HEGGIES

REPORT 40-1530-R2

Revision 3

PNG LNG Project - Upstream
Environmental Noise Impact Assessment

PREPARED FOR

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PNG LNG Project - Upstream

Environmental Noise Impact Assessment

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EXECUTIVE SUMMARY

The Papua New Guinea Liquefied Natural Gas (PNG LNG) Project involves the development of a number of gas fields and facilities in a series of development phases to produce liquefied natural gas (LNG) for export.

This report presents the findings of the noise assessment including potential noise impacts associated with the construction and operation of the proposed upstream facilities. Some aspects of this project, such as construction of the pipeline, was covered in the previous PNG Gas Project. The findings from the previous study are summarised in this report.

The upstream facilities of the Juha Production Facility and Hides Gas Conditioning Plant are located in the rugged mountains of the Southern Highlands Province and the Western Province.

The proposed site for the Juha Production Facility is in remote, hilly terrain, approximately 60 km west of Hides. The district is sparsely populated and it is understood that no communities live in the vicinity of the proposed site.

The proposed Hides Gas Conditioning Plant site is located southeast of the base of the Hides Ridge approximately 2 km north-northeast from the centre of the village of Laite. The nearest potentially affected noise-sensitive receptors to the Hides Gas Conditioning Plant site are residents in the villages of Laite and Para.

Noise monitoring was conducted at two locations close to the proposed Hides Gas Conditioning Plant during April 2008 to determine and characterise existing ambient noise levels. The noise environment at both monitoring locations was generally similar in character, with the main noise sources being natural sources such as wind noise in foliage, insects, birds, periods of heavy rain and domesticated animals, together with typical village activities.

The results at all monitoring sites indicate that evening and night-time background noise levels are higher than during the day time. Recordings taken during the night period indicated that insect noise dominates the ambient noise environment which is a common feature of the ambient environment all year round. The prevailing meteorological conditions were evaluated and it was concluded that winds and temperature inversions with the ability to enhance noise propagation are a feature of the region during certain times of the year.

Project operational and construction noise criteria were developed with consideration to the WHO *Guidelines for Community Noise* and the International Finance Corporation (IFC) (World Bank) *Noise Management Guidelines*. Appropriate criteria for blasting and the site boundary were also developed.

Computer noise modelling was utilised to predict noise levels at receptors for a number of construction and operational scenarios. For aspects of the project where detailed information is not available a maximum required buffer distance approach has been adopted.

A preliminary investigation of noise levels surrounding well drilling at Hides 4 Pad A indicates that up to 10 receptor locations would potentially be impacted during the night period. Appropriate mitigation measures will need to be investigated during detailed design when further equipment information is available.

Noise modelling indicates that construction of the Juha Production Facility and Hides Gas Conditioning Plant will be compliant with project noise criteria under all conditions during the day period. Furthermore, construction noise is likely to be inaudible against the existing ambient background noise level at many of the nearby receptors in Laite.

EXECUTIVE SUMMARY

Predicted noise levels of the operations of the upstream project components such as wellheads, pipelines and the Juha Production Facility were found to comply with all noise criteria.

Predicted operational noise levels of the Hides Gas Conditioning Plant facility and utilities exceed the night period noise criteria under neutral meteorological conditions at a relatively small number of receptors (fourteen). Twelve of these are predicted to exceed by less than 3 dBA, which would be considered a minor exceedance and unlikely to be perceptively different from other compliant locations. Two locations are predicted to exceed the boundary fence criteria of 45 dBA by less than 2 dBA. It may be feasible to modify the perimeter boundary fence position so as to include these additional isolated receptors within the relocation zone area.

The noise exceedances predicted for the Hides Gas Conditioning Plant under neutral propagation conditions are considered manageable.

Under adverse propagation conditions thirteen receptors are predicted to exceed the Boundary Noise Target of 45 dBA. A further twenty three receptors exceed the night period noise assessment criteria of 40 dBA. The number of predicted exceedances under adverse propagation conditions is significant, however, it requires to be considered in the context of the likelihood and frequency of occurrence that conditions capable of resulting in such impacts take place.

There is preliminary evidence to show that the prevailing conditions at the Hides Gas Conditioning Plant site serve to reduce noise propagation in the direction of receptors and not enhance it. If this is the case the noise model assumed for 'adverse' conditions yields conservatively high results. It is important to note that all analysis has been completed using the TAPM model generated data and as such should only be treated as an approximation. Real measured meteorology data from the site would be necessary confirm the propagation effects to a greater degree of accuracy and confidence.

The noise emissions from the Hides Gas Conditioning Plant will need to be considered further and evaluated in greater detail during the detailed engineering design phase of the project. Operations noise will need to be re-assessed for conformance to project noise criteria in the Environmental Noise Management Plan.

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1 INTRODUCTION

Heggies Pty Ltd has been commissioned by Coffey Natural Systems, on behalf of ExxonMobil, to conduct an environmental noise impact assessment for the proposed upstream components of the Papua New Guinea Liquified Natural Gas Project (PNG LNG).

This report presents the findings of the noise assessment including potential noise impacts associated with the construction and operation of the proposed upstream facilities.

Construction of the pipeline was, essentially, covered in the previous PNG Gas Project. The findings from the previous study are summarised in this report.

This report presents:

- A brief description of the overall project, in particular, the upstream components; including site location and closest affected residential areas.
- Some introductory information about the nature of noise.
- A review of the existing ambient noise environment.
- A review of meteorological data and its influence on noise propagation.
- A review of relevant benchmarks for noise levels to determine appropriate standards during construction and operation of the project.
- A comparison of preliminary predictions of noise levels against project noise standards.

2 PROJECT DESCRIPTION

The Papua New Guinea Liquefied Natural Gas (PNG LNG) Project involves the development of a number of gas fields and facilities in a series of development phases to produce liquefied natural gas (LNG) for export. The development will also produce condensate. The development of the Hides, Angore, and Juha gas fields and blowdown of the gas caps at the existing Kutubu, Agogo and Gobe oil fields will supply the gas resources. An extensive onshore and offshore pipeline network will enable transportation of the gas to a new LNG Plant near Port Moresby and stabilised condensate to the existing oil processing and storage, and offloading facilities at the Kutubu Central Processing Facility and Kumul Marine Terminal respectively. Small amounts of condensate are also produced at the LNG Facilities site.

Esso Highlands Limited (Esso), a Papua New Guinea subsidiary of the Exxon Mobil Corporation (ExxonMobil), is the operator of the PNG LNG Project. The PNG LNG Project will be developed in five phases over a period of 10 years to ensure reliability and consistent quality of supply of LNG for over the 30 year life of the project.

A list of the proposed developments is provided below, and **Figure 1** shows a schematic of facilities and pipelines:

2.1 Upstream Development Components

- Hides gas field development:
  - Seven wellpads with a total of eight new wells and re-completion of two existing wells.
  - Hides gathering system including gas flowlines from new and re-completed Hides wells.
  - Hides spineline and mono-ethylene glycol (MEG) Pipeline in the same right of way (ROW).
  - Hides Gas Conditioning Plant.
  - Hides–Kutubu Condensate Pipeline in the same ROW as the LNG Project Gas Pipeline.
- Juha gas field development:
  - Three new wellpads with four new wells.
  - Juha gathering system including gas flowlines from new Juha wells.
  - Juha spinelines and MEG Pipeline in the same ROWs.
  - Juha Production Facility.
  - Juha–Hides pipelines right of way (ROW) containing three pipelines including Juha–Hides Rich Gas Pipeline, Juha–Hides Liquids Pipeline and Hides–Juha MEG Pipeline.
- Angore gas field development:
  - Two new wellpads with two new wells.
  - Angore gathering system including gas flowlines from new Angore wells.
  - Angore spineline and Angore MEG Pipeline to Hides Gas Conditioning Plant, both in the same ROW.
- Gas from existing fields:
  - Gas treatment at the Agogo Production Facility and a new Agogo Gas Pipeline from the Agogo Production Facility to LNG Project Gas Pipeline.
  - Gas treatment at the Gobe Production Facility and a new Gobe Gas Pipeline from the Gobe Production Facility to LNG Project Gas Pipeline.
  - Gas treatment at the Kutubu Central Processing Facility and a new Kutubu Gas Pipeline from the Kutubu Central Processing Facility to the LNG Project Gas Pipeline.

    - South East Hedinia gas field development: one new wellpad and two new wells; new gathering system including gas flow lines from the South East Hedinia new wells to the Kutubu Central Processing Facility in the same ROW as the Kutubu Gas Pipeline.
- Kopi scraper station.
- LNG Project Gas Pipeline:
    - Onshore: from Hides Gas Conditioning Plant to Omati River Landfall.
    - Offshore: Omati River Landfall to Caution Bay Landfall.

2.2 LNG Facilities Development Components

- Onshore LNG Plant including gas processing and liquefaction trains, storage tanks, flare system and utilities.
- Marine facilities including jetty, LNG and condensate export berths, materials offloading facility and tug moorage.

2.3 Supporting Facilities and Infrastructure

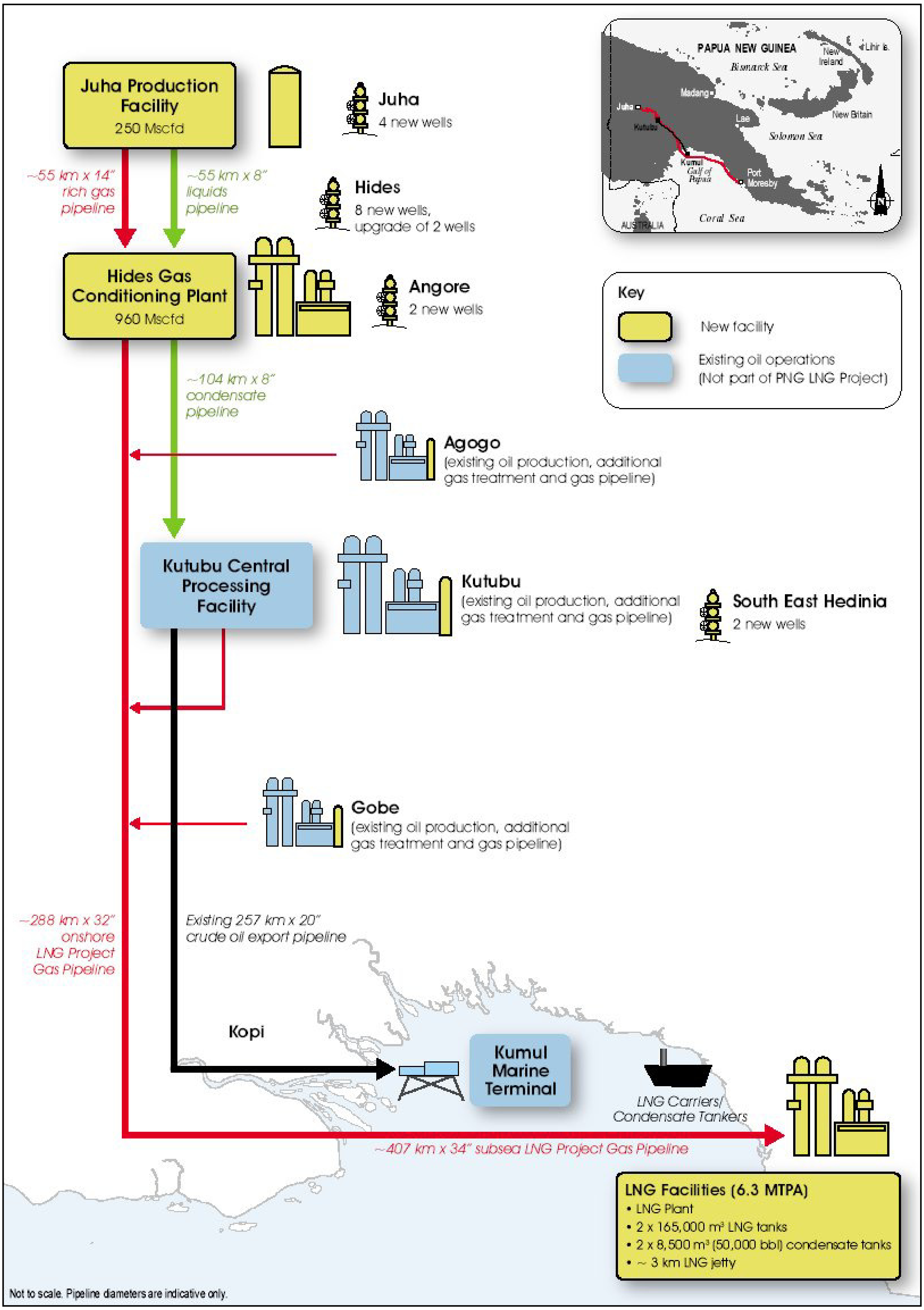
In addition to the principal gas production, processing and transport, and LNG production and export facilities, the project will involve the following permanent infrastructure and facilities:

- New roads and upgrade of existing roads.
- New bridges and upgrade of existing bridges.
- Upgrade of two existing airfields (upstream at Komo and Tari).
- New helipads (multiple).
- New wharf and an upgrade of the existing Kopi roll-on, roll-off facility.
- Water supply systems and pipelines, wastewater and waste management facilities.
- Operations Camps (at Hides, Juha and Tari).

A series of temporary works and access roads will also be required during the construction phase, including:

- Construction camps (multiple).
- Material/pipe laydown areas.

Figure 1 Project Overview



3 SITE DETAILS AND OVERVIEW

3.1 Site Location

The upstream facilities of the Juha Production Facility and Hides Gas Conditioning Plant are located in the rugged mountains of the Southern Highlands Province and the Western Province.

3.1.1 Juha

The proposed site for the Juha Production Facility is in remote, hilly terrain, approximately 60 km west of Hides. The district is sparsely populated and it is understood that no communities live in the vicinity of the proposed site. The closest villages are Siabi, 9 km to the west, and Gesesu, 11 km southeast. The region around the proposed plant is bound by the Karius Range to the north and east and by the Carrington River to the south. The three Juha wellpads will be located to the west and northwest of the Juha Production Facility site, with a steep gorge separating the southern from the northern wellpad sites.

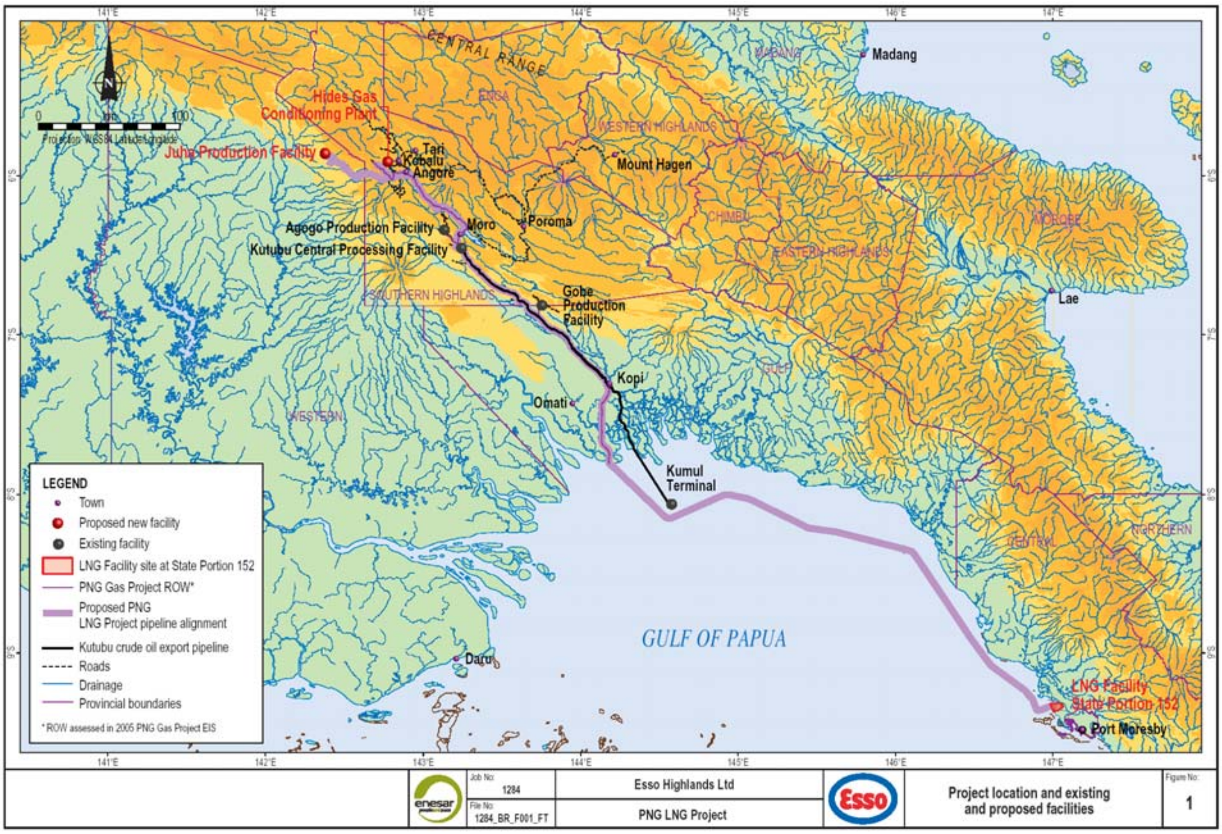
3.1.2 Hides

The proposed Hides Gas Conditioning Plant site is located southeast of the base of the Hides Ridge approximately 2 km north-northeast from the centre of the village of Laite.

The seven Hides wellpads are positioned on the crest of the Hides Ridge, which rises to the northwest of the Hides Gas Conditioning Plant site. The two Angore wellpads will be located between the Tagari and Dagia rivers approximately 7 km east of the Hides Gas Conditioning Plant.

Figure 2 shows the location of the Juha Production Facility and Hides Gas Conditioning Plant sites in relation to Port Moresby and other facilities.

Figure 2 Location of Upstream PNG LNG Project Components



3.2 Affected Receptors - Hides Gas Conditioning Plant

3.2.1 Laite

The nearest potentially affected noise-sensitive receptors to the Hides Gas Conditioning Plant site are residents in the village of Laite. Laite is geographically spread along the Para - Kolate Road, with huts and gardens generally within 1 km either side of the road.

