above, **Table 5** indicates compliance with the design goal at all receivers. Noise Contours for the three scenarios for the air cooled condenser option with noise mitigation are also presented in **Appendix C**.

4 CONCLUSION

Delta Electricity (Delta) proposes to construct a gas turbine power station and associated infrastructure, including transmission connections at Bamarang. The proposal is planned to be developed in two stages consisting initially of two open cycle gas turbines for a peaking facility (Stage1) which are then converted to a combined cycle gas turbine power facility to meet intermediate/base load demands (Stage 2).

GHD was originally commissioned by Delta to assess the acoustic impacts of the proposed gas turbine power facility. This previous assessment was conducted in December 2005 and is based on a water cooling system (cooling towers) for the plant. It is now planned to replace the water cooling with air cooling to reduce operational water requirements of the plant and Heggies have been commissioned by GHD on behalf of Delta to access the noise impact of the power station using to air cooling. The results of the study are summarised in the following points:

- Heggies produced a noise model using the SoundPLAN noise prediction software and the CONCAWE industrial noise algorithm. The model was based on the plant noise emission data from the December 2005 study and the more recent modelling was validated against the results of the previous study.
- Design criteria where set in accordance with the December 2005 study.
- The unmitigated noise levels are predicted to exceed the design criterion by up to 7 dBA at the receivers under meteorologically enhanced conditions.
- In principle noise mitigation measures have been considered in order to achieve compliance at the receivers.

ACOUSTIC TERMINOLOGY USED IN THE REPORT

1 Sound Level or Noise Level

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

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

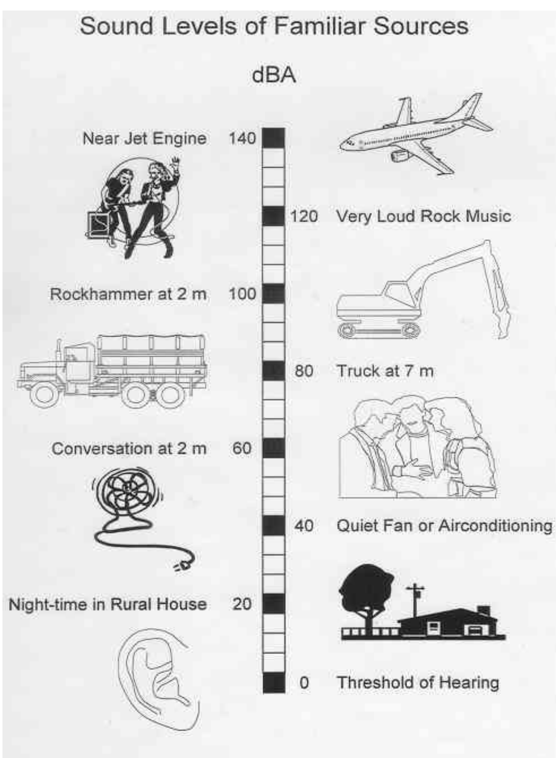
The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2×10^{-5} Pa.

2 "A" Weighted Sound Pressure Level

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

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

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



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

3 Sound Power Level

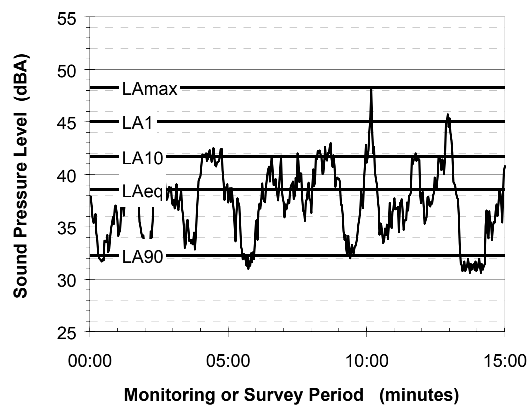
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

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

4 Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{AN}, where L_{AN} is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the L_{A1} is the noise level exceeded for 1% of the time, L_{A10} the noise exceeded for 10% of the time, and so on.

