ORANGE
Australia's Colour City
ABN: 85 985 402 386

Completion of the North Orange By-pass from Astill Drive (North) to Chinaman's Bend, Orange

Validation of Traffic Noise Model and Noise Control Measures

Prepared by

Heggies Pty Ltd

March 2009

Specialist Consultant Studies Compendium: Part 2A

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Validation of Traffic Noise Model and Noise Control Measures

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1 INTRODUCTION

The Northern Distributor Road (NDR) at Orange consists of a two lane rural road to facilitate the movement of local and through traffic around the city of Orange and to help reduce traffic congestion in the city centre. Stages 1 to 4 of the NDR have been completed and consist of the section of road between Leeds Parade and The Escort Way, Orange.

Heggies Pty Ltd (Heggies) completed a traffic noise impact assessment of Stages 1 to 4 of the NDR in January 2004, referred to hereafter as Heggies (2004). This section of the road was subsequently completed in February 2008. In order to reduce operational impacts, traffic noise control measures were included in the road construction which included earth bunds and noise walls.

Orange City Council has subsequently commissioned Heggies to conduct a noise monitoring programme in the vicinity of the existing NDR to determine the adequacy of the existing noise mitigation and to validate the noise assessment undertaken as part the previous EIS. This has been done to enable the validity of assumptions made during preparation of the previous assessment to be validated prior to undertaking further assessment to determine the noise impacts associated with completion of the North Orange By-pass from the Mitchell Highway to the Northern Distributor Road at Astill Drive. The results of that assessment are presented in the Part 2A report included in this *Specialist Consultant Studies Compendium*.

This report presents the results of the monitoring programme and includes a validation of the noise modelling (Heggies, 2004).

Appendix A, *Acoustic Terminology* contains an explanation of the various acoustic terms and descriptors used throughout the report.

2 OPERATIONAL ROAD TRAFFIC NOISE CRITERIA

The NSW Department of Environment and Climate Change's (DECC) "*Environmental Criteria for Road Traffic Noise*" May 1999 (ECRTN) were adopted for the 2004 EIS, and are summarised in this section of the report. The policy document presents the NSW Government's guidelines for road traffic noise assessment and provides road traffic noise criteria for proposed road or residential land use developments as well as criteria for other sensitive land uses.

The road traffic criteria recommended in the policy document are based on the functional categories of the subject roads, as applied by the RTA, as follows.

- Arterial roads (including freeways and sub-arterial roads): these carry predominantly through traffic from one region to another, forming principal avenues of communication for urban traffic movements and characterised by heavy and continuous traffic flow during peak periods.
- Collector roads: these connect the local road system in built-up areas to freeways, arterial and sub-arterial roads.

- Local roads: these are the subdivisional roads within a particular developed area. These are used solely as local access roads and are characterised by intermittent traffic flow.
- New Road (any of the above categories): these are roads proposed on a corridor which has not previously been used for a freeway, arterial or sub-arterial road.
- Redeveloped Road (any of the above categories): an existing road corridor where, through design or engineering changes, the project is intended to (substantially) increase traffic-carrying capacity or the mix of traffic.

When determining the appropriate road category for noise assessment purposes, it is necessary to determine the functional use of the proposed road(s). In this instance, the NDR could be seen as performing the function of a collector road by allowing traffic on local roads to access Bathurst Road, Molong Road and The Escort Way. However, the proposed NDR could also be seen as performing the function of an arterial or sub-arterial road, carrying through traffic from Bathurst to Parkes or Forbes.

In order to provide a conservative assessment of the NDR, the “new arterial” road category was assumed for the purposes of the EIS. The “new arterial” road category is the most stringent with respect to noise design goals. Also, due to the substantial realignment of Leeds Parade and the substantial increase in traffic numbers following the opening of the NDR, the “new arterial” road category has also been assumed for the realigned section of Leeds Parade.