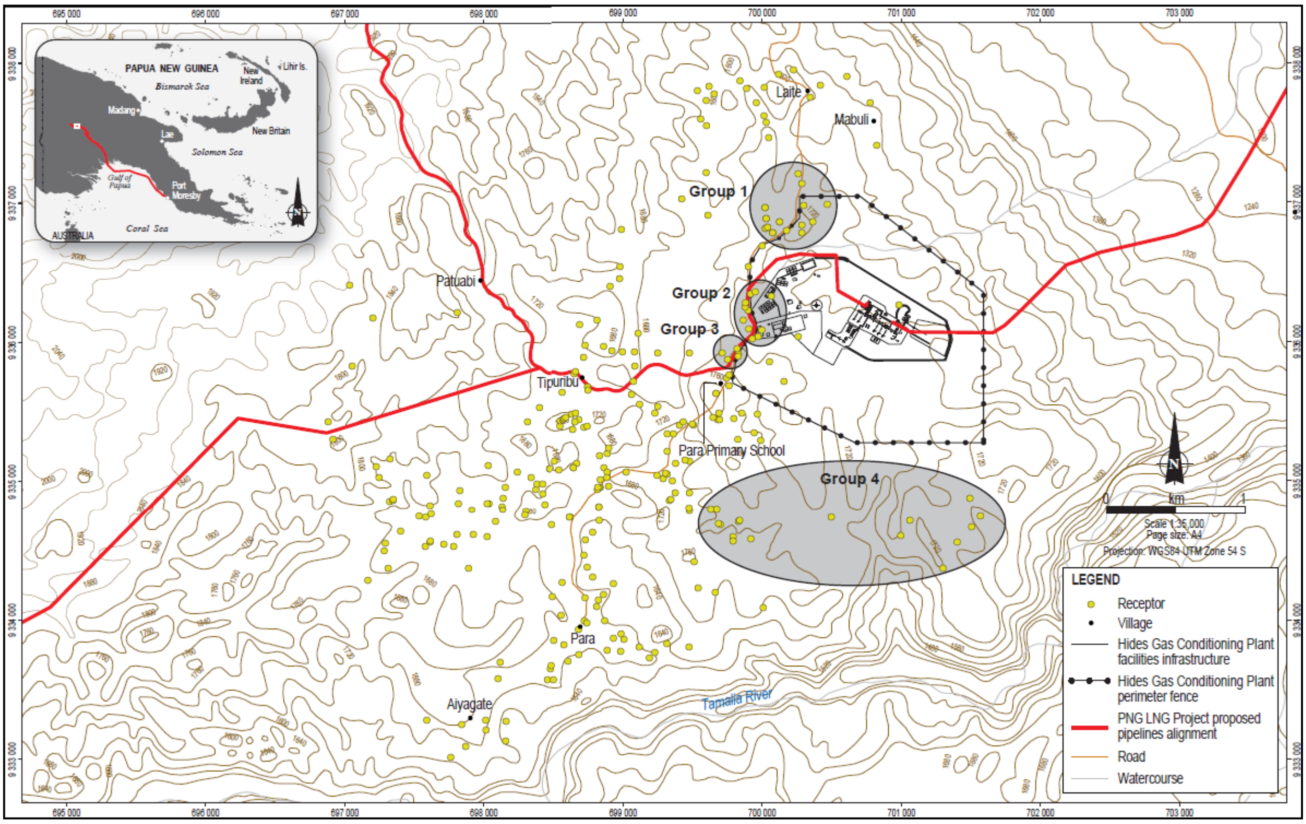
The houses are generally of lightweight construction and made of bush timber, grass roofs, fibro cement sheet, timber weatherboard or tin.

Para Primary School is located to the southern end of Laite and consists of several school buildings around a large open playground, as well as residences for the headmaster and several teachers.

3.2.2 Para

Para is located immediately to the south of Laite. The community is further away from the Hides Gas Conditioning Plant site and being on the southern slope of Hides Ridge, is better shielded from noise from the project site.

Figure 3 Proposed Hides Gas Conditioning Plant and Surrounding Residential Communities



The nearest surrounding receptors to the Hides Gas Conditioning Plant site can be loosely categorised by four groupings as indicated in **Figure 3** and **Table 1**.

Table 1 Receptor Groupings

Group 1	900-1500 m northwest of Hides Gas Conditioning Plant
Group 2	600-800 m west of Hides Gas Conditioning Plant
Group 3	Para Primary School
Group 4	1500 - 1800 m south of Hides Gas Conditioning Plant

3.3 Affected Receptors – Juha Production Facility

The proposed location of the Juha Production Facility site is remote and relatively uninhabited. The nearest settlements are at Siabi, approximately 9 km to the west and Gesesu, approximately 11 km to the southeast of the Juha Production Facility. There are no dwellings or noise sensitive receptors within 2 km of the proposed Juha Production Facility site.

4 NOISE FUNDAMENTALS

4.1 Noise

Hearing is a fundamental human sense and is used constantly for communication and awareness of the environment.

Noise is generally described as being 'unwanted' or 'unfavourable' sound and, to some extent, is an individual or subjective response as what may be sound to one person, may be regarded as noise by another.

The measurement and assessment of sound has been developed steadily over the last century, taking into account human response measures such as hearing damage and other potential health affects such as stress. Complex sound measurement and analytical devices have also been developed.

4.2 A-weighting and 'dBA'

The overall level of a sound is usually expressed in terms of dBA, which is measured using the 'A-weighting' filter incorporated in sound level meters. These filters have a frequency response corresponding approximately to that of human hearing. People's hearing is most sensitive to sounds at mid frequencies (typically 500 Hz to 4,000 Hz) and less sensitive at lower and higher frequencies. The level of a sound in dBA is a considered a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally as loud, although the perceived loudness can also be affected by the character of the sound (e.g. the loudness of human speech and a distant motorbike may be perceived differently, although they can be of the same dBA level).

A change of up to 3 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.

Table 2 presents examples of typical noise levels.

Table 2 Typical Noise Levels

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

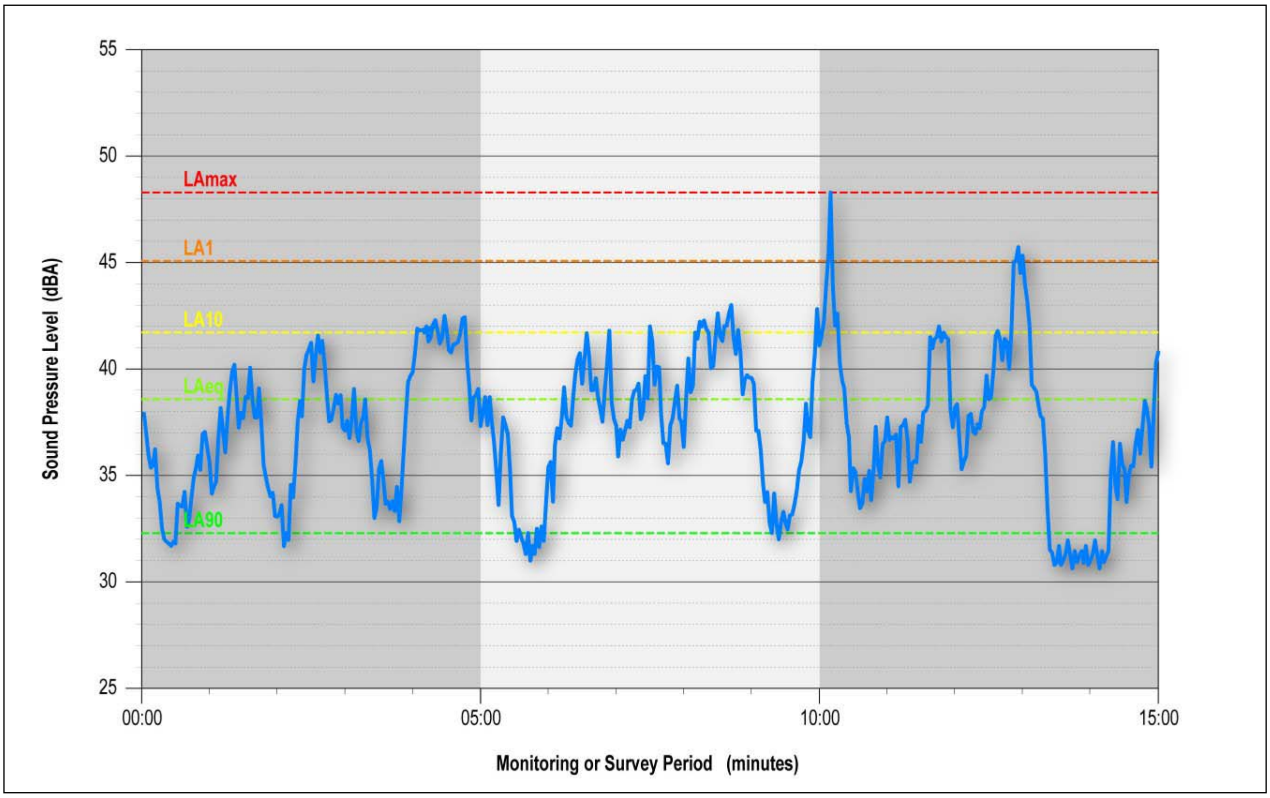
4.3 Statistical Noise Level Descriptors

As environmental noise usually varies in level over time, it is common to present the results of environmental noise testing in the form of statistical descriptors.

An explanation of noise level descriptors typically used for assessing the noise environment are illustrated in **Figure 4** and described below.

LAmax	The maximum A-weighted noise level associated with a noise measurement interval.
LA1	The noise level exceeded for 1% of a given measurement period. This parameter is often used to represent the typical maximum noise level in a given interval.
LA10	The A-weighted sound pressure level exceeded 10% of a given measurement interval and is utilised normally to characterise average maximum noise levels.
LAeq	The A-weighted equivalent continuous sound level. It is defined as the steady sound level that contains the same amount of acoustical energy as a given time-varying sound over the same measurement interval. Can be loosely thought of as the 'average'.
LA90	The A-weighted sound pressure level exceeded 90% of a given measurement interval and is representative of the average minimum sound level. Often used to describe the 'background' level.

Figure 4 Graphical Display of Typical Noise Indices



4.4 Character

The A-weighted noise level alone is a simplistic parameter and may not be sufficient in providing a thorough assessment of noise. The subjective character of a sound is also a significant parameter that needs to be considered.

Some basic characteristics of sound which can make a sound more or less intrusive include:

- The frequency content of a sound – i.e. low frequency sound such as exhaust noise or high frequency sound such as birds or insects,
- the 'tonality' of a sound – i.e. sound contains one or more prominent tones such as a horn or a whistle,
- the 'impulsiveness' of a sound – i.e. hammering, dog barking or a intermittently operating power saw.

The above parameters can usually be indicatively subjectively assessed, but more thorough assessment can be made with advanced sound measuring devices (i.e. narrow band or one-third octave analysis). Many noise policies provide an assessment method which applies penalties to sounds that exhibit particular characteristics such as the above.

5 EXISTING NOISE AND METEOROLOGICAL ENVIRONMENT

5.1 Noise Environment

Fundamental to the noise assessment is determining the existing noise climate at surrounding villages to project areas.

In April 2008, noise monitoring and surveys were conducted in the Hides area at two locations close to the proposed project area to characterise existing ambient and background noise levels. The selected monitoring sites were:-

- Location BG4 - Laite, approximately 750 m west of the proposed Hides Gas Conditioning Plant site;
- Location BG6 - Laite, approximately 1.2 km southwest of the proposed Hides Gas Conditioning Plant site.

A 24 hour period of background noise monitoring was conducted at a village in the Hides area by Holmes Air Sciences Pty Ltd from 31st May 2005 as part of the Noise Impact Assessment for the PNG Gas Project[1]. The monitoring location was approximately 1 km to the northwest from the Hides Processing Facility site of that project.

The survey noted ambient sources such as birds and domestic chickens, with the sound of a distant river contributing to the minimum background noise level. The results of the historical Hides background monitoring have been re-processed and are provided in **Table 4.**

It should be noted that the length of monitoring was short and only limited data was collected.

The selected locations give a good representation of the village areas nearest to the proposed operations. Photographs taken at each of the monitoring sites are depicted in **Figure 5, Figure 6** and **Figure 7.** All measurements were conducted with Acoustic Research Laboratories ARL Type 316 noise loggers which were set to log 15 minute statistical intervals, including L_1, L_{10}, L_{90} and L_{eq} noise level descriptors.

Details regarding the location and equipment details for each receiver are provided in **Table 3.**

All acoustic instrumentation employed throughout the monitoring programme complied with the requirements of Australian Standard 1259.2:1990 – *Sound Level Meters* and carried current National Association of Testing Authorities (NATA) or manufacturer calibration certificates. Instrument calibration was checked before and after each measurement survey, with the variation in calibrated levels not exceeding ±0.5 dBA.

Table 3 Noise Monitoring Locations and Details

Location	Description of Location and GPS co-ordinates	Measurement Period	Logger Details
BG4 - Laite Village	south east corner of house GPS 0699958, 9336028	1615 h 2 May 2008 to 1445 h 4 May 2008	S/N 16-306-040
BG5 - Para Primary School - Laite	north east corner of house GPS 0699638, 9335660	1545 h 4 May 2008 to 0830 h 5 May 2008	S/N 16-306-040
BG6 - Hides Historic	Near hut close to PNG GAS Project Hides Processing Facility	1100 h 31 May 2005 to 1100 h 1 June 2005	S/N 19446

[1] Holmes, N.E. (2005) *Noise Impact Assessment: PNG Gas Project*

Figure 5 Noise Monitoring at Location BG 4 - Laite

Figure 6 Noise Monitoring at Location BG 5, Para Primary School - Laite

Figure 7 Historical Noise Monitoring at Location BG 6 - 1 km northwest of Previously Proposed PNG Gas Project site

Table 4 Summary of Ambient and Background Noise Levels

	Ambient Noise Level, dBA								
Location	**Day (07:00h to 18:00h)**			**Evening (18:00h to 22:00h)**			**Night (22:00h to 07:00h)**		
	L_{90}	L_{10}	L_{eq}	L_{90}	L_{10}	L_{eq}	L_{90}	L_{10}	L_{eq}
BG4	35	53	60	40	50	55	42	48	50
BG5	38	54	57	42 *	48 *	51*	34	44	47
BG6	43	47	50	45	51	48	46	50	48

* level estimated as entire period was strongly affected by local insect noise

The results of all noise monitoring are provided in **Appendix A**.

From the monitoring data presented in **Table 4** it appears that BG5 (the school) has lower night-time background noise levels compared to BG4 (village hut). This is likely a result of the more cleared and developed nature of the school area, with limited gardens and bush surroundings resulting in fewer insects. It is concluded that BG4 and the historic data more representative of most village huts.

The results at all monitoring sites indicate that evening and night-time background noise levels are higher than during the day period.

In order to supplement the unattended logger measurements and to assist in identifying the source and character of ambient noise sources, operator attended daytime surveys were also conducted at all background noise monitoring sites. The operator-attended measurement surveys and results are summarised in **Table 5**.

The noise environment at all monitoring locations was generally similar in character, with the main noise sources being natural sources such as wind noise in foliage, insects, birds, periods of heavy rain and domesticated animals, together with typical village activities.

Night period attended noise surveys were not possible so, in order to characterise the night period noise environment at locations BG4 and BG5, a digital audio recorder was deployed alongside the noise logger. This enabled identification of particular sources of noise and assisted with post-measurement analysis.

Playback of the recordings taken during the night period indicated that insect noise dominates the noise environment.

It is surmised that high insect noise levels are a common feature of the ambient environment all year round as the tropical nature of the climate results in little variation in temperature from season to season. Discussions with the project biodiversity specialist[2] confirm that whilst the prevalence and activity of individual insect species may vary slightly throughout the year, there is generally a consistently high level of overall insect activity all year round.

A limited amount of monitoring data that was clearly affected by a single insect located close to the microphone at BG4 was removed for the purposes of analysis as this was deemed unrepresentative of the typical background.

Table 5 Operator-Attended Ambient Noise Environment (dBA re 20 µPa)

Location	Date - Start Time Weather	Measurement Description	Primary Noise Descriptor (dBA re 20 µPa)				Description of Noise Emission and Typical Maximum Levels
			L_{Amax}	L_{A10}	L_{A90}	L_{Aeq}	L_{Amax} – dBA
Hides 4 well head	2/05/08 14:40 pm cloudy W=2-3m/s S Temp=27°C	Ambient	56	41	36	40	Breeze in trees + bird calls & insects+ very distant talking+ = 36-40 dog barking wind gust to 48
BG4	3/05/08 16:10 pm cloudy W=1m/s S Temp=27°C	Ambient	61	45	37	42	wind in trees ~37 bird calls to 41 distant talking on road to 38 chickens wind gust 43-52
Hides Gas Conditioning Plant site	4/05/08 11:20 am cloudy W=calm Temp=25°C	Ambient	51	34	31	33	Birds, insects + breeze + mountain stream = 31-33 wood chopping 35-37
BG5	4/05/08 15:40 pm cloudy W=2-3m/s S Temp=28°C	Ambient	52	47	40	44	Insects+ breeze+ people talking/playing

[2] Francis Crome - Coffey Natural Systems - biodiversity specialist

5.2 Meteorological Environment

5.2.1 Prevailing Wind

Wind that is light, stable and blowing towards the receiver from the source of noise has the potential to increase noise levels. For this reason, the effect of such wind conditions should be considered when it features in the project region.

As the strength of the wind increases, noise produced by wind will obscure noise from most industrial and transport sources. Winds are therefore generally only considered to be noise-enhancing up to 3 m/s.

A commonly implemented method for assessing meteorological effects and prevailing conditions is presented by the NSW EPA Industrial Noise Policy (2000), as used during the PNG Gas Project, which states:

> *Wind effects need to be assessed where wind is a feature of the area. Wind is considered to be a feature where source to receiver wind speeds (at 10 m height) of 3 m/s or below occur for 30 percent of the time or more in any assessment period in any season.*

An assessment of existing wind conditions has been prepared from meteorological data produced by Holmes Air Sciences using the CSIRO's TAPM model using data for 2006. The dominant seasonal wind speeds and directions are presented in **Appendix B** and are shown for day (7.00 a.m. to 6.00 p.m.), evening (6.00 p.m. to 10.00 p.m.) and night (10.00 p.m. to 7.00 a.m.) periods.

The prevailing winds with velocities less than or equal to 3 m/s with a frequency greater than or equal to 30% are considered relevant to the site in accordance with the NSW Industrial Noise Policy (INP) and are shown in **Table 6.**

Table 6 Project Prevailing Wind Conditions in Accordance with the NSW Industrial Noise Policy

Season	Winds ± 45° ≤3 m/s with a Frequency of Occurrence ≥30%		
	Daytime	**Evening**	**Night-time**
Annual	SE, SSE, S, SSW	S, SSW, SW, WSW, W	SSW, SW, WSW, W, WNW
Summer	SE, SSE, S, SSW, SW	SSW, SW, WSW, W, WNW	SSW, SW, WSW, W, WNW
Autumn	ESE, SE, SSE, S, SSW	SSW, SW, WSW, W, WNW	SSW, SW, WSW, W, WNW
Winter	SE, SSE, S, SSW	S, SSW, SW, WSW, W	SSW, SW, WSW, W, WNW
Spring	ESE, SE, SSE, S, SSW	S, SSW, SW, WSW, W	SSW, SW, WSW, W, WNW

The analysis shows that wind conditions in the region with the ability to enhance noise propagation prevail in the area all year round. Receptors will generally only be downwind of noise sources during the day period, as all directions from SSW through to WNW winds will act to reduce noise levels to receptors.