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



Of particular relevance, are:

L_{AMax} The maximum noise level of the 15 minute interval.

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

L_{A10} The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.

L_{A90} The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

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

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

ACOUSTIC TERMINOLOGY USED IN THE REPORT

This method produces a level representing the "repeatable minimum" L_{A90} noise level over the daytime and night-time measurement periods, as required by the DEC. In addition the method produces mean or "average" levels representative of the other descriptors (L_{Aeq}, L_{A10}, etc).

5 Tonality

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

6 Impulsiveness

An impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.

7 Frequency Analysis

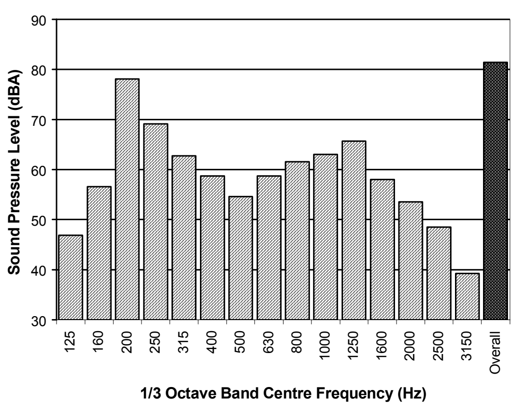
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.



8 Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of "peak" velocity or "rms" velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as "peak particle velocity", or PPV. The latter incorporates "root mean squared" averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (10^{-9} m/s). Care is required in this regard, as other reference levels may be used by some organizations.

9 Human Perception of Vibration

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

10 Over-Pressure

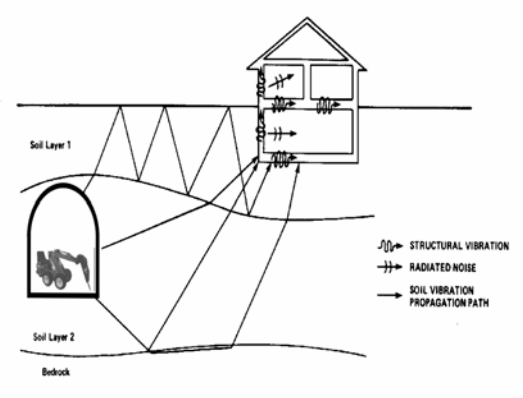
The term "over-pressure" is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