Enhancement due to wind has been included as a part of this comprehensive assessment as a 'worst case' situation. For this 'worst case' situation it has been assumed that a steady 3 m/s wind blows in the direction of the receiver from each source.

5.2.2 Temperature Inversions

Temperature inversions, when they occur, have the ability to increase noise levels by focusing sound waves. Temperature inversions occur predominantly at night during the winter months.

The NSW Industrial Noise Policy (2000) Section 5.2, Temperature Inversions, states:

Assessment of impacts is confined to the night noise assessment period (10.00 pm to 7.00 am), as this is the time likely to have the greatest impact – that is, when temperature inversions usually occur and disturbance to sleep is possible.

Where inversion conditions are predicted for at least 30% (or approximately two nights per week) of total night-time in winter, then inversion effects are considered to be significant and should be taken into account in the noise assessment.

An assessment of atmospheric stability conditions has also been prepared from the 2006 TAPM generated meteorological data set previously described. The frequency of each atmospheric stability class during winter evening and night periods is shown in **Table 7.**

Table 7 Atmospheric Stability Frequency of Occurrence - Evening and Night-time

Stability Class	Occurrence Percentage					Estimated ELR[1] °C/100 m	Qualitative Description
	Annual	Summer	Autumn	Winter	Spring		
A	0.0%	0.0%	0.0%	0.0%	0.0%	<-1.9	Temperature Lapse
B	0.0%	0.0%	0.0%	0.0%	0.0%	-1.9 to-1.7	Temperature Lapse
C	0.0%	0.0%	0.0%	0.0%	0.0%	-1.7 to-1.5	Temperature Lapse
D	33.5%	31.8%	20.1%	38.2%	44.0%	-1.5 to-0.5	Neutral
E	26.7%	27.4%	22.7%	30.1%	26.5%	-0.5 to 1.5	Weak Inversion
F	39.9%	40.9%	57.3%	31.7%	29.5%	1.5 to 4.0	Moderate/Strong Inversion

1 ELR (Environmental Lapse Rate)

The frequency of occurrence of moderate to strong (ie 1.5 to >4.0°C/100 m) temperature inversions is greater than 30% during the combined evening and night periods for all seasons and therefore requires consideration.

5.2.3 Noise Modelling Meteorology - CONCAWE

The meteorological parameters used in noise modelling in the CONCAWE Environmental Parameters are shown in **Table 8**.

Table 8 Non Adverse (Calm) and Adverse Noise Modelling Meteorological Parameters

Condition	Period	Air Temp	Relative Humidity	Barometric Pressure	Wind Velocity	Atmospheric Stability Class
Non-Adverse	Day	27°C	95%	1015mBar	0 m/s	D
Worst Case Adverse	Evening and Night	27°C	95%	1015mBar	3 m/s (source to receiver)	F

6 ENVIRONMENTAL NOISE STANDARDS

There are currently no known government policies or guidelines for environmental noise in Papua New Guinea.

The primary objective of any environmental noise assessment or policy is to protect people from the adverse affects of noise. Excessive noise has the ability to cause nuisance, including sleep deprivation, stress and increased blood pressure, as well as other physical, physiological and psychological affects.

In addition, any noise policy also has to allow for businesses and industries to be able to operate without having to comply with unnecessarily stringent requirements.

Many countries around the world have developed their own noise policies to protect residents and to provide some protection for industries (by, for example, nominating land use zonings or buffer zones which allow higher noise levels in particular areas). The policies are typically developed based on previous studies and experience within those countries (and are often based on statistical analysis of community reaction to various levels of noise), or by reference to studies undertaken elsewhere around the world.

There are two international documents that provide indicative noise assessment criteria and which provide some guidance for this assessment, being the World Health Organisation (WHO) *Guidelines for Community Noise* and the International Finance Corporation (IFC) (World Bank) *Noise Management Guidelines*. The criteria presented in these documents are based on numerous historical studies and, ultimately, are similar to many criteria developed in Australia and other developed countries.

6.1 WHO *Guidelines for Community Noise*

The WHO *Guidelines for Community Noise* provide detailed background information and cover various noise related issues such as hearing impairment (occupational noise), sleep disturbance, cardiovascular and physiological affects.

Recommendations from the WHO *Guidelines* relevant to the PNG LNG Project are provided below.

6.1.1 Night Period – Sleep Disturbance

The WHO *Guidelines* generally prescribe two noise levels at residential locations to ensure that sleep is not adversely affected, being;-

- Up to 30 dBA for continuous noise.
- Up to 45 dBA for single events (maximums).

These levels are at the person's ear (i.e. typically within the residential building) and the *Guidelines* suggest that a building insertion loss correction of 15 dBA is applied to determine the equivalent external criteria for a typical house with the windows slightly open. Given the general lightweight construction of houses around the project area and considerable number of openings in most façades, a more appropriate building insertion loss correction for Papua New Guinea is considered to be 10 dBA. Consequently, an appropriate external noise limit for continuous noise is 40 dBA.

The *Guidelines* also note that special attention should be given to the following considerations when investigating sleep disturbance:

a. Noise sources in an environment with a low background noise level. For example, night traffic in suburban residential areas.

b. Environments where a combination of noise and vibrations are produced. For example, railway noise or heavy duty road vehicles.

c. Sources with low-frequency components. Disturbances may occur even though the sound pressure level during exposure is below 30 dBA.

6.1.2 Day Period

The WHO *Guidelines* recommend day period noise levels as follows:

- 55 dBA L_{eq} to 'protect the majority of people from being seriously annoyed';
- 50 dBA L_{eq} to 'protect the majority of people from being moderately annoyed'.

In addition, the *Guidelines* nominate an internal noise level inside dwellings of 35 dBA L_{eq} for the purpose of allowing good speech communications.

6.1.3 Impulsive Noise Sources

Blasting can cause high instantaneous sound levels.

The primary concern regarding blasting is that it should not cause damage to hearing. Studies presented in the WHO *Guidelines* prescribe the following limits for sources such as blasts:

- 140 dB peak for adults.
- 120 dB peak for children.

The above levels are those recommended to ensure that the potential for hearing damage is minimised.

Similarly, in Australia, the most common criteria for blasting is a peak level no greater than 115 dB, but with allowance for a small percentage to be up to 120 dB at the receptor.

6.2 IFC / World Bank *Noise Management Guidelines*

The IFC / World Bank Noise Management Guidelines prescribe noise levels for the day and night periods. The following is an extract:

> *Noise impacts should not exceed the levels presented in Table 1.7.1, or result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site.*

Table 1.7.1 Noise Level Guidelines

Receptor	*One Hour L_{Aeq} (dBA)*	
	Day (0700-2200)	*Night (2200-0700)*
Residential / Institutional /educational	*55*	*45*
Industrial / Commercial	*70*	*70*

> *Highly intrusive noises, such as noise from aircraft flyovers and passing trains, should not be included when establishing background noise level.*

The noise levels presented in the Table above are referenced as coming from the WHO *Guidelines* detailed in **Section 6.1**.

We note that for a generally quiet rural area, the ‘background + 3 dBA’ limit would be the limiting criteria. The intent of this criterion is somewhat open to interpretation and the IFC document refers to the use of a trained specialist for determining appropriate measurement parameters.

It is considered that a reasonable interpretation of the IFC Guidelines’ requirement of *‘should not result in a maximum increase in background levels of 3 dB*’ is that future plant noise L_{Aeq} imissions[3] should not be more than 3 dB greater than the existing background noise level, determined as an arithmetic average of the L_{A90} statistics for the night period.

This interpretation:

- Facilitates assessment for predicted L_{Aeq} levels. L_{A90} imissions[3] from plant would not be able to be predicted; however, we anticipate that, over the propagation distances involved for this project, they would be at least 3 to 5 dBA lower than L_{Aeq} imission[3] levels.
- Would result in compliance with the original IFC Guideline objective. If plant noise L_{Aeq} imissions[3] are limited to up to 3 dB greater than the existing background L_{A90} noise level then we would anticipate that L_{A90} imissions[3] from plant would be of approximately the same magnitude or less than existing background L_{A90} levels. This would generally result in the combined ambient level measured L_{A90} (plant + background) being no more than 3 dB greater than the pre-existing (no plant) level.
- Will protect the acoustic amenity in the critical night period, where ambient background levels are low.

6.3 Australian Criteria

Most states of Australia have thorough guidelines and policies in place for the assessment of environmental noise. A thorough review of them is not appropriate in this report; although, generally speaking, they all adopt a ‘background +’ criterion in most circumstances to determine if noise is intrusive. The measurement intervals and statistical analysis methods slightly differ between states and there is some consideration of land use zoning, but typically, for the critical night period, the noise limits are in the order of ‘background + 3 to 5 dBA’, and are based on averaging of background noise levels for the specific period being investigated (night period from 10.00 p.m. to 7.00 a.m., day from 7.00 a.m. to 6.00 p.m., evening 6.00 p.m. to 10.00 p.m.).

In addition, some policies nominate a ‘minimum’ noise limit for extremely quiet rural areas, when background noise levels are found to be particularly low. Two such criteria for night period operations are:

- 32 dBA in Victoria.
- 35 dBA in New South Wales.

The above criteria are external to buildings. Day period criteria are typically in the order of 10 to 15 dBA higher than the night period, as there is less potential for disturbance during the day, and generally higher levels of local activity and higher background noise levels.

6.4 Construction Noise

Construction noise is generally dealt with separately from operational noise. Regulatory authorities in Australia provide guidelines that provide provisions for:

- Adopting ‘good industry practice’ to avoid unnecessary impacts by ensuring all reasonable and practicable measures are taken to minimise noise resulting from the activity
- Limiting the hours of construction to standard daytime hours

[3] immission level is noise level from plant at the receiver

- Practical noise limits for construction activities occurring during the day period. For construction projects that are short in duration (i.e. less than 1 month, less than 6 months) it is generally acceptable to have elevated noise limits. For extended construction periods (i.e. greater than 6 months) the appropriate noise limit would be consistent with standard operational noise limits.
- For construction outside standard 'daytime' hours, such as night works, noise should be generally inaudible at residential locations or comply with standard operational noise limits.

6.5 Blasting

The ground vibration and airblast levels that cause concern or discomfort to residents are generally lower than the relevant building damage limits. Australian state EPAs advocate the use of the Australian and New Zealand Environment Conservation Council's (ANZECC) *Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration,* (ANZECC guidelines).

The ANZECC guidelines for control of blasting impact at residences are as follows:

- The recommended maximum level for airblast is 115 dB Linear. The level of 115 dB Linear may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 120 dB Linear at any time.
- The recommended maximum for ground vibration is 5 mm/s, Peak Vector Sum (PVS) vibration velocity. It is recommended, however, that 2 mm/s (PVS) be considered as the long-term regulatory goal for the control of ground vibration. The PVS level of 5 mm/s may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 10 mm/s at any time.
- Blasting should generally only be permitted between the hours of 9.00 a.m. to 5.00 p.m. Monday to Saturday. Blasting should not take place on Sundays and public holidays.
- Blasting should generally take place no more than once per day.

The Australian Standard 2187.2:1993 *Explosives – Storage, Transport and Use. Part 2: Use of Explosives* does not present human comfort criteria for ground vibration from blasting. It does, however, make mention of human comfort level for airblast in saying 'a limit of 120 dB for human comfort is commonly used'. This is consistent with the ANZECC guidelines. AS 2187.2:1993 nominates building damage assessment criteria as presented in **Table 9**.

Table 9 Blast Emission Building Damage Assessment Criteria (AS 2187)

Building type	Vibration level	Airblast level
Sensitive (and heritage)	PVS 5 mm/s	133 dB(Linear) Peak
Residential	PVS 10 mm/s	133 dB(Linear) Peak
Commercial/industrial	PVS 25 mm/s	133 dB(Linear) Peak

6.6 Boundary Noise Target

ExxonMobil has produced a noise philosophy document for the project which has the purpose of guiding design and detailed engineering to ensure suitable noise outcomes for the project with respect to;

- In-plant sound levels and occupational noise management and hearing protection.
- Designing appropriate sound levels for noise sensitive spaces within the facility such as control rooms, workshops, muster areas and accommodation areas.
- Developing noise performance specifications for equipment.

- Limiting noise impacts to potential community areas outside the facility. The approach proposed is to consider the proximity of any dwellings to the facility, with consideration of the potential for local communities to build new residences at the project fence lines.

With respect to this last objective it is appropriate to consider the IFC guideline noise limits of 55 dBA during the day and 45 dBA at night.

Consideration of the pre-existing background noise level in this circumstance is not deemed necessary as currently the area adjacent to the proposed lease boundary fence is uninhabited and should people choose to move closer to the facility the background noise of the area would already be dominated by the facility.

The boundary noise target would provide a similar acoustic environment to that of the worker accommodation area.

6.7 Other Considerations

There are additional social and economic considerations which are relevant to setting noise criteria and assessment methods.

The nuisance caused by noise is also dependent on a community's relationship with the noise source. For example, an industry that provides some form of social or economic benefit to a community may not be considered a nuisance by locals even when compared to most standards it can be shown that the noise level is considered high.

While it is very difficult to provide a measure or 'adjustment' to a noise limit based on the above, some consideration needs to be given to this.

6.9 Project Noise Criteria

With reference to the guidelines and consideration presented in **Sections 6.1** to **6.7**, a summary of possible criteria for various activities associated with the project is presented in **Table 10** and have been used to assess the potential noise impacts from the project.

Table 10 Project Noise Criteria

Activity / Operation	Noise Criteria (external)		Comment
	Day / Evening (7.00 a.m. to 10.00 p.m.)	**Night (10.00 p.m to 7.00 a.m.)**	
General Operational Noise	50 dBA L_{eq}[1]	Lower of Average night background level (L_{90}) + 3 dBA[2] or 40 dBA L_{eq}[3]	The night limit will be defined as 40 dBA after consideration of existing background levels (see **Section 5.1)**
Construction Noise	50 dBA L_{eq}	40 dBA L_{eq}	The length of construction period is significant and accordingly construction noise limits are equivalent to operational noise limits.
Blasting	Typically 115 dB but up to 120 dB Peak if small percentage	Inaudible	Generally not considered appropriate to allow any night period blasting.
Single Events (traffic pass-bys on roads etc.)	No criteria suggested but 60 dBA L_{max} would be reasonable design goal	45 dBA L_{max}	Primarily concerned with sleep disturbance for night period.
Boundary Noise Target	55 dBA L_{eq}[4]	45 dBA L_{eq}[4]	Pre-existing background noise limit on boundary not relevant (see discussion in **Section 6.6**).

1 50 dBA based on the WHO *Guidelines* recommended day period to 'protect the majority of people from being moderately annoyed'. Whilst this criteria is 5 dBA more conservative than limit presented in Table 1.7.1. of the IFC requirements it is deemed a more appropriate long-term limit.

2 Based on IFC requirement to not *'result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site'.*

3 40 dBA based on WHO sleep disturbance criteria of 30 dBA for continuous noise with 10 dBA allowance for building insertion loss correction.

4 Based on IFC guidelines.

7 NOISE MODELLING METHODOLOGY

7.1 Introduction

Noise modelling of construction activities and operations of the project was completed using the CONCAWE (Conservation of Clean Air and Water Europe) noise prediction method incorporated in the "SoundPLAN" noise modelling program.

The CONCAWE method is a research paper especially designed and originally developed for the requirements of large facilities, specifically petrochemical complexes, in Europe. It was published in 1981 under the title, *The propagation of noise from petroleum and petrochemical complexes to neighbouring communities.* This method was selected due to the capability of modelling meteorological effects on noise propagation over large distances.

The SoundPLAN noise modelling program uses the following information to predict noise levels at nearby receivers:

- Three-dimensional digital terrain map of site and surrounding area.
- Frequency-based sound power level noise data for plant and equipment operating at the site.
- Intervening ground cover.
- Shielding by barriers, intervening buildings or topography.
- Atmospheric conditions.

7.2 Construction Noise

Construction activity associated with the upstream project components will be extremely varied and geographically diverse. Construction activities include:

- Pipeline installation;
- Project roads and bridges;
- Upgrades to Kopi Wharf;
- Construction of heavy lift aircraft airfield;
- New and upgraded gas wellheads;
- Upgrades to existing plant at Gobe, Kutubu and Agogo;
- Juha Processing Facility; and
- Hides Gas Conditioning Plant..

The large scale of the project requires that construction is staged. The effects of construction work will be of limited duration lasting from weeks to months and will affect any one place for less than a year.

Due to the very long length of the project's pipelines, it is not practical, nor it is it necessary, to assess the effects of construction noise at every work area.

7.2.1 Pipeline Routes

The construction of the gathering system pipelines to wellheads and product delivery pipelines will generally involve a similar construction method and equipment list.

Construction of the pipeline route has been previously assessed for the PNG Gas Project by Holmes Air Sciences.[4]

The assessment considered the activities associated with clearing the ROW, trenching, stringing, bending, lowering and backfilling. An indicative flat ground computer noise model was created to predict and assess noise levels in areas surrounding a typical construction site.

It is anticipated that construction of the pipeline will take approximately 3 years

Section 4.1.1 of the PNG Gas Project Noise Impact Assessment report contains the detailed method and input assumptions for pipeline construction.

7.2.2 Well pads and Drilling

The construction of new well heads requires drilling. This will require the development of drill pads to support drill rigs and laydown area. This will generally involve a similar construction methodology and equipment list for each well head

Construction of the well pads and drilling has been previously assessed for the PNG Gas Project by Holmes Air Sciences. [3]

The assessment considered the activities associated with well pad construction and drilling. An indicative flat ground computer noise model was created to predict and assess noise levels in areas surrounding a typical construction site.

It is anticipated that construction of the well pads will take approximately 2 weeks per well site and that drilling will take up to 4 months per well. Some sites, such as Pad A at Hides 4, require two wells to be drilled and drilling is anticipated to last approximately 8 months. The Pad A site has receptors surrounding the site and has accordingly been noise modelled in more detail.

Section 4.1.4 of the PNG Gas Project Noise Impact Assessment report contains the detailed methodology and input assumptions for well pad construction and drilling.

7.2.3 Kopi Wharf

Construction of the Kopi Wharf and laydown area has been previously assessed for the PNG Gas Project by Holmes Air Sciences.

Section 4.1.5 of the PNG Gas Project Noise Impact Assessment report contains the method and input assumptions for Kopi construction works.

7.2.4 Cargo Aircraft Airfield

During the construction of the Hides Gas Conditioning Plant a considerable number of plant equipment items will be transported to the region possibly using cargo aircraft. These aircraft may be used to transport equipment that is too heavy or shock sensitive for transport via the Highlands Highway.

Preliminary selection during FEED has identified Komo as the site for the project airfield to support Hides Gas Conditioning Plant and the future Juha developments. Komo has been used in the past as an airfield to support gas exploration activity and an airstrip exists at the site. A new runway approximately 1900 m long by 30 m wide, suitable for cargo aircraft will be constructed, additional support facilities will include hanger, passenger terminal, administration, fuel storage and dispensing, helipad and security.

[4] Holmes, N.E. (2005) *Noise Impact Assessment: PNG Gas Project*

A preliminary investigation of noise impacts from construction have been examined from a minimum buffer distance approach. It has been assumed that site preparation and civil works will include vegetation clearance and timber removal, using chainsaws and bulldozers, topsoil removal using bulldozers and scrapers and earthworks using front-end loaders, backhoes, graders, rollers, dump trucks and water carts.

During the airfields operation when aircraft are landing and taking off noise under the flight path close to the airport may be high in level. However, as movements are anticipated to be infrequent and only during the day period, the relative risk of impacts is low. A more detailed investigation may be required during detailed design when further information is available.

7.2.5 Hides Gas Conditioning Plant

The construction of the Hides Gas Conditioning Plant will take approximately 3 to 4 years and include the following stages:

Site preparation and civil works

Site preparation includes significant noise producing activities such as:

- Vegetation clearance and timber removal, using chainsaws and bulldozers;
- Topsoil removal using bulldozers and scrapers;
- Earthworks using front-end loaders, backhoes, graders, rollers, dump trucks and water carts; and

Civil works such as:

- Installation and operation of concrete and asphalt batch plants:
- Installation of foundation structures and paved areas within the Hides Gas Conditioning Plant facility using pile drivers, heavy rollers, dump trucks, concrete trucks, generators and steel reinforcement fabrication hand tools such as grinders, welders etc.
- Installation of on-site roads using equipment such as rollers, dump trucks and asphalt laying equipment.

During the course of construction many of these activities would occur simultaneously and at varying levels of intensity. It is most difficult therefore to accurately predict construction noise emissions throughout the entire construction period. In order to facilitate the noise assessment, three typical worst-case scenarios have been developed.

The predicted noise level in the model is based on the assumption that all equipment is operating simultaneously and at full load. The nature of construction activities using a fleet of mobile equipment is that the intermittent nature of operations and reduced duty cycles of equipment leads to typical overall site noise emissions being approximately 3-8 dBA below that predicted. A conservative 'de-rating' factor of 3 dBA has been applied to model predicted noise levels shown in **Table 19.**

The site preparation scenario assumes that topsoil removal and earthworks with the equipment shown in **Table 11** occurs simultaneously.

Table 11 Site Preparation Scenario - Equipment List

Equipment	Sound Power Level dBA re: 10^{-12} W	Number of items
Chainsaws	114	3
Bulldozer small	114	1
Bulldozer large	116	1
Scraper	113	1
Grader	110	1
Front End Loader / Backhoe	108	1
Roller	106	1
Dump truck	115	2
General 4wd vehicles	80	3

The civil works scenario assumes the following equipment operating simultaneously

Table 12 Civil Works Scenario - Equipment Listing

Equipment	Sound Power Level dBA re: 10^{-12} W	Number of items
Pile driver	122	1
Roller	106	2
Concrete batch plant	111	1
Concrete mixer truck	110	3
Concrete pump & vibrator	112	2
Grinders	111	3
Generator and Welder	105	3
General 4WD vehicles	80	5

Construction of the Hides Gas Conditioning Plant facilities and utilities

Construction of the Hides Gas Conditioning Plant facilities and utilities will include noise-producing activities such as:

- Transportation and unloading of large plant items by lowloader, trucks, crawler cranes and forklifts;
- Onsite steel fabrication and pipe erection using tower cranes, grinders, welders, generators, air compressors and tools;
- Erection and assembly of plant items which will typically require equipment such as tower cranes, forklifts, generators, air compressors and tools; and
- Construction of the permanent accommodation village;

Activities included in the Hides Gas Conditioning Plant construction scenario are equipment unloading, on-site steel fabrication, plant assembly and erection, concurrent with village construction using the equipment listed in **Table 13**.

Table 13 Construction of the Hides Gas Conditioning Plant Facilities, Utilities and Offsites - Equipment List

Equipment	Sound Power Level dBA re: 10^{-12} W	Number of items
Crawler crane	111	2
Welder & genset	105	3
Grinder	110	3
Air compressor	106	2
Forklift	95	2
General 4wd vehicles	80	4

7.2.6 Juha Production Facility

The construction of the Juha Production Facility will take approximately 2 years and will also include the general stages of site clearing, preparation, civil works and construction. This facility is significantly smaller than the Hides Gas Conditioning Plant and will generally require less equipment and time for completion.

7.3 Operational Noise

Upstream operations comprise a number of processes, activities and equipment that can produce noise. The most significant of these include:

- Well head noise;
- Juha Production Facility; and
- Hides Gas Conditioning Plant.

Pipelines do not produce any perceptible noise and therefore the only noise emissions from the various pipeline routes will be from vehicles or aircraft traversing the route during inspections. These relatively infrequent events would generally be undertaken during day period only and be of such short duration that adverse impacts on the community are unlikely.

The operational duty cycles of items of equipment are variable and difficult to approximate at this early stage. Accordingly a typical worst-case approach has been adopted. Scenarios that include significant noise producing operations at each of the upstream areas have been modelled.

7.3.1 Well Pads and Well Heads

No powered equipment will operate at well heads during normal operation.

The only noise producing activities from well heads are from chokes or during the extremely rare event of cold venting of the gas.

Figure 8 Hides 4 Well Head

7.3.2 Juha Production Facility

The most significant noise producing equipment at Juha Production Facility will be;

- Rich gas compressor (a 21 MW RB211 or equivalent) with assumed sound power level of 136 dBA;
- Turbo generator (a 3.5 MW Taurus 60 or equivalent) with assumed sound power level of 117 dBA; and
- An elevated flare (approximately 30 m above ground) with assumed sound power level of 124 dBA.

Other noise sources include liquid hydrocarbon and booster pumps, MEG injection pump, flare drum pumps, liquid and water transfer pumps, compressor interstage and aftercoolers and inlet coolers. These sources have been assumed to comply with general ExxonMobil OH&S noise requirements of meeting 80 dBA at 1 metre.

7.3.3 Hides Gas Conditioning Plant

The most significant noise producing equipment at Hides Gas Conditioning Plant will be;

- Pipeline gas compressors (3 off 21 MW RB211 or equivalent);
- Booster gas compressors (2 off 21 MW RB211 or equivalent);
- Turbo generator package (3 off 3.5 MW Taurus 60 or equivalent);
- Elevated flare (approximately 30 m above ground); and,
- JT valve.

Other noise sources include stabiliser overhead compressor, MEG injection pump, MEG vent gas incinerator and blower, flare drum pumps, liquid and water transfer pumps, air compressor, pipeline and booster compressor interstage and aftercoolers and inlet coolers.

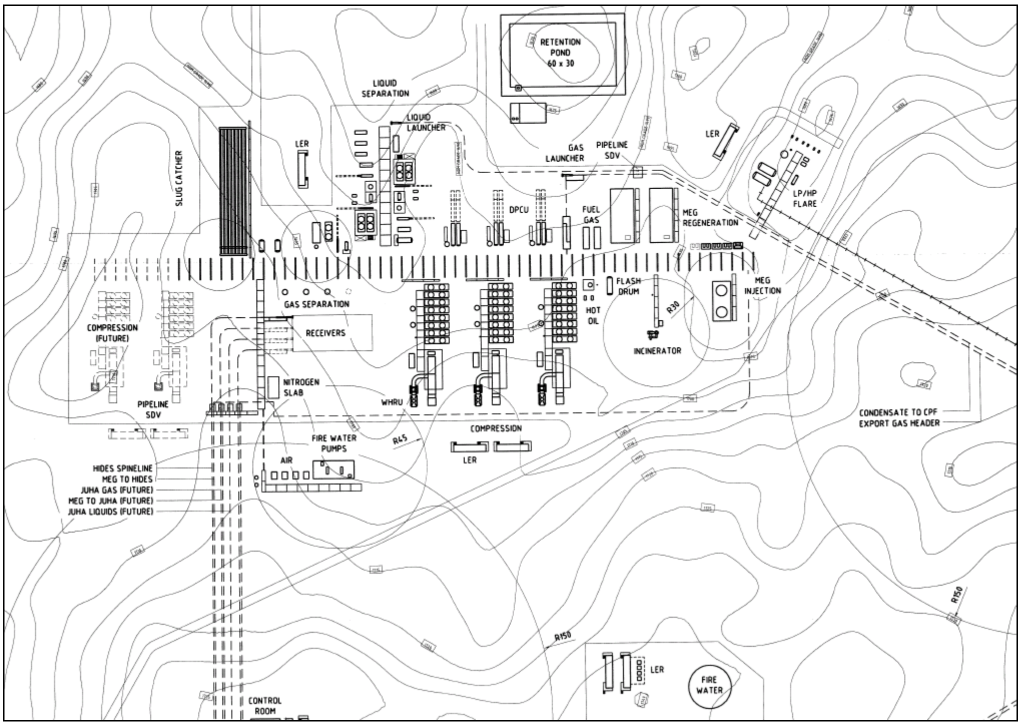
Noise modelling of the Hides Gas Conditioning Plant processing operations was undertaken by engineering and construction services company, KBR, in Houston, Texas. KBR have extensive experience in the design of LNG facilities and have taken noise measurements of similar existing facilities.

Their noise model incorporates sound power level information obtained from a combination of measured levels from similar facilities and general OH&S performance requirements.

The following input assumptions have been provided by KBR:

- Class D Acoustic insulation for compressor suction and discharge piping.
  Consists of a porous layer 50 mm thick with 0.8 mm thick aluminised steel jacketing (7.8 kg/m^2) and a second porous layer 50 mm thick with 1.3 mm aluminised steel jacketing (11.3 kg/m^2).
- Turbines include acoustic enclosures. Total sound power level of 115 dBA from all turbines.
- Compressors have no acoustic enclosures. Total sound power level of 122 dBA from all compressors.
- Air coolers with a total sound power level of 115 dBA;
- No inline silencers for compressor suction or discharge lines;
- 85 dBA @ 1 m for all enclosures;
- 80 dBA @ 1 m for all ducting and intake silencers;
- 80 dBA @ 1 m for all other rotating equipment and control valves;

Figure 9 Proposed Hides Gas Conditioning Plant Layout



7.3.4 Flare

During normal operations it is necessary to, occasionally and intermittently, burn unwanted gas from a flare tower. The gas flare tower will be located approximately 150 metres east of the processing facility and will be up to 30 metres high.

ExxonMobil has an equipment performance specification that requires vendor-supplied elevated gas flare equipment to have a maximum sound power level presented in **Table 14.**

Table 14 Elevated Flare Maximum Sound Power Level - dB re: 10^{-12} W

Equipment	Octave Band Center Frequencies, Hz								
	63	125	250	500	1,000	2,000	4,000	8,000	Total
Elevated Flares	119	118	115	110	109	109	111	112	124 dB

Furthermore, ExxonMobil has OH&S noise performance criteria for emergency venting of 105 dBA.

8 MODEL PREDICTIONS AND ASSESSMENT

8.1 Construction Noise Assessment

8.1.1 Pipeline

Construction of the pipeline route has been previously assessed for the PNG Gas Project by Holmes Air Sciences[5] (refer **Section 6.1.1** of *PNG Gas Noise 05Dec05.doc*).

The assessment was based on a conservative approach that assumes a full complement of equipment working simultaneously in two areas along the ROW separated by 2.5 km in flat terrain. The findings are summarised in **Table 15**.

Table 15 Pipeline Construction Noise Assessment Summary

Time period	Construction noise criteria <4 weeks	Maximum required buffer distance
Day	60 dBA	500 m
Night	47 dBA	1600 m

Thus, should night-time construction activities need to occur closer than 1600 m to settled areas it would be appropriate to consider scaling back the noisiest operations to reduce impacts.

8.1.2 Well pads and Drilling

Construction of the well pads and drilling has been previously assessed for the PNG Gas Project by Holmes Air Sciences [4] (refer **Section 6.1.4** of *PNG Gas Noise 05Dec05.doc*).

Based on the conservative assumption that a full compliment of equipment working simultaneously at the well pad in flat terrain, the following was determined:

Table 16 Well Pad Construction Noise Assessment Summary

Activity	Duration of Activity	Time period	Construction noise criteria	Maximum required buffer distance
Well Pad	< 4 weeks	Day	60 dBA	316m
		Night	47 dBA	2,000 m
Drilling	< 6 months	Day	50 dBA	250m
		Night	47 dBA	500 m

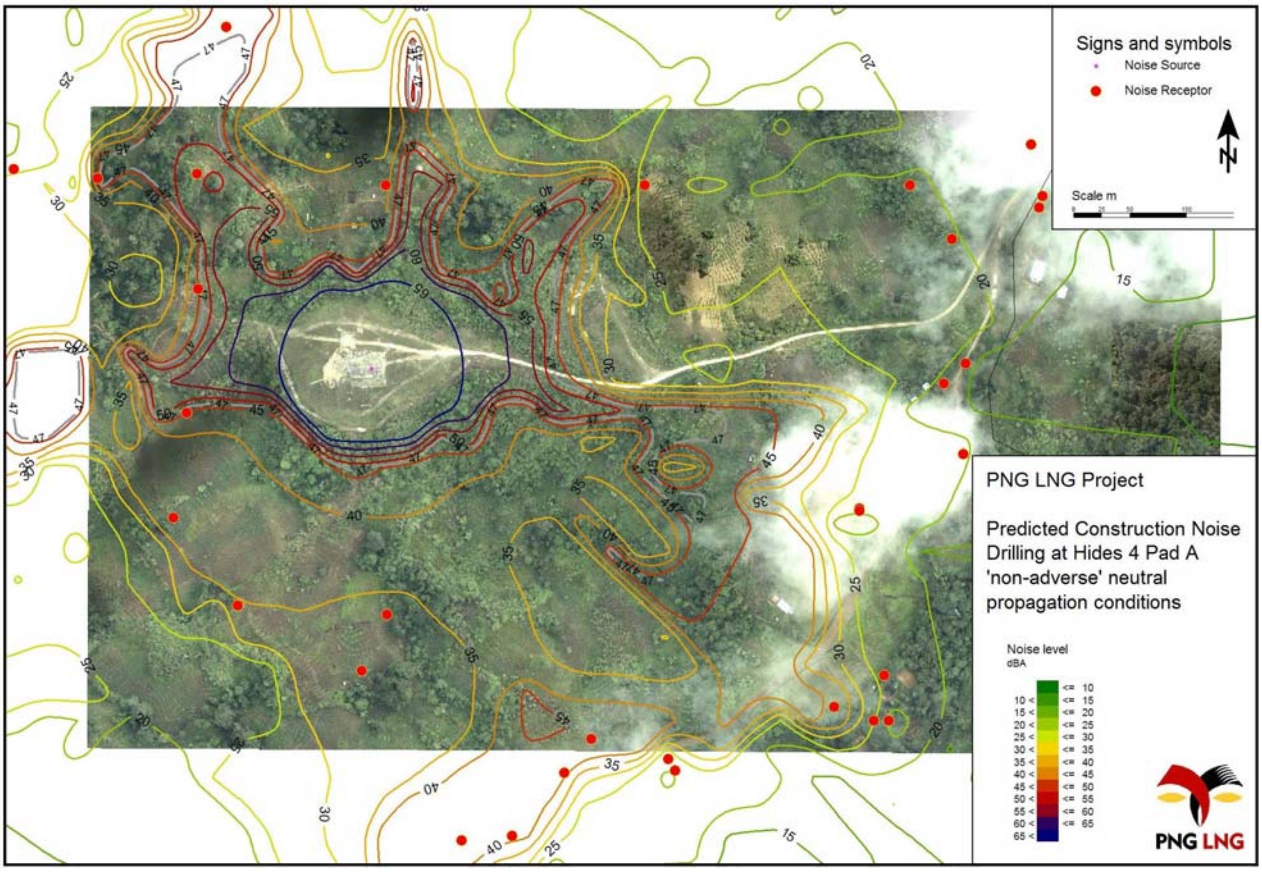
Whereas most well sites are anticipated to be in remote and relatively uninhabited areas the well located at Pad A at Hides 4 is close to a community and is likely going to require a drilling programme of approximately 8 months.

The most significant noise sources associated with the drilling process are the array of diesel generators required to supply power to the drill, the mud pump and hoists and other equipment used in drilling. It is anticipated that the equipment required will comprise up to eight 1600 kW diesel generators of which six would be expected to be operating at any given time, giving approximately 13000 HP total. Diesel generators of this capacity installed within acoustic enclosures and enhanced exhaust silencers will have a sound power level of approximately 108 dBA re: 10^{-12} W.

[5] Holmes, N.E. (2005) *Noise Impact Assessment: PNG Gas Project*

A detailed noise model of the site was used to predict likely noise levels into the surrounding region. Noise contours for neutral propagation conditions are shown for drilling of Pad A at Hides 4 in **Figure 10**.

Figure 10 Drilling noise for Pad A at Hides 4



Evaluating the predicted noise contours shows that the nearest receptors are anticipated to receive approximately 55 dBA with approximately 10 receptor locations exceeding the night construction criteria of 47 dBA.

The potential impact on surrounding receptors should be re-evaluated once equipment selection has been finalised.

8.1.3 Kopi Wharf

Construction of a laydown area at Kopi has been previously assessed for the PNG Gas Project by Holmes Air Sciences[6] (refer **Section 6.1.5** of *PNG Gas Noise 05Dec05.doc*).

Table 17 Kopi Wharf Construction Noise Assessment Summary

Time period	Construction noise criteria <6 months	Maximum required buffer distance
Day	50 dBA	1,400 m

[6] Holmes, N.E. (2005) *Noise Impact Assessment: PNG Gas Project*

8.1.4 Cargo Aircraft Runway

Construction of the cargo aircraft runway has been modelled for site clearing and civil works using preliminary assumptions for construction equipment. The result of the modelling is included in **Table 18**.

Table 18 Cargo Aircraft Runway Construction Noise Assessment Summary

Time period	Construction noise criteria <6 months	Maximum required buffer distance
Day	50 dBA	750 m

8.1.5 Hides Gas Conditioning Plant

Hides Gas Conditioning Plant construction noise levels have been predicted for the three scenarios detailed in **Section 7.2.5.** Each scenario represents a typical worst-case activity with all equipment operating. The predicted L_{Aeq} noise levels are shown in **Table 19** and have been predicted for 'neutral' and 'adverse' meteorologically enhanced conditions, as described in **Section 5.2.**

Table 19 Predicted Construction Noise Levels in dBA re: 20 µPa

Receptor group [1]	Location of most affected receptors in Laite	Noise criteria		Site preparation		Civil works		Construction of Hides Gas Conditioning Plant & utilities & off-sites	
		Day	Night	Neutral	Adverse	Neutral	Adverse	Neutral	Adverse
1	500-900 m NW of Hides Gas Conditioning Plant	50	40	26 - 44	31- 49	25 - 44	30 - 49	18- 36	22 - 40
2	600-800 m W of Hides Gas Conditioning Plant	50	40	22 - 42	27 - 44	16 - 38	21 - 43	11 - 35	15 - 39
3	Para Primary School	50	40	32 - 34	37 - 39	19 - 20	24 - 25	18 - 21	22 - 25
4	1500 - 1800 m S of Hides Gas Conditioning Plant	50	40	10 - 25	15 - 30	10 - 12	15 - 18	1 - 7	6 - 11

1 Refer to Figure 3.

Noise contours for neutral propagation conditions are shown for the site preparation scenario, the civil works scenario, and the construction of Hides Gas Conditioning Plant facilities and utilities scenario in **Figures 11, 12** and **Figure 13** respectively.