2 Ground-borne Noise, Structure-borne Noise and Regenerated Noise

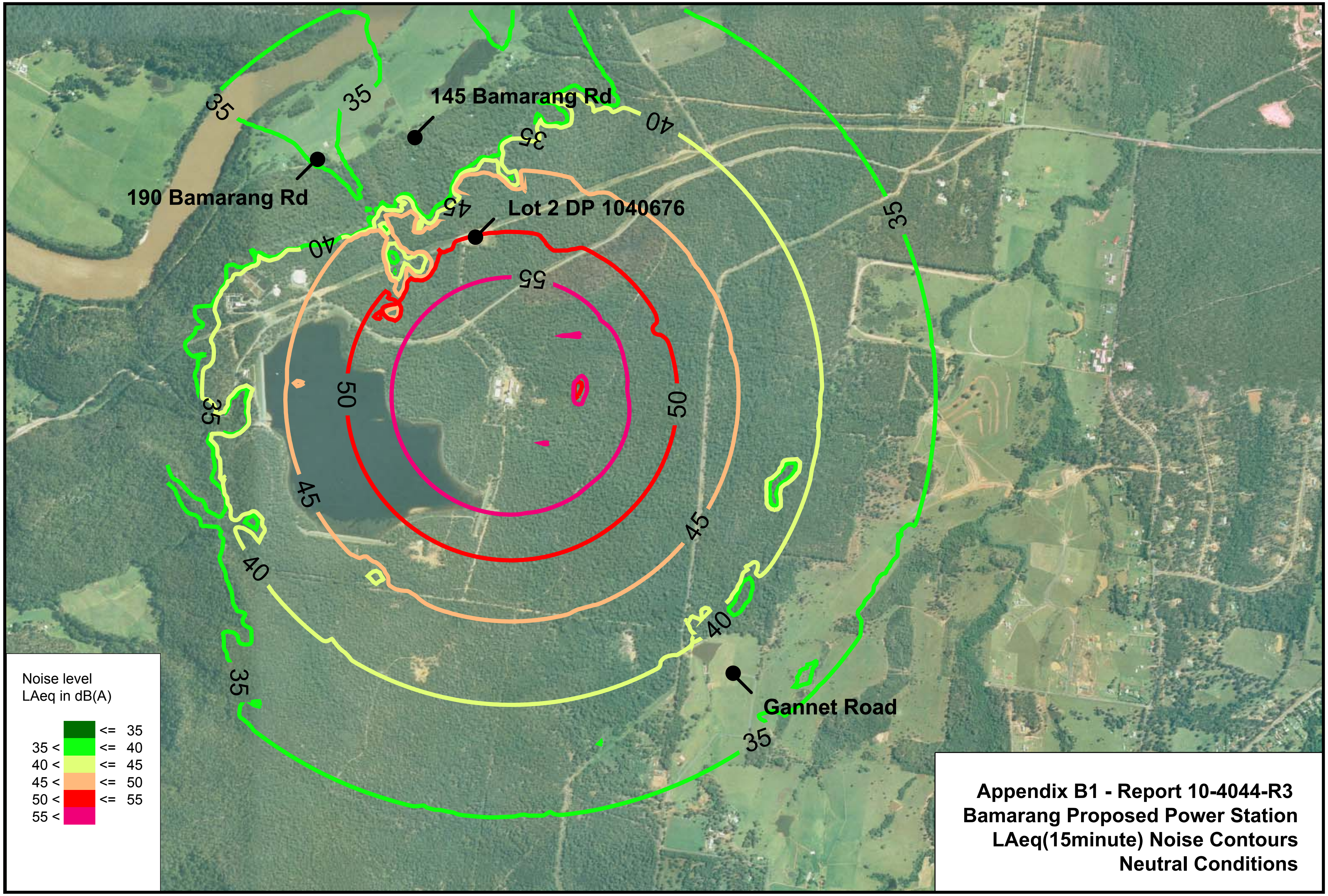
Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed "structure-borne noise", "ground-borne noise" or "regenerated noise". This noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.

Typical sources of ground-borne or structure-borne noise include tunnelling works, underground railways, excavation plant (eg rockbreakers), and building services plant (eg fans, compressors and generators).