The steep terrain in the region provides, in places, significant acoustic shielding, which can be seen in the non-uniform nature of the noise contours and the sometimes significant range of predicted noise levels for each receptor region, as shown in **Table 19.**

The predicted construction noise levels will comply with standard operational noise criteria at all receptors under all conditions during the day period and are likely to be inaudible against the existing ambient background noise levels at all but the most exposed receptors in Laite. It is understood that construction of the Hides Gas Conditioning Plant is only planned for the day period.

8.1.6 Juha Production Facility

The construction of the Juha Production Facility will be shorter in duration and generally require less equipment than Hides Gas Conditioning Plant construction. Furthermore, the isolated and uninhabited surrounding area of the site will unlikely result in any noise impacts.

8.2 Blasting

It is not anticipated that blasting will be required as part of the construction of the Juha Production Facility or Hides Gas Conditioning Plant; however, some blasting may be required to break up rock during road construction or pipeline trenching.

Details that would enable prediction of airblast and vibration levels (i.e. the location and size of these blasts) are not available, however, it is anticipated that the requirements of the ANZECC guideline and AS 2187.2-1993 (provided in **Section 6.5**) will be satisfied and accordingly, blasting is unlikely to cause significant impacts to residential amenity.

Figure 11 Predicted Site Preparation Scenario Noise Contours

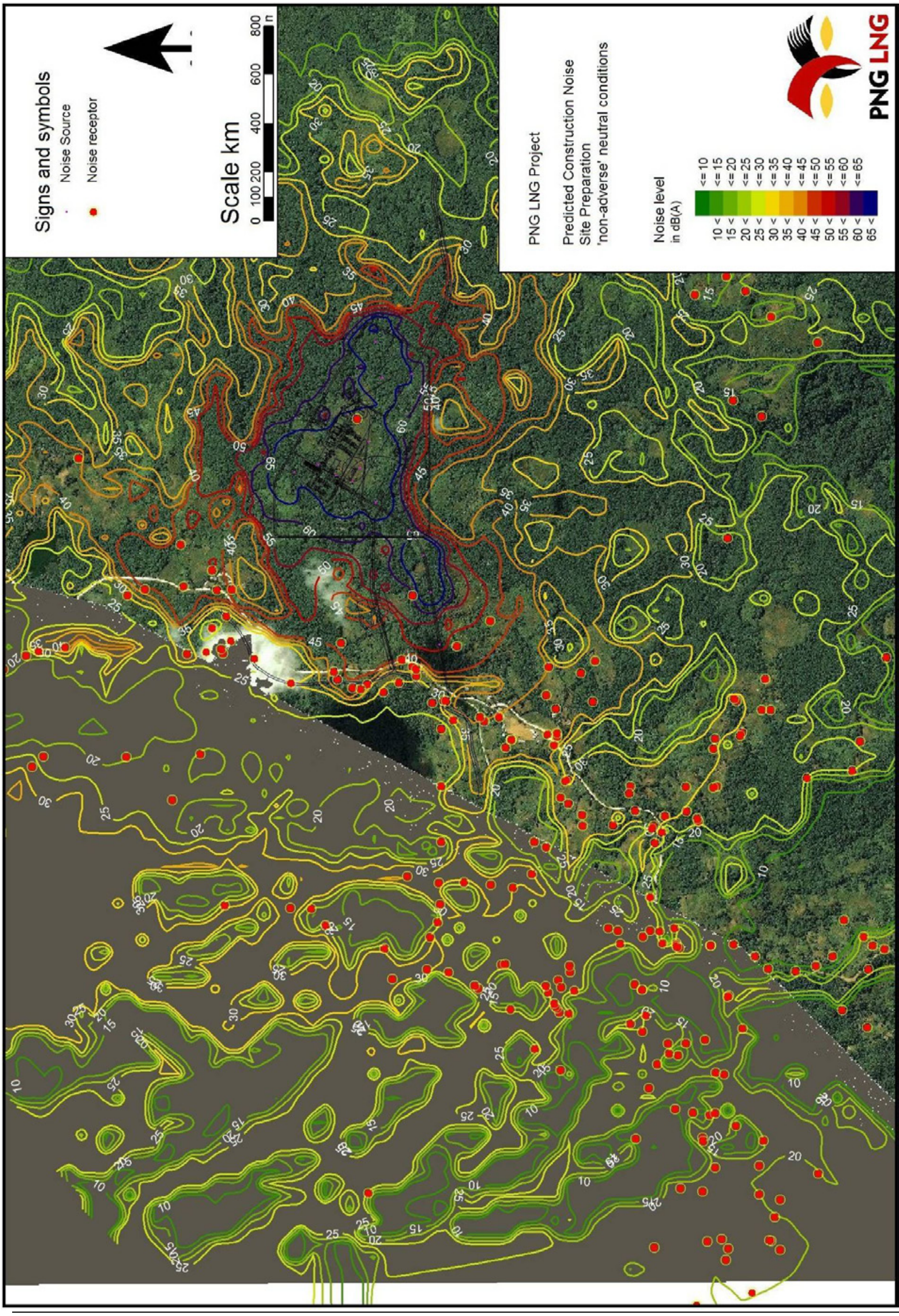


Figure 12 Predicted Civil Works Scenario Noise Contours

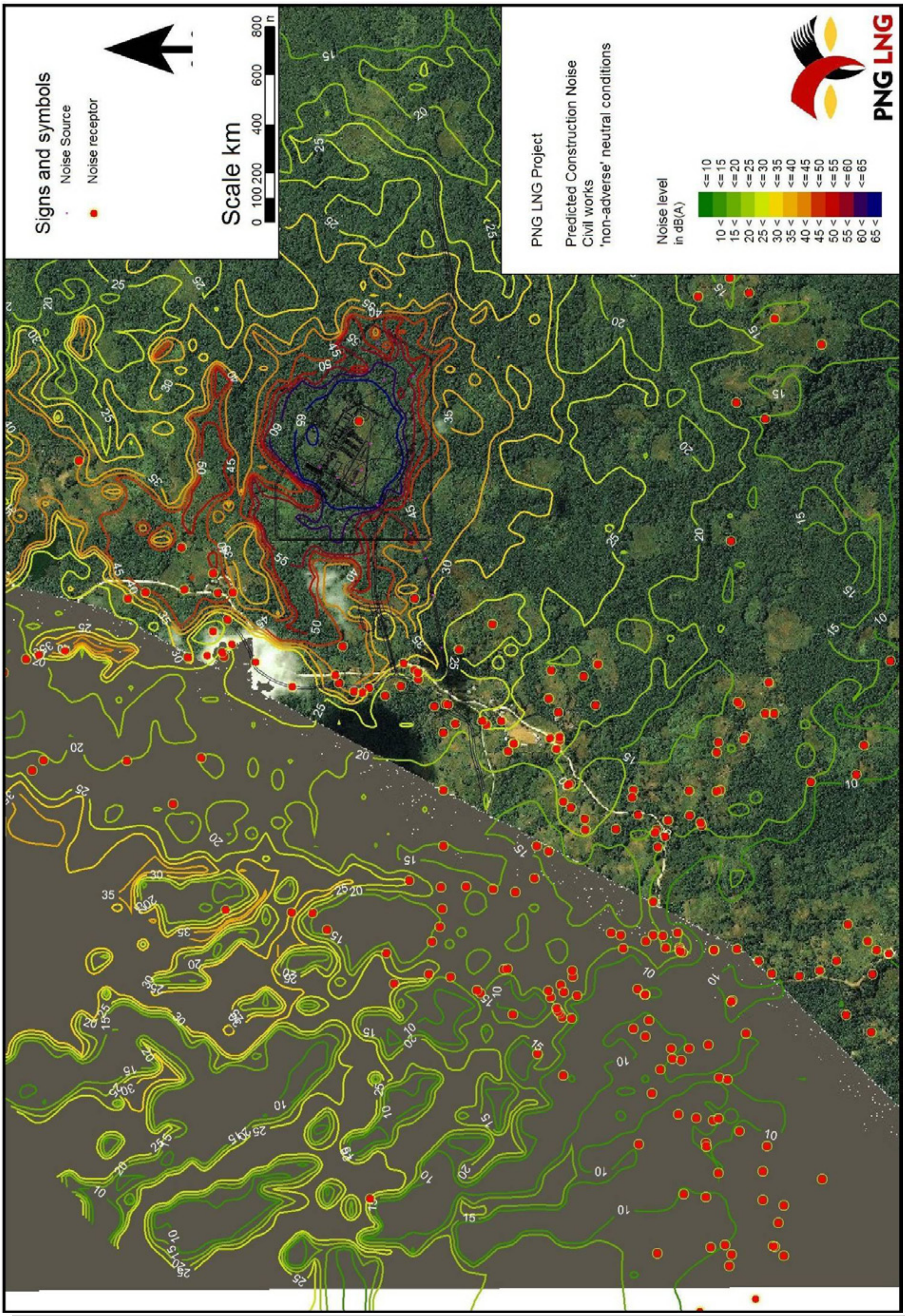
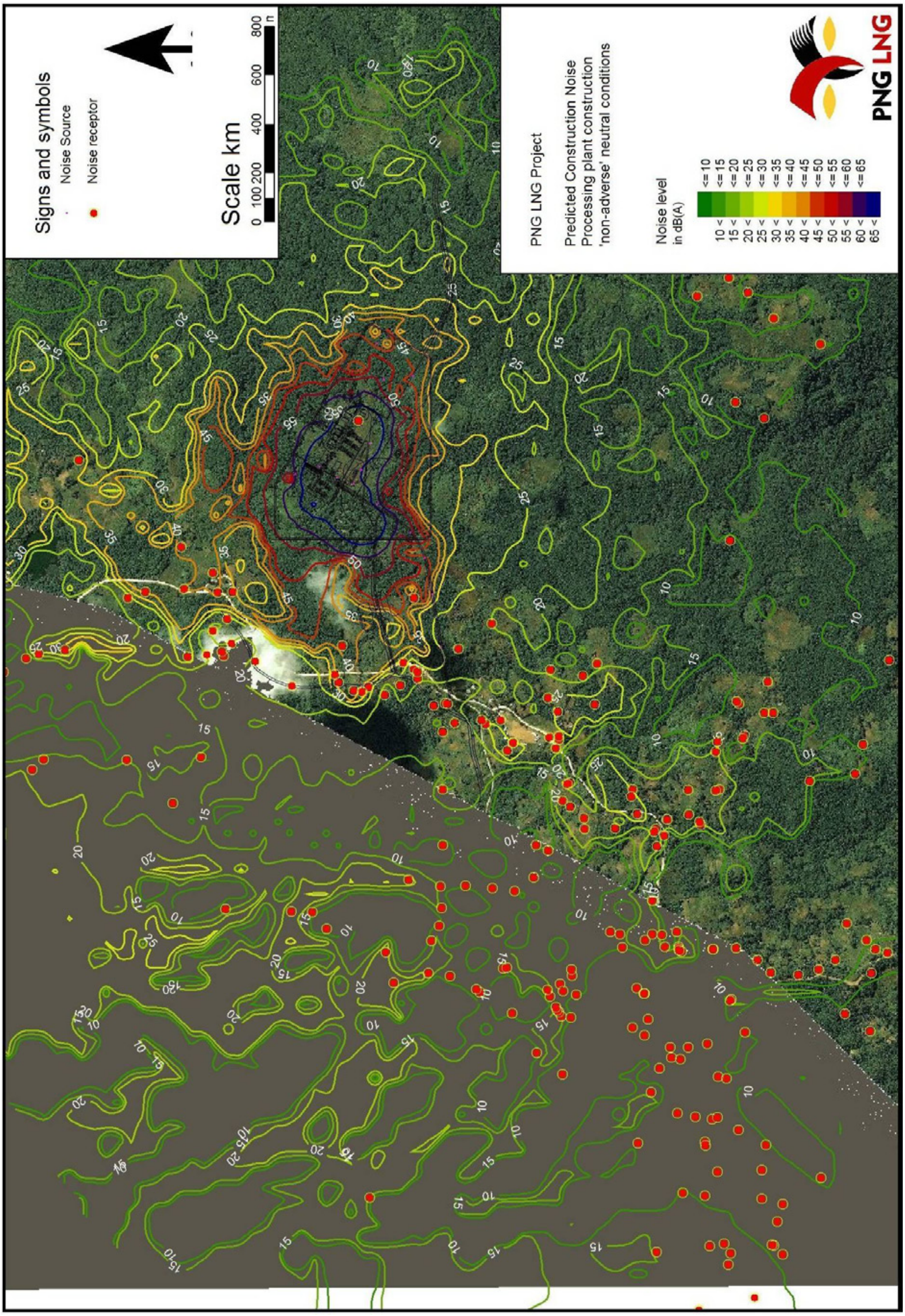


Figure 13 Predicted Construction of Hides Gas Conditioning Plant Facilities Scenario Noise Contours



8.2.1 Well Head

The only noise producing activities from wellheads are from chokes or during the extremely rare event of cold venting. Chokes are assumed to comply to OH&S requirements of 80 dBA at 1 metre.

Based on this assumption, the night period noise criteria will be met at a distance of 100 metres. It is assumed that no receptor locations will be within 100 metres of operational well heads.

8.2.2 Pipeline

Pipelines do not produce any perceptible noise and therefore the only noise emissions along the various pipelines will be from vehicles or aircraft traversing the route during inspections. These relatively infrequent events will generally be undertaken during the day period only and be of such short duration that adverse impacts are unlikely.

8.2.3 Juha Production Facility

Juha Production Facility operational noise levels have been predicted for ‘neutral’ and ‘adverse’ meteorologically-enhanced conditions based on the assumptions detailed in **Section 7.3.2.** and a further assumption of flat ground. This would be considered a conservative approach as topography would generally provide noise shielding resulting in lower noise levels at receptors.

Under neutral conditions, a day period noise criteria of 50 dBA will be met at a distance of approximately 1,200 m and a night period noise criteria of 40 dBA will be met at approximately 2,000 m.

Under adverse meteorologically-enhanced conditions, the day noise criteria will be met at approximately 1,500 m and the night period noise criteria will be met at a distance of approximately 2,600 m.

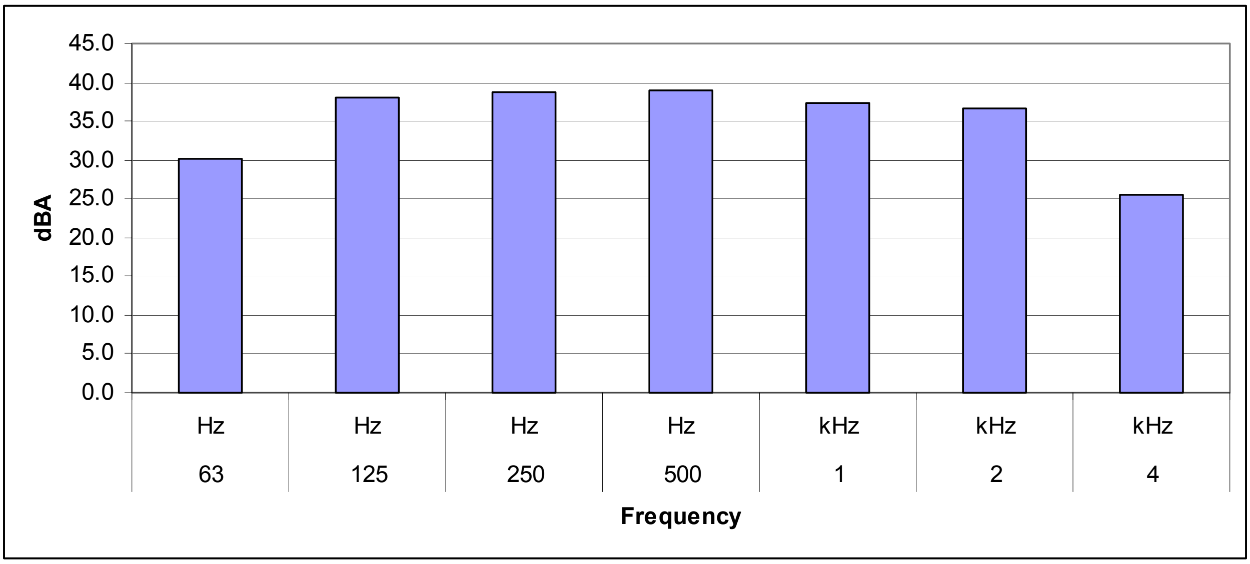
It is understood that there are no noise sensitive receptors located within this distance around the proposed Juha Production Facility site.

8.2.4 Hides Gas Conditioning Plant

Hides Gas Conditioning Plant operations noise has been predicted by KBR with the assumptions as detailed in **Section 7.3.3.** Each scenario represents a typical worst-case activity with all equipment operating. The predicted L_{Aeq} noise level has been predicted for neutral and adverse meteorologically-enhanced conditions.

A typical received A-weighted frequency spectrum is shown in **Figure 14** and this illustrates that the character of the noise at receptor locations is likely to have predominantly mid and low frequency components. A commonly applied test for low frequency is to evaluate the difference between the A-weighted and the C-weighted overall noise level and where this is greater than 15 dB a penalty is applied. The predicted receptor levels have been found to be approximately 13 dB different in overall level for the two frequency weightings.

Figure 14 Typical Received Frequency Spectrum



A number of individual noise sources within the Hides Gas Conditioning Plant facility are tonal in character, however, the large number of total noise sources and more dominant broadband sources are likely going to result in overall received noise being more broadband in nature. The predicted received noise levels are presented in **Table 20**.

Table 20 Operational Noise Levels in dBA re: 20 µPa

Receptor group [1]	Location of most affected receptor	Noise criteria		Predicted noise level	
		Day	**Night**	**Neutral**	**Adverse**
1	500-900 m northwest of Hides Gas Conditioning Plant	50	40	32 - 45	36 - 49
2	600-800 m west of Hides Gas Conditioning Plant	50	40	28 - 43	32 - 47
3	Para Primary School	50	40	42 - 43	46 - 48
4	1500 - 1800 m south of Hides Gas Conditioning Plant	50	40	16 - 28	21 - 33

1 Refer to Figure 3.

The predicted levels shown in **Table 20** do not comply with noise criteria at receptor Group 1, Group 2 and Group 3. Receptor Group 4 meets the noise criteria during the day and night time periods under all meteorological conditions.