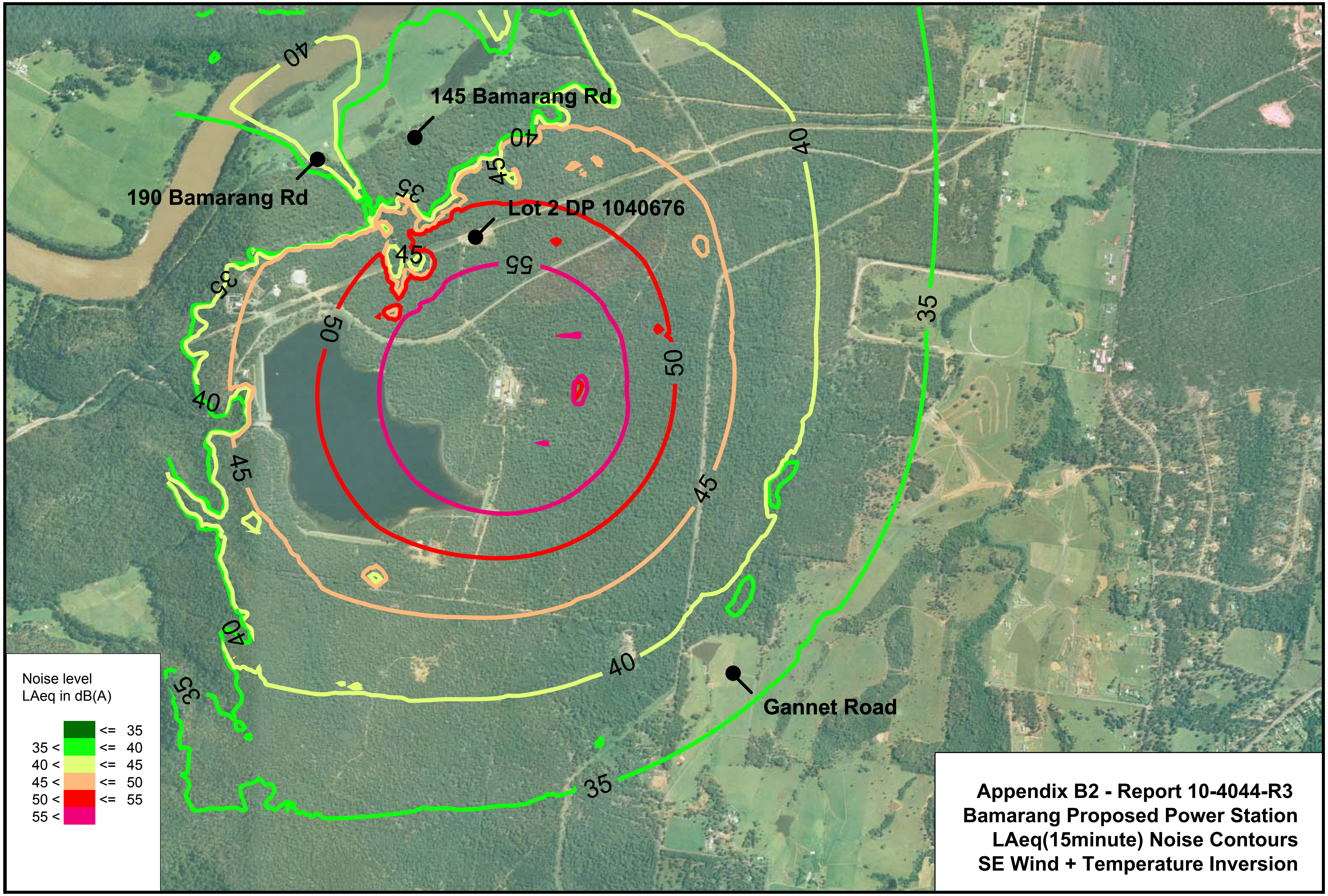
The following figure presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.



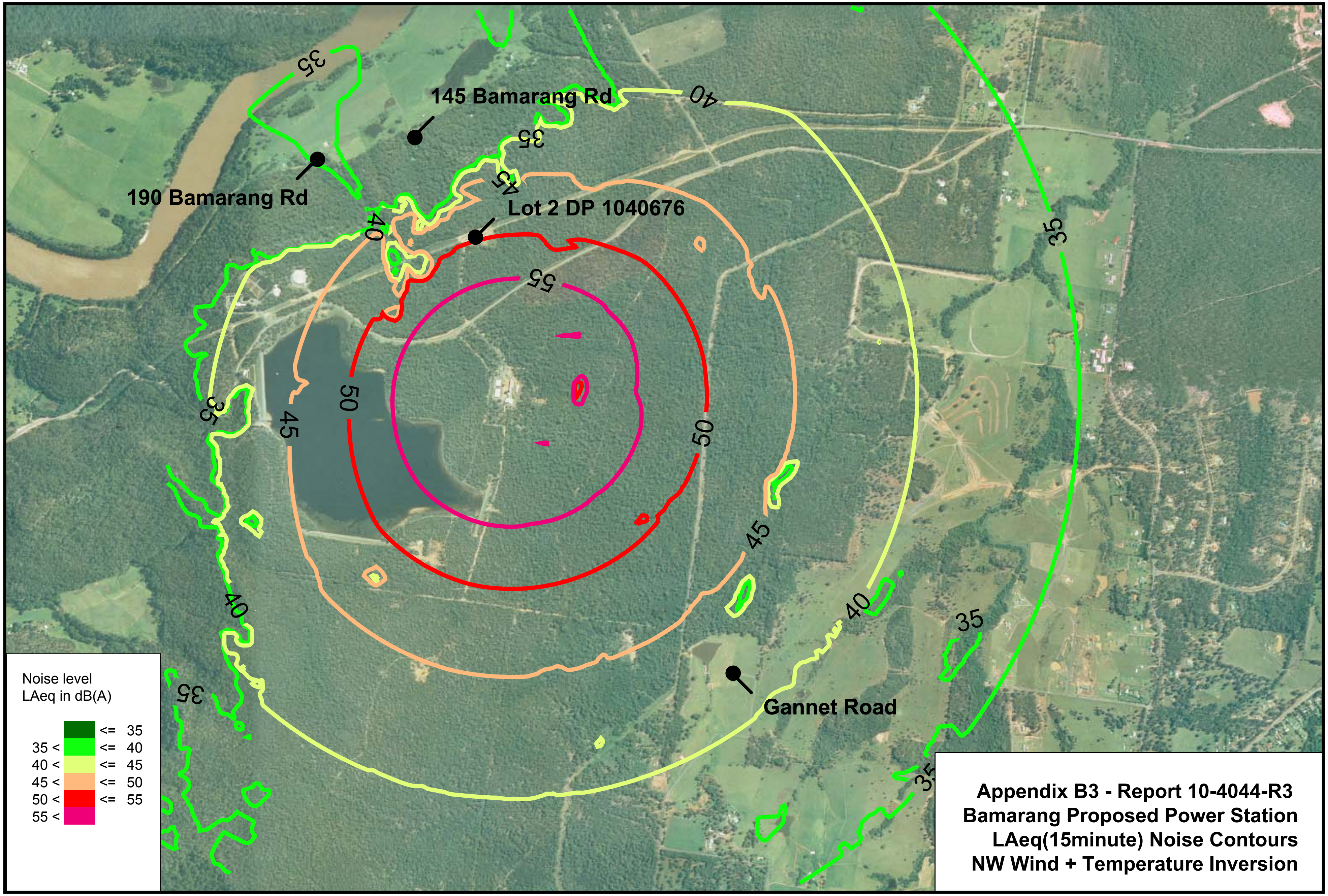
The term "regenerated noise" is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect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