Noise contours for neutral propagation conditions are shown in **Figure 15** and for adverse propagation conditions in **Figure 16**. The total number of receptors exceeding noise criteria is shown in **Table 21.**

Table 21 Total Number of Receptors Exceeding Criteria

Propagation conditions	Noise criteria		
	Night 40 dBA	**Boundary fence 45 dBA**	**Day 50 dBA**
Neutral	24	6	0
Adverse	35	21	5

Perimeter Fence

A perimeter fence position has been established for the Hides Gas Conditioning Plant. All receptors positioned within the perimeter fence will be relocated. This has the benefit of removing many of the closest receptors which were amongst those potentially impacted by noise.

The number of receptors located outside of the perimeter fence which exceed noise criteria is shown in **Table 22**.

Table 22 Number of Receptors Outside of Perimeter Fence Exceeding Criteria

Propagation conditions	Noise criteria		
	Night 40 dBA	**Boundary fence 45 dBA**	**Day 50 dBA**
Neutral	14	2	0
Adverse	23	13	1

Figure 15 **Predicted Hides Gas Conditioning Plant - Neutral Conditions**

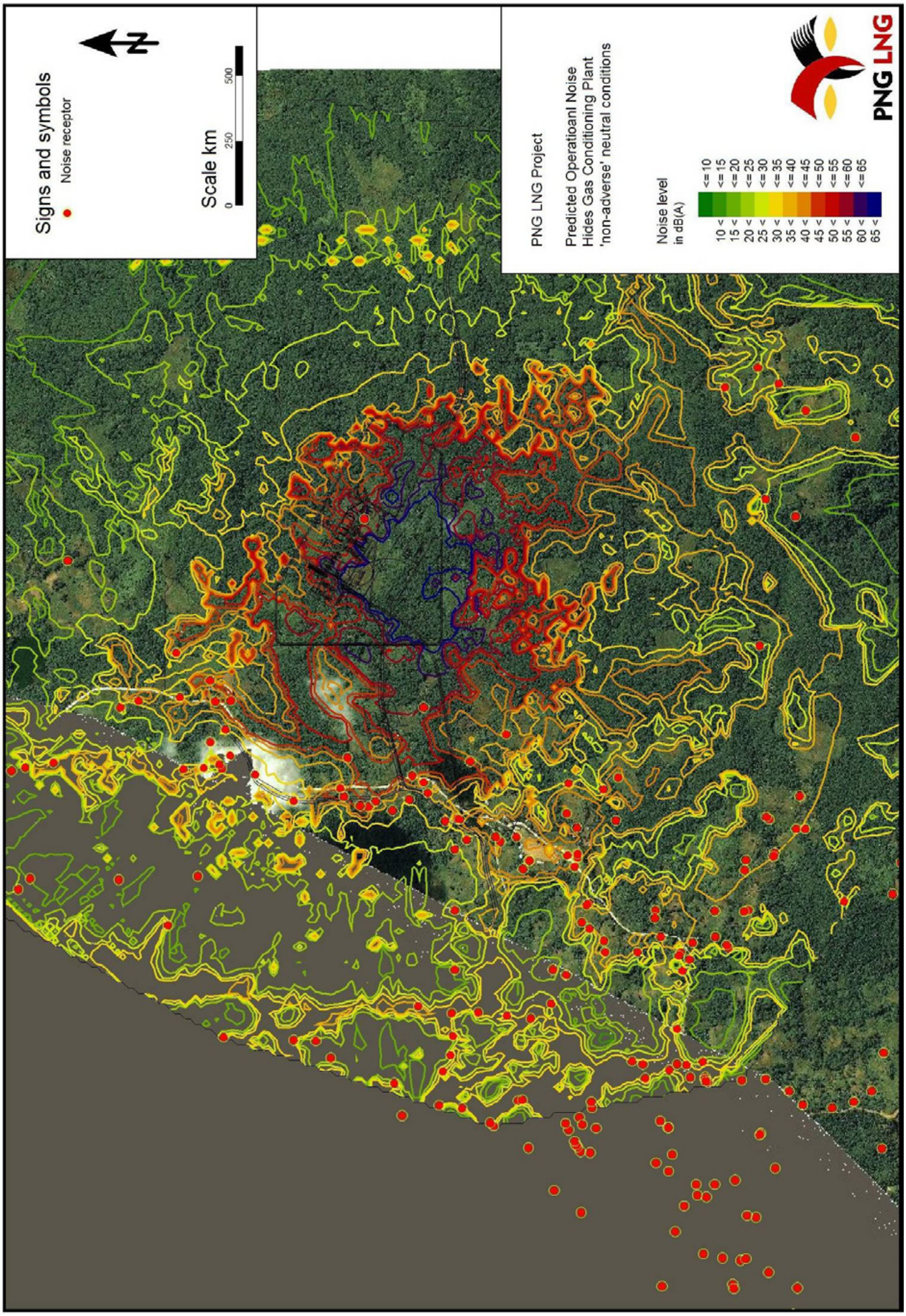
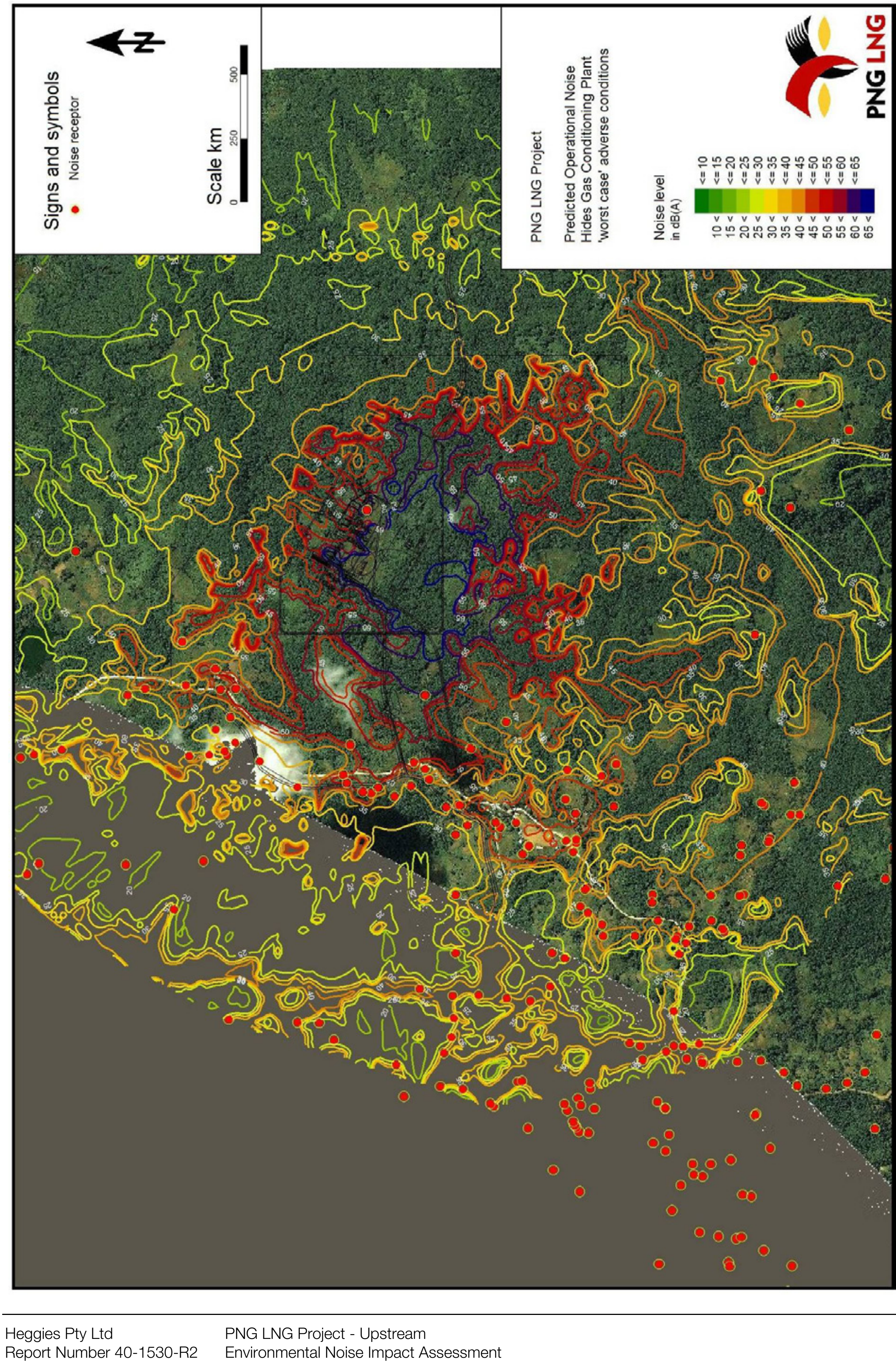


Figure 16 Predicted Hides Gas Conditioning Plant - Adverse Propagation Conditions



8.2.5 Flare

During the occasional occurrence of emergency venting from the flares at Juha Production Facility and Hides Gas Conditioning Plant noise levels will be elevated.

The night period noise criteria will be achieved at distance of 1,250 metres under neutral conditions and at distance of 1,600 metres under 'adverse propagation' conditions.

Some receptors close to the Hides Gas Conditioning Plant site will experience noise levels up to 10 dBA in excess of the night period criteria during emergency flaring, however, given the infrequent nature of these events this is unlikely to cause any significant impacts.

No receptors around the Juha Production Facility site are likely to be impacted by these events.

9 DISCUSSION

9.1 Construction Noise

During construction of the pipelines, modelling predicts that a full complement of equipment working along a 2.5 km section of pipe in flat terrain is likely to comply with project noise criteria at distances greater than 500 m during the day and 1,600 m during the night.

During the drilling of wells, modelling predicts that a wellpad on flat terrain is likely to comply with project noise criteria at distances greater than 250 m during the day and 500 m during the night.

A preliminary investigation of noise levels surrounding drilling at Hides 4 Pad A indicates that up to 10 receptor locations would potentially be impacted during the night period. Appropriate mitigation measures will need to be investigated during detailed design when further equipment information is available. It is understood that this drill rig will first be used in remote uninhabited well head sites before relocating to Hides 4 Pad A. This will allow detailed equipment noise measurements and mitigation to be developed prior to commencement at this more populated site. Drilling noise will need to be re-assessed for conformance to project noise criteria in the Environmental Noise Management Plan.

For the construction of a laydown area at Kopi, modelling predicts that a full complement of equipment working simultaneously on flat terrain is likely to comply with project noise criteria at distances greater than 1,400 m during the day.

At distances closer than those presented above there is a risk of noise impacts occurring; however, given the conservative approach used in this assessment (i.e. assuming no shielding and all equipment operating simultaneously at full power etc.) project sites working at closer distances may still be at levels below the project noise criteria. A case-by-case risk assessment approach, which is to be outlined in a subsequent Construction Noise Management Plan, should be evaluated prior to working at closer distances.

Where there is a high risk of adverse impacts from noise, consideration should be given to mitigation measures such as:

- Adopting best practice techniques with regards to equipment selection, maintenance and operation;
- Prior notification to local community of anticipated noise impact;
- Avoiding night time construction;
- Reducing the construction fleet;
- Limiting the duration of the activities likely to breach noise criteria;
- Limiting night works in noise-sensitive areas or during adverse conditions; and
- Using hoarding or other structures to provide shielding against noise.

Noise modelling indicates that construction of the Juha Production Facility and Hides Gas Conditioning Plant will be compliant with project noise criteria under all conditions during the day period. Furthermore, construction noise is likely to be inaudible against the existing ambient background noise level at many of the nearby receptors in Laite.

Additional noise mitigation beyond the implementation of best practice techniques will generally not be required.

9.2 Operations Noise

Generally the only noise-producing activities from wellheads are from chokes, which will meet night period noise criteria at a distance of approximately 100 metres.

Pipelines do not produce any perceptible noise and the only noise emissions in their vicinity will be vehicles or aircraft traversing the route during inspections. These relatively infrequent events will normally be undertaken during the day and of such short duration that adverse impacts are unlikely.

9.2.1 Juha Production Facility

Predicted operational noise levels at the Juha Production Facility are expected, under neutral conditions, to comply with the daytime noise criteria of 50 dBA at approximately 1,200 m. At night it will comply with the night period noise criteria of 40 dBA at approximately 2,000 m. Under adverse, meteorologically-enhanced conditions, the day noise criteria will be met at approximately 1,500 m and the night period noise criteria at approximately 2,600 metres.

It is understood that no noise sensitive receptors are located within this distance to the proposed Juha Production Facility site and therefore noise impacts are unlikely.

9.2.2 Hides Gas Conditioning Plant

The operational noise of the Hides Gas Conditioning Plant facility and utilities has been predicted using preliminary estimations and assumptions for equipment specification and sound power level.

Predicted operational noise levels of the Hides Gas Conditioning Plant facility and utilities exceed the night period and boundary fence noise criteria under neutral and adverse meteorological conditions.

The total number of receptors outside of the perimeter fence that exceed the noise criteria is presented in **Table 22**.

Under neutral propagation conditions a relatively small number of receptors (fourteen) are predicted to exceed the night period noise assessment criteria of 40 dBA. Twelve of these are predicted to exceed by less than 3 dBA, which would be considered a minor exceedance and unlikely to be perceptively different from other compliant locations. Two locations are predicted to exceed the boundary fence criteria of 45 dBA by less than 2 dBA and these locations in receptor Group 1 and Group 2 are adjacent to the perimeter fence and close to receptors already identified for relocation. It may be feasible to modify the perimeter boundary fence position so as to include these additional isolated receptors within the relocation zone area.

The noise exceedances predicted for the Hides Gas Conditioning Plant under neutral propagation conditions are considered manageable.

Under adverse propagation conditions thirteen receptors are predicted to exceed the Boundary Noise Target of 45 dBA. A further twenty three receptors exceed the night period noise assessment criteria of 40 dBA. The number of predicted exceedances under adverse propagation conditions is significant, however, it should be considered in the context of the likelihood and frequency of occurrence that conditions capable of resulting in such impacts take place.

It is worth noting that the noise model 'adverse' conditions replicate down wind propagation in all directions. An investigation of prevailing winds of velocity less than (or equal to) 3 m/s with a frequency of occurrence greater than (or equal to) 30% was conducted on a TAPM data set in **Section 5.2.1**. Prevailing winds in the night period were found to be consistent throughout all seasons and from the south-southwest, southwest, west-southwest, west and west-northwest, which are all blowing in directions away from receptors. Such winds will have the effect of reducing noise levels at the receptors.

An investigation of prevailing temperature inversion conditions was conducted on a TAPM data set in **Section 5.2.2** and determined that the frequency of occurrence of moderate to strong (ie 1.5 to >4.0°C/100 m) temperature inversions is greater than 30% during the combined evening and night-time periods for all seasons and therefore requires consideration. The high percentage of occurrence in Autumn (57%) and Summer (41%) is perhaps somewhat countered by the fact that during these seasons evening and night period propagation enhancing winds are anticipated to be from the WSW with a distribution of between 80-90% i.e. in the opposite direction from receptors.

A further consideration with regards to temperature inversion effects on noise propagation in regions with considerable terrain is the associated adiabatic flows also known as drainage flows. These are caused when heavier cooler air near the earths surface sinks and "flows" downhill and down valleys causing an air movement that enhances noise propagation in that direction. Given the site of the Hides Gas Conditioning Plant and surrounding terrain, with steep downward slopes leading away to the east, the site could exhibit temperature inversion induced drainage flows away from the receptor areas.

In consideration of the above there is preliminary evidence to show that the prevailing conditions at the Hides Gas Conditioning Plant site serve to reduce noise propagation in the direction of receptors and not enhance it. Furthermore, if this is the case the noise model assumed for 'adverse' conditions yields conservatively high results. It is important to note that all analysis has been completed using the TAPM model generated data and as such should only be treated as an approximation. Real measured meteorology data from the site would be necessary to confirm the propagation effects to a greater degree of accuracy and confidence.

The noise emissions from the Hides Gas Conditioning Plant will need to be considered further and evaluated in greater detail during the detailed engineering design phase of the project. Operations noise will need to be re-assessed for conformance to project noise criteria in the Environmental Noise Management Plan.

10 REFERENCES

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"Environmental Health and Safety (EHS) Guidelines - General EHS Guidelines: Environmental Noise Management " General EHS Guidelines [Complete version] at www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

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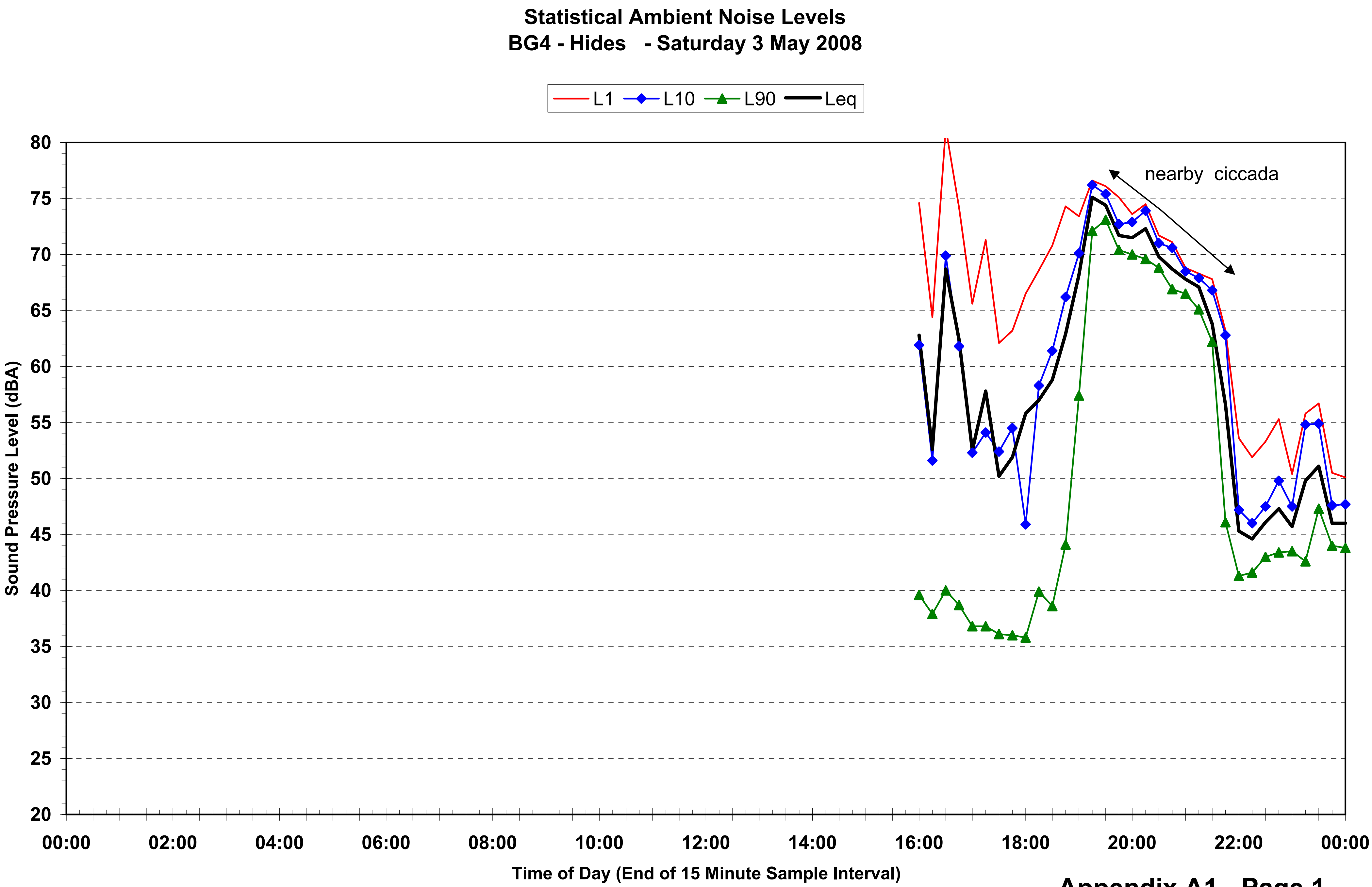
Manning C.J (1981)
"The propagation of noise from petroleum and petrochemical complexes to neighbouring communities 4/81" CONCAWE's Special Task Force on Noise propagation Den Haag, NL,

Australian and New Zealand Environment Conservation Council (Sep 1990)
Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration.