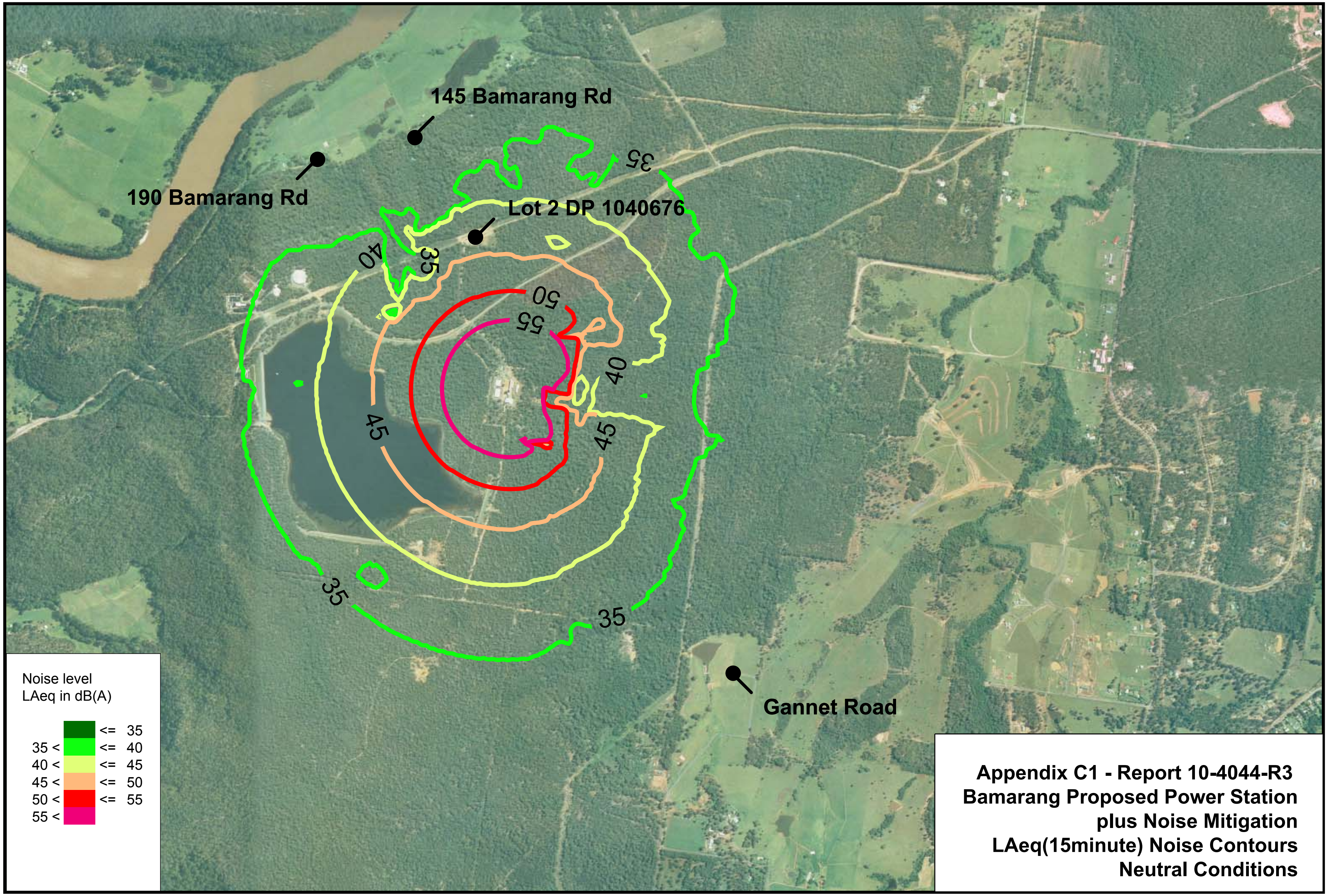
Appendix B1 - Report 10-4044-R3
Bamarang Proposed Power Station
LAeq(15minute) Noise Contours
Neutral Conditions



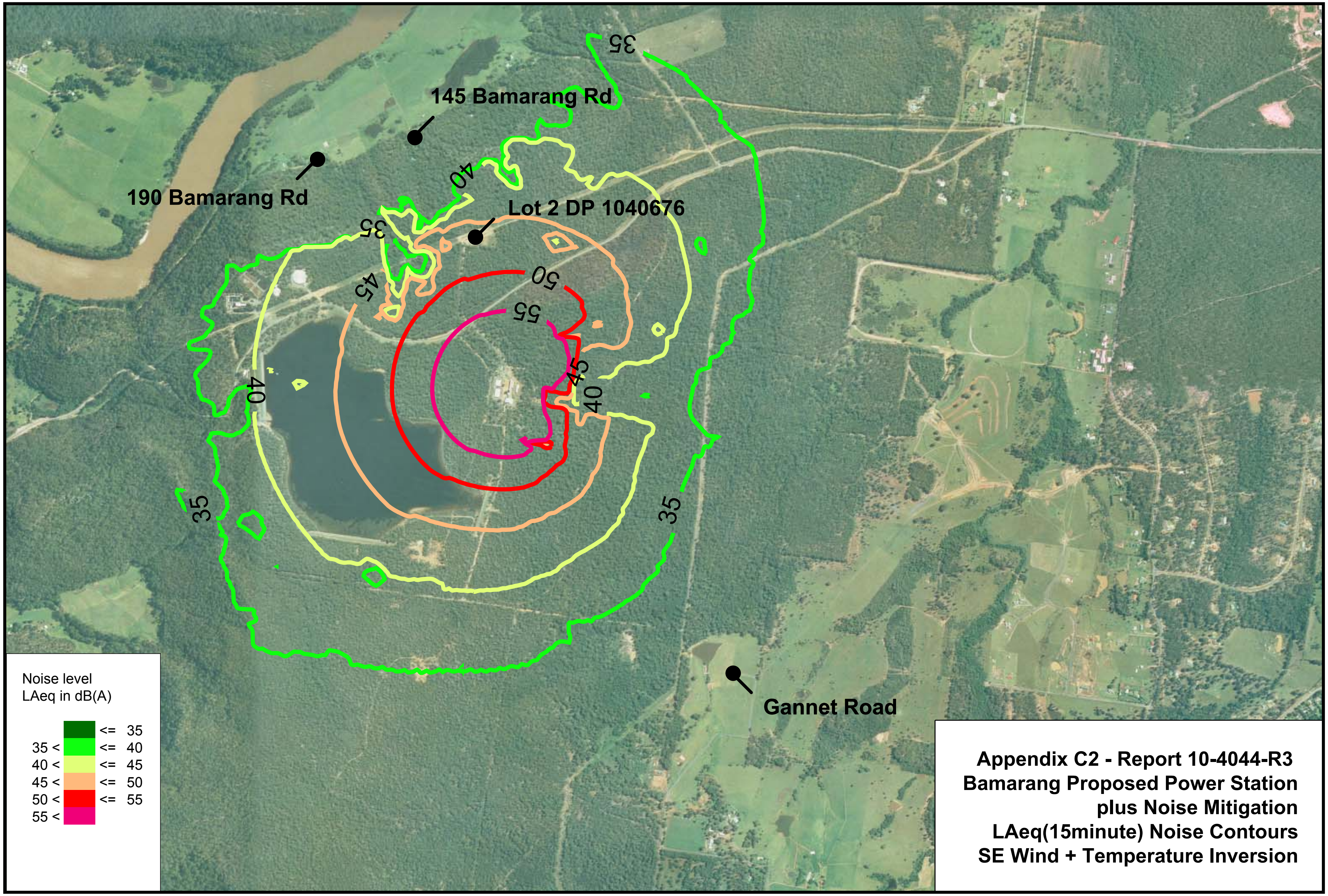
Appendix B2 - Report 10-4044-R3
Bamarang Proposed Power Station
LAeq(15minute) Noise Contours
SE Wind + Temperature Inversion