BASELINE NOISE MONITORING

STATISTICAL NOISE LEVELS



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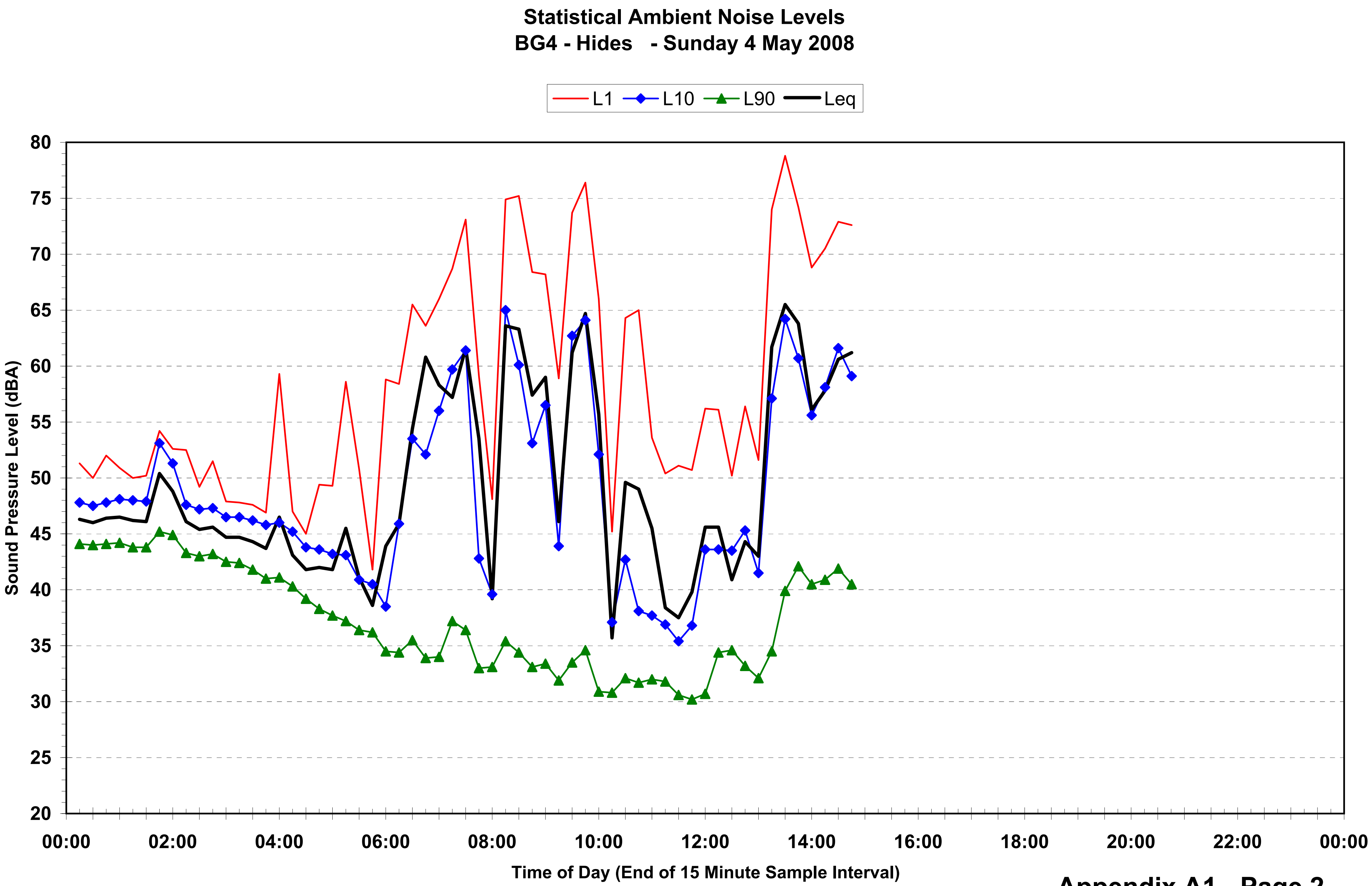
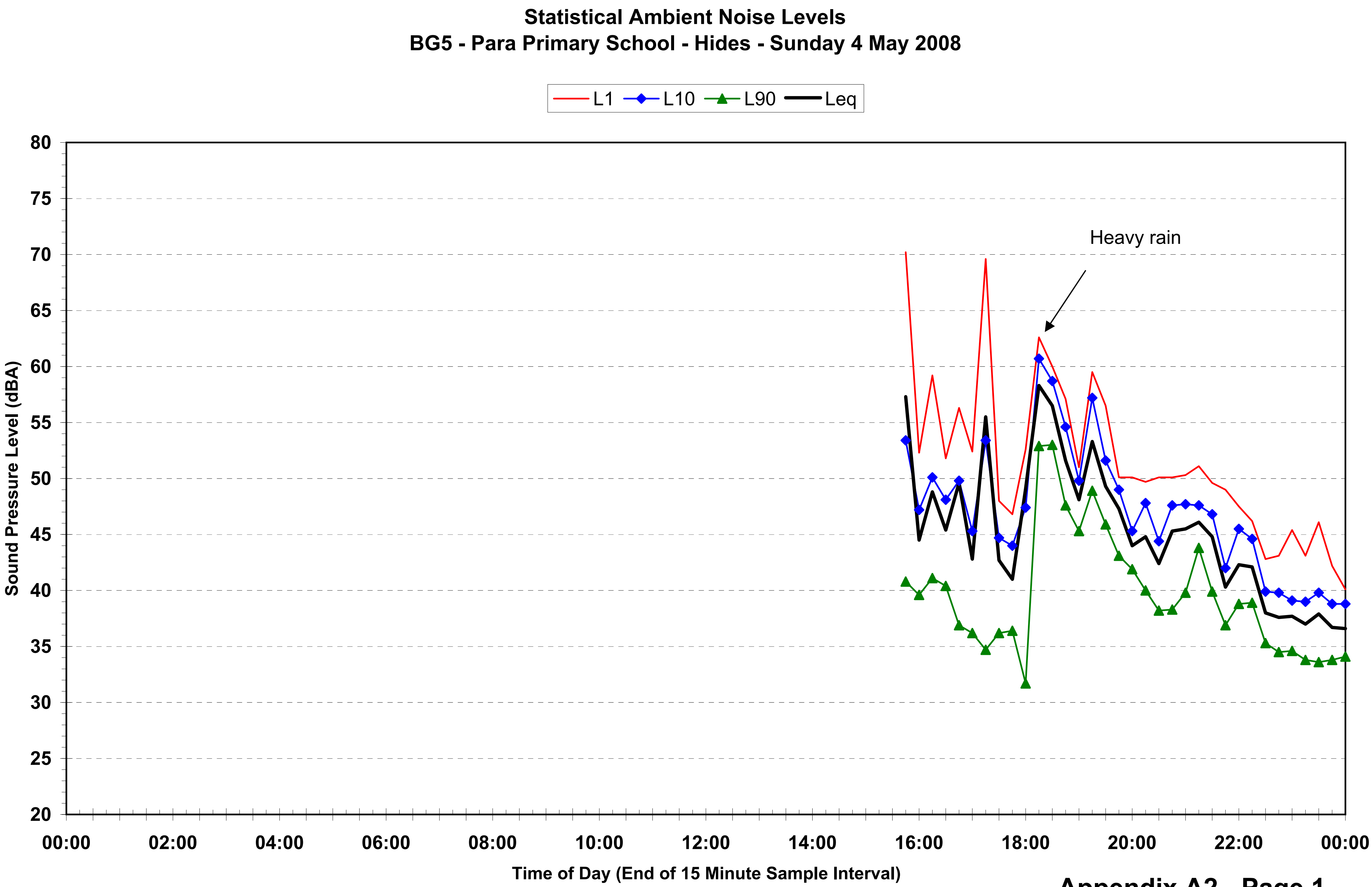
Statistical Noise Levels

Heggies Report 40-1530


Statistical Ambient Noise Levels
BG4 - Hides - Sunday 4 May 2008
L1
L10
L90
Leq
80
75
70
65
60
55
50
45
40
35
30
25
20
Sound Pressure Level (dBA)
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
Time of Day (End of 15 Minute Sample Interval)



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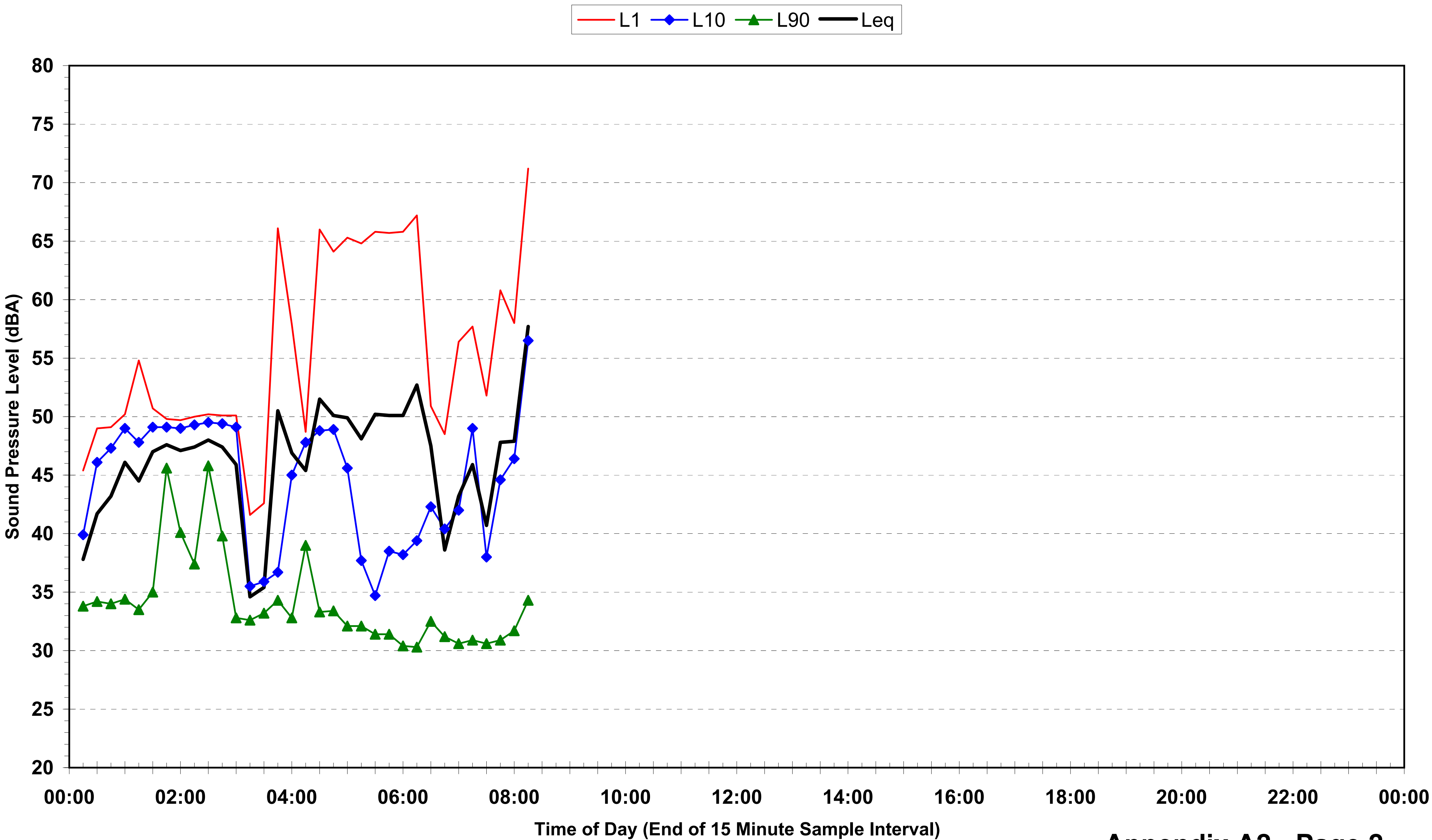
Statistical Noise Levels

Heggies Report 40-1530

Statistical Ambient Noise Levels
BG5 - Para Primary School - Hides - Monday 5 May 2008



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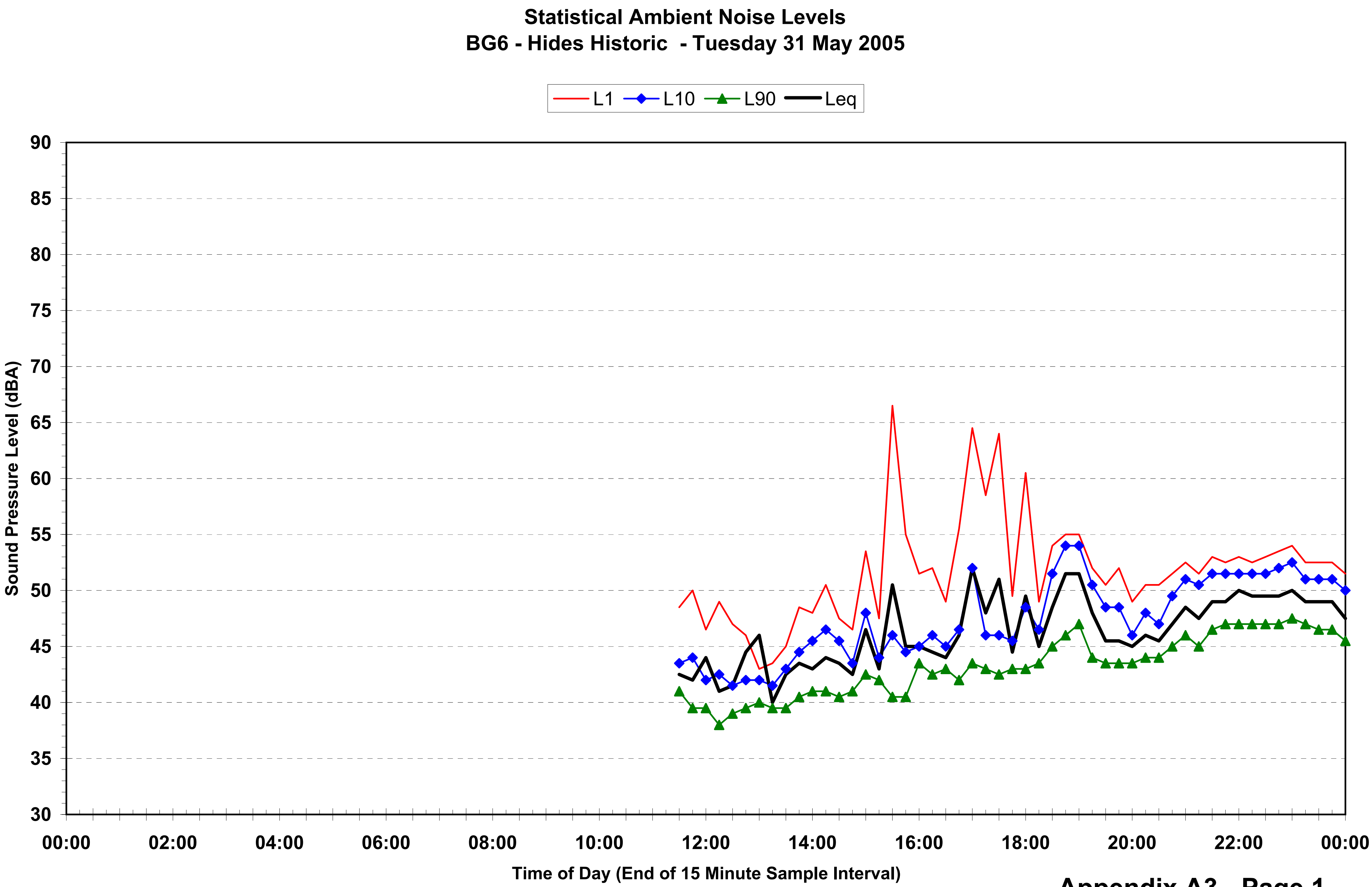
Statistical Noise Levels
Heggies Report 40-1530