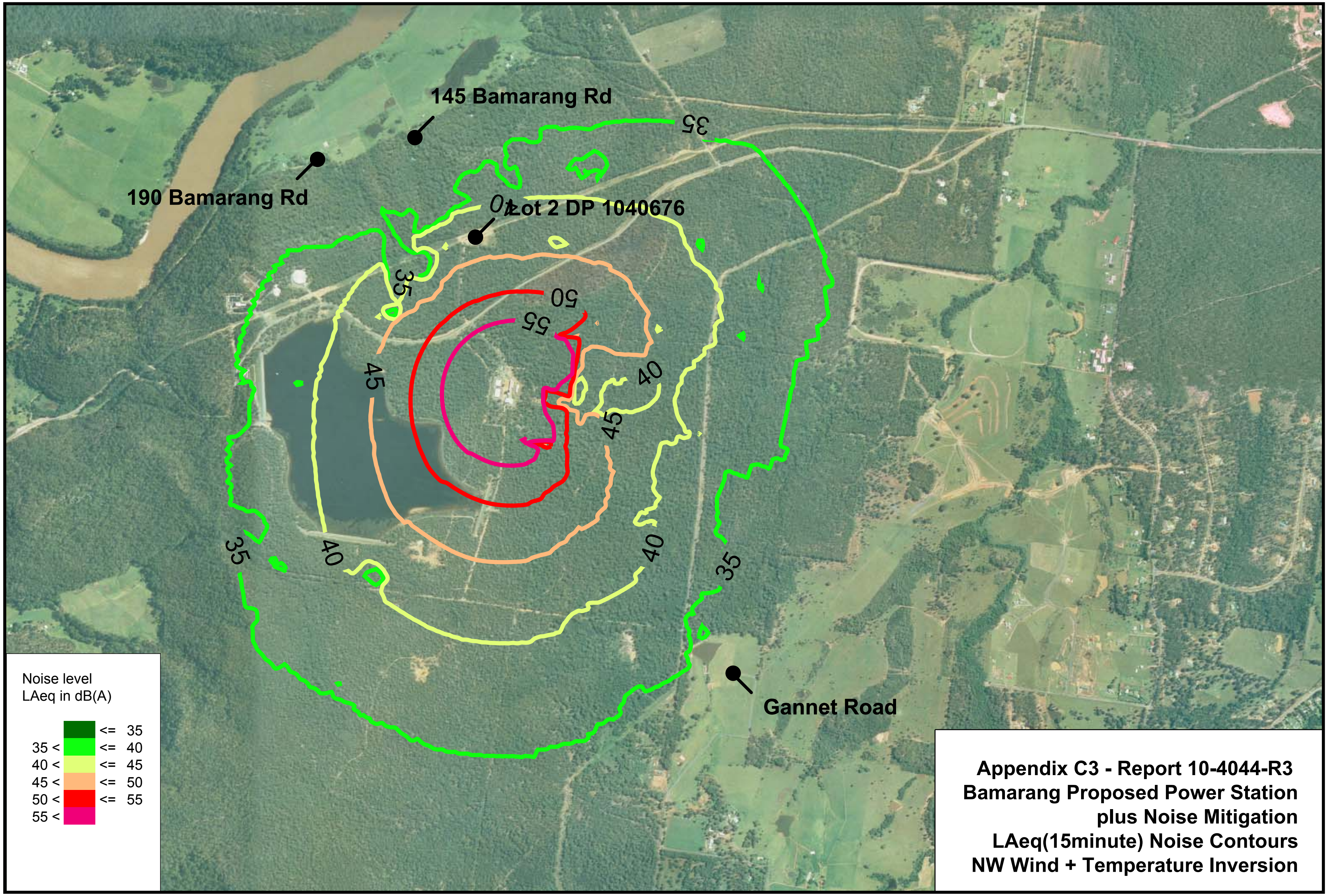
Appendix B3 - Report 10-4044-R3
Bamarang Proposed Power Station
LAeq(15minute) Noise Contours
NW Wind + Temperature Inversion



Appendix C1 - Report 10-4044-R3
Bamarang Proposed Power Station
plus Noise Mitigation
LAeq(15minute) Noise Contours
Neutral Conditions



Appendix C2 - Report 10-4044-R3
Bamarang Proposed Power Station
plus Noise Mitigation
LAeq(15minute) Noise Contours
SE Wind + Temperature Inversion


145 Bamarang Rd
190 Bamarang Rd
Lot 2 DP 1040676
Gannet Road
35
40
45
50
55
Noise level
LAeq in dB(A)
<= 35
35 < <= 40
40 < <= 45
45 < <= 50
50 < <= 55
55 <
Appendix C3 - Report 10-4044-R3
Bamarang Proposed Power Station
plus Noise Mitigation
LAeq(15minute) Noise Contours
NW Wind + Temperature Inversion