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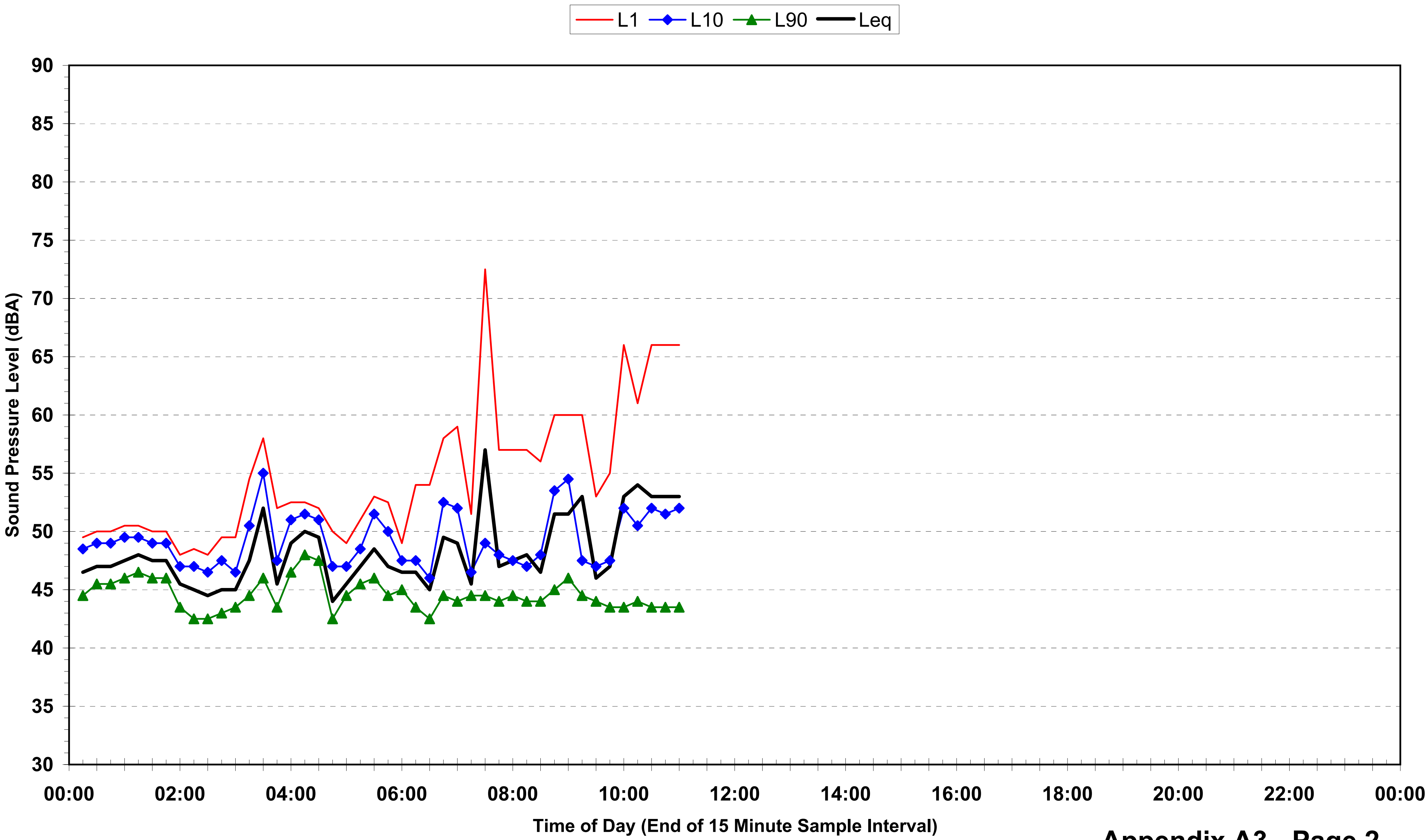
Statistical Noise Levels

Heggies Report 40-1530

Statistical Ambient Noise Levels
BG6 - Hides Historic - Wednesday 1 June 2005



SEASONAL WIND ANALYSIS

Annual Wind Speed and Direction Percentage

Day

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	1.4%	0.8%	2.2%	0.7%	0.0%
NNE	0.0%	0.9%	0.2%	1.1%	0.3%	0.0%
NE	0.0%	0.9%	0.0%	1.0%	0.0%	0.0%
ENE	0.0%	2.4%	0.3%	2.7%	0.1%	0.0%
E	0.0%	6.4%	4.6%	11.0%	2.3%	0.0%
ESE	0.0%	13.2%	13.7%	26.9%	6.9%	0.0%
SE	0.0%	20.8%	22.7%	43.4%	10.1%	0.0%
SSE	0.0%	25.2%	27.9%	53.1%	11.1%	0.0%
S	0.0%	24.0%	26.8%	50.8%	10.2%	0.0%
SSW	0.0%	19.1%	20.0%	39.1%	7.4%	0.0%
SW	0.0%	12.7%	12.3%	25.0%	5.5%	0.0%
WSW	0.0%	8.0%	7.6%	15.6%	4.8%	0.0%
W	0.0%	5.9%	5.1%	10.9%	3.6%	0.0%
WNW	0.0%	4.6%	3.3%	7.9%	2.2%	0.0%
NW	0.0%	3.2%	2.3%	5.6%	1.3%	0.0%
NNW	0.0%	2.1%	1.5%	3.6%	0.9%	0.0%
Total	**8.0%**	**37.7%**	**37.3%**	**75.0%**	**16.9%**	**0.1%**

Evening

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	1.0%	0.1%	1.1%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	0.6%	0.1%	0.7%	0.0%	0.0%
SSE	0.0%	10.5%	4.5%	15.0%	0.1%	0.0%
S	0.0%	28.2%	12.2%	40.4%	0.5%	0.0%
SSW	0.0%	41.4%	22.4%	63.8%	2.5%	0.0%
SW	0.0%	48.4%	31.9%	80.3%	4.5%	0.0%
WSW	0.0%	42.9%	31.0%	73.9%	4.9%	0.0%
W	0.0%	27.9%	23.7%	51.7%	4.4%	0.0%
WNW	0.0%	15.7%	13.7%	29.4%	2.4%	0.0%
NW	0.0%	8.2%	4.0%	12.2%	0.4%	0.0%
NNW	0.0%	3.7%	0.6%	4.3%	0.0%	0.0%
Total	**1.8%**	**57.1%**	**36.1%**	**93.2%**	**4.9%**	**0.0%**

Night

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	0.6%	0.2%	0.8%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%
SSE	0.0%	1.8%	0.1%	1.9%	0.0%	0.0%
S	0.0%	11.4%	5.4%	16.8%	0.2%	0.0%
SSW	0.0%	31.1%	21.1%	52.2%	0.4%	0.0%
SW	0.0%	50.6%	33.2%	83.8%	0.6%	0.0%
WSW	0.0%	58.4%	35.4%	93.7%	0.6%	0.0%
W	0.0%	51.2%	30.6%	81.8%	0.4%	0.0%
WNW	0.0%	32.1%	15.1%	47.2%	0.1%	0.0%
NW	0.0%	12.6%	3.0%	15.5%	0.0%	0.0%
NNW	0.0%	3.0%	0.8%	3.8%	0.0%	0.0%
Total	**0.0%**	**63.2%**	**36.2%**	**99.4%**	**0.6%**	**0.0%**

Summer Wind Speed and Direction Percentage

Day

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	1.8%	1.6%	3.4%	1.3%	0.0%
NNE	0.0%	0.9%	0.5%	1.4%	0.6%	0.0%
NE	0.0%	1.2%	0.1%	1.3%	0.0%	0.0%
ENE	0.0%	3.6%	0.3%	3.9%	0.1%	0.0%
E	0.0%	8.4%	3.8%	12.2%	1.0%	0.0%
ESE	0.0%	14.3%	9.1%	23.4%	1.7%	0.0%
SE	0.0%	18.6%	13.3%	31.9%	1.8%	0.0%
SSE	0.0%	19.9%	17.5%	37.5%	2.8%	0.0%
S	0.0%	17.7%	20.1%	37.8%	4.6%	0.0%
SSW	0.0%	14.3%	19.8%	34.1%	7.2%	0.0%
SW	0.0%	12.8%	18.7%	31.5%	9.7%	0.0%
WSW	0.0%	11.9%	16.5%	28.3%	9.6%	0.0%
W	0.0%	10.7%	12.0%	22.7%	7.2%	0.0%
WNW	0.0%	9.1%	8.0%	17.1%	4.6%	0.0%
NW	0.0%	6.0%	5.4%	11.4%	2.6%	0.0%
NNW	0.0%	3.2%	3.2%	6.4%	1.6%	0.0%
Total	**9.9%**	**38.6%**	**37.5%**	**76.1%**	**14.0%**	**0.0%**

Evening

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	1.0%	0.1%	1.1%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SSE	0.0%	1.7%	2.4%	4.0%	0.0%	0.0%
S	0.0%	8.8%	11.3%	20.0%	0.7%	0.0%
SSW	0.0%	21.9%	29.0%	51.0%	3.9%	0.0%
SW	0.0%	33.9%	44.7%	78.6%	7.1%	0.0%
WSW	0.0%	37.5%	47.1%	84.6%	7.8%	0.0%
W	0.0%	32.5%	38.6%	71.1%	7.1%	0.0%
WNW	0.0%	20.3%	21.0%	41.3%	3.9%	0.0%
NW	0.0%	8.3%	5.3%	13.6%	0.7%	0.0%
NNW	0.0%	3.1%	0.6%	3.6%	0.0%	0.0%
Total	**0.0%**	**42.2%**	**50.0%**	**92.2%**	**7.8%**	**0.0%**

Night

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	0.7%	0.2%	0.9%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	0.2%	0.0%	0.2%	0.0%	0.0%
SSE	0.0%	1.2%	0.0%	1.2%	0.0%	0.0%
S	0.0%	9.2%	4.1%	13.3%	0.0%	0.0%
SSW	0.0%	29.9%	22.1%	52.0%	0.0%	0.0%
SW	0.0%	49.0%	37.2%	86.2%	0.0%	0.0%
WSW	0.0%	55.6%	39.0%	94.6%	0.0%	0.0%
W	0.0%	50.1%	35.7%	85.9%	0.0%	0.0%
WNW	0.0%	30.1%	17.9%	48.0%	0.0%	0.0%
NW	0.0%	10.9%	2.8%	13.6%	0.0%	0.0%
NNW	0.0%	3.2%	1.0%	4.2%	0.0%	0.0%
Total	**0.0%**	**60.0%**	**40.0%**	**100.0%**	**0.0%**	**0.0%**

Autumn Wind Speed and Direction Percentage

Day

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	2.2%	0.8%	3.1%	0.6%	0.2%
NNE	0.0%	1.5%	0.2%	1.7%	0.2%	0.1%
NE	0.0%	1.6%	0.1%	1.7%	0.0%	0.0%
ENE	0.0%	4.3%	0.5%	4.8%	0.3%	0.0%
E	0.0%	10.9%	4.4%	15.3%	1.0%	0.0%
ESE	0.0%	19.7%	10.7%	30.3%	1.7%	0.0%
SE	0.0%	27.7%	15.7%	43.4%	1.9%	0.0%
SSE	0.0%	30.9%	19.5%	50.3%	2.2%	0.0%
S	0.0%	26.9%	20.0%	46.9%	3.9%	0.0%
SSW	0.0%	19.6%	17.2%	36.8%	7.1%	0.1%
SW	0.0%	12.1%	13.5%	25.5%	9.5%	0.2%
WSW	0.0%	6.9%	9.8%	16.7%	9.4%	0.2%
W	0.0%	5.0%	6.2%	11.3%	7.2%	0.2%
WNW	0.0%	4.3%	3.4%	7.7%	3.8%	0.2%
NW	0.0%	3.7%	2.3%	5.9%	1.4%	0.2%
NNW	0.0%	3.0%	1.8%	4.7%	0.8%	0.2%
Total	**10.3%**	**45.1%**	**31.5%**	**76.6%**	**12.7%**	**0.4%**

Evening

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	0.5%	0.4%	1.0%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	0.4%	0.0%	0.4%	0.0%	0.0%
SSE	0.0%	2.9%	0.4%	3.3%	0.0%	0.0%
S	0.0%	10.5%	4.1%	14.5%	1.0%	0.0%
SSW	0.0%	21.7%	19.8%	41.6%	4.8%	0.0%
SW	0.0%	30.2%	39.4%	69.6%	8.6%	0.0%
WSW	0.0%	33.4%	46.7%	80.2%	9.5%	0.0%
W	0.0%	28.9%	44.2%	73.1%	8.6%	0.0%
WNW	0.0%	18.2%	28.8%	47.0%	4.8%	0.0%
NW	0.0%	9.4%	9.2%	18.6%	1.0%	0.0%
NNW	0.0%	3.7%	1.5%	5.2%	0.0%	0.0%
Total	**1.9%**	**39.9%**	**48.6%**	**88.6%**	**9.5%**	**0.0%**

Night

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	0.7%	0.2%	0.8%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SSE	0.0%	1.1%	0.0%	1.1%	0.0%	0.0%
S	0.0%	8.1%	2.0%	10.1%	0.0%	0.0%
SSW	0.0%	23.8%	19.8%	43.6%	0.4%	0.0%
SW	0.0%	43.8%	38.1%	81.9%	0.8%	0.0%
WSW	0.0%	53.9%	40.9%	94.8%	0.8%	0.0%
W	0.0%	48.7%	39.5%	88.2%	0.8%	0.0%
WNW	0.0%	33.7%	21.9%	55.6%	0.4%	0.0%
NW	0.0%	13.7%	3.6%	17.3%	0.0%	0.0%
NNW	0.0%	2.5%	0.7%	3.2%	0.0%	0.0%
Total	**0.0%**	**57.5%**	**41.7%**	**99.2%**	**0.8%**	**0.0%**

Winter — Wind Speed and Direction Percentage

Day

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	0.8%	0.6%	1.5%	1.0%	0.0%
NNE	0.0%	0.6%	0.1%	0.8%	0.5%	0.0%
NE	0.0%	0.5%	0.0%	0.5%	0.0%	0.0%
ENE	0.0%	0.6%	0.0%	0.6%	0.0%	0.0%
E	0.0%	2.1%	3.1%	5.2%	2.6%	0.0%
ESE	0.0%	6.7%	14.0%	20.7%	11.3%	0.0%
SE	0.0%	15.8%	27.6%	43.4%	19.0%	0.0%
SSE	0.0%	23.6%	34.5%	58.1%	20.6%	0.0%
S	0.0%	26.0%	32.9%	58.9%	18.0%	0.0%
SSW	0.0%	23.8%	22.5%	46.3%	9.3%	0.0%
SW	0.0%	16.1%	9.2%	25.3%	1.7%	0.0%
WSW	0.0%	9.0%	2.7%	11.8%	0.1%	0.0%
W	0.0%	5.7%	1.8%	7.5%	0.1%	0.0%
WNW	0.0%	3.5%	1.8%	5.3%	0.6%	0.0%
NW	0.0%	2.3%	1.7%	4.0%	1.1%	0.0%
NNW	0.0%	1.4%	1.2%	2.6%	1.1%	0.0%
Total	**5.1%**	**34.7%**	**38.4%**	**73.1%**	**21.7%**	**0.0%**

Evening

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	1.0%	0.0%	1.0%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	0.5%	0.3%	0.8%	0.0%	0.0%
SSE	0.0%	17.0%	7.6%	24.6%	0.3%	0.0%
S	0.0%	44.8%	17.4%	62.2%	0.5%	0.0%
SSW	0.0%	59.5%	20.8%	80.3%	0.8%	0.0%
SW	0.0%	63.5%	21.3%	84.8%	1.1%	0.0%
WSW	0.0%	50.8%	14.4%	65.2%	0.8%	0.0%
W	0.0%	26.0%	4.9%	30.8%	0.5%	0.0%
WNW	0.0%	12.2%	1.5%	13.7%	0.3%	0.0%
NW	0.0%	7.7%	0.7%	8.4%	0.0%	0.0%
NNW	0.0%	3.9%	0.3%	4.2%	0.0%	0.0%
Total	**4.9%**	**71.7%**	**22.3%**	**94.0%**	**1.1%**	**0.0%**

Night

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	0.5%	0.2%	0.7%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SSE	0.0%	2.4%	0.2%	2.6%	0.0%	0.0%
S	0.0%	12.9%	8.9%	21.8%	0.6%	0.0%
SSW	0.0%	33.0%	22.3%	55.3%	1.2%	0.0%
SW	0.0%	53.7%	28.4%	82.1%	1.2%	0.0%
WSW	0.0%	62.0%	30.1%	92.1%	1.2%	0.0%
W	0.0%	54.0%	22.2%	76.3%	0.6%	0.0%
WNW	0.0%	34.4%	9.1%	43.5%	0.0%	0.0%
NW	0.0%	13.7%	3.0%	16.7%	0.0%	0.0%
NNW	0.0%	3.0%	1.1%	4.1%	0.0%	0.0%
Total	**0.0%**	**67.4%**	**31.4%**	**98.8%**	**1.2%**	**0.0%**

Spring Wind Speed and Direction Percentage

Day

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	0.6%	0.0%	0.6%	0.0%	0.0%
NNE	0.0%	0.4%	0.0%	0.4%	0.0%	0.0%
NE	0.0%	0.4%	0.0%	0.4%	0.0%	0.0%
ENE	0.0%	1.1%	0.2%	1.3%	0.1%	0.0%
E	0.0%	4.4%	7.0%	11.4%	4.6%	0.0%
ESE	0.0%	11.9%	21.1%	33.0%	13.0%	0.0%
SE	0.0%	21.0%	34.0%	55.0%	17.8%	0.0%
SSE	0.0%	26.3%	40.0%	66.3%	18.6%	0.0%
S	0.0%	25.2%	34.3%	59.5%	14.3%	0.0%
SSW	0.0%	18.7%	20.5%	39.2%	5.9%	0.0%
SW	0.0%	10.0%	7.7%	17.7%	1.2%	0.0%
WSW	0.0%	4.2%	1.5%	5.7%	0.2%	0.0%
W	0.0%	2.1%	0.4%	2.5%	0.0%	0.0%
WNW	0.0%	1.3%	0.2%	1.5%	0.0%	0.0%
NW	0.0%	1.0%	0.0%	1.0%	0.0%	0.0%
NNW	0.0%	0.7%	0.0%	0.7%	0.0%	0.0%
Total	**6.9%**	**32.4%**	**41.8%**	**74.1%**	**19.0%**	**0.0%**

Evening

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	1.4%	0.0%	1.4%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	1.4%	0.3%	1.6%	0.0%	0.0%
SSE	0.0%	20.5%	7.4%	27.9%	0.0%	0.0%
S	0.0%	48.6%	16.2%	64.8%	0.0%	0.0%
SSW	0.0%	62.2%	20.1%	82.3%	0.5%	0.0%
SW	0.0%	65.8%	22.4%	88.2%	1.2%	0.0%
WSW	0.0%	49.9%	16.1%	65.9%	1.4%	0.0%
W	0.0%	24.5%	7.4%	31.9%	1.4%	0.0%
WNW	0.0%	12.2%	3.6%	15.8%	0.8%	0.0%
NW	0.0%	7.3%	1.0%	8.2%	0.1%	0.0%
NNW	0.0%	4.1%	0.1%	4.3%	0.0%	0.0%
Total	**0.5%**	**74.5%**	**23.6%**	**98.1%**	**1.4%**	**0.0%**

Night

Direction	Calm - <=0.5m/s	0.5m/s - <=2m/s	2m/s - <=3.0m/s	0.5m/s - <=3.0m/s	3.0m/s - <=5.0m/s	> 5.0m/s
N	0.0%	0.6%	0.0%	0.6%	0.0%	0.0%
NNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ENE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%
SSE	0.0%	2.6%	0.1%	2.7%	0.0%	0.0%
S	0.0%	15.6%	6.6%	22.2%	0.0%	0.0%
SSW	0.0%	37.7%	20.2%	57.9%	0.1%	0.0%
SW	0.0%	55.9%	29.2%	85.1%	0.2%	0.0%
WSW	0.0%	62.0%	31.4%	93.3%	0.2%	0.0%
W	0.0%	51.7%	25.2%	76.9%	0.2%	0.0%
WNW	0.0%	30.2%	11.5%	41.8%	0.1%	0.0%
NW	0.0%	12.0%	2.5%	14.5%	0.0%	0.0%
NNW	0.0%	3.3%	0.3%	3.6%	0.0%	0.0%
Total	**0.1%**	**67.9%**	**31.7%**	**99.6%**	**0.2%**	**0.0%**