Table 1 present the relevant ECRTN noise criteria adopted in the EIS for the NDR and the realigned section of Leeds Parade. These criteria are applicable for traffic conditions prevailing 10 years after project opening. As this project (ie. Stages 1 to 4) was expected to be staged, the ultimate time of assessment was taken to be Year 2020, 10 years after opening of the last stage. For all other roads intersecting with the proposed NDR, the ECRTN recommends that as redeveloped roads, the noise emissions should not increase by more than 2 dBA at a point in time 10 years after opening, where the “future-existing” noise levels already exceed the ECRTN recommended noise levels for the appropriate road category. The “future-existing” noise level is defined as the noise level immediately before opening of the road, for the “do nothing” case.

Table 1
Road Traffic Noise Criteria for Proposed Road Development

Type of Development	**Criteria**		
	Day 7am - 10pm (dBA)	**Night 10pm - 7am (dBA)**	**Where Criteria are Already Exceeded**
Criteria for Residences adjoining the New NDR			
New freeway or arterial road corridor	$L_{Aeq(15hour)}$ 55 dBA	$L_{Aeq(9hour)}$ 50 dBA	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dBA. Where feasible and reasonable, noise levels from existing roads should be reduced to meet the noise criteria. In many instances this may be achievable only through long-term strategies, such as improved planning, design and construction of adjoining land use developments; reduced vehicle emission levels through new vehicle standards and regulation of in-service vehicles; greater use of public transport; and alternative methods of freight haulage.

It is noted that the noise criteria presented within the ECRTN noise policy document are guidelines and as such are non mandatory.

3 NDR TRAFFIC FLOWS

As part of the 2004 Study for the NDR, traffic volumes were predicted and used in the noise modelling. These volumes are presented in **Table 2**.

Traffic counters were installed on the NDR during April 2008, concurrent with the ambient noise monitoring, and the measured traffic volumes are summarised in **Table 3**.

Table 2
Traffic Volume Details as used in the 2004 EIS

Survey Location[1]	**Road Section**	**Traffic Volume**				**Percentage Heavy Vehicles**			
		Daytime		**Night-time**		**Daytime**		**Night-time**	
1.	Realigned Leeds Parade	North 4,037	South 4,037	North 314	South 314	North 8%	South 6%	North 19%	South 17%
2.	NDR - West of Leeds Parade	West 3,767	East 3,767	West 284	East 284	West 8%	East 6%	West 21%	East 19%
3.	NDR – West of Mitchell Hwy	South 652	North 666	South 64	North 50	South 11%	North 10%	South 34%	North 24%
4.	NDR - East of Mitchell Hwy	West 2,465	East 2,468	West 186	East 186	West 8%	East 6%	West 21%	East 19%
Note 1: Survey Locations see **Figure 1**.									
Source: Northern Transport Planning and Engineering.									

Table 3
Traffic Volume Details as Measured in April 2008

Survey Location[1]	**Road Section**	**Traffic Volume**				**Percentage Heavy Vehicles**			
		Daytime		**Night-time**		**Daytime**		**Night-time**	
1.	Realigned Leeds Parade	North 1,587	South 1,557	North 105	South 120	North 12%	South 14%	North 22%	South 20%
2.	NDR - West of Leeds Parade	West 1,480	East 1,446	West 95	East 119	West 13%	East 17%	West 24%	East 20%
3.	NDR – West of Mitchell Hwy	South 494	North 503	South 30	North 30	South 9%	North 11%	South 14%	North 13%
4.	NDR - East of Mitchell Hwy	West 1,137	East 1,133	West 76	East 85	West 10%	East 9%	West 27%	East 17%
Note 1: Survey Locations see **Figure 1**.									
Source: Northern Transport Planning and Engineering - Summary of traffic counter results for April 2008.									

3.1 Analysis of April 2008 Traffic Volume Survey

In summary, the following conclusions are reached for the 2008 traffic volumes when compared to the traffic volumes assumed in the 2004 EIS, as presented in **Table 2** and **Table 3**.

- NDR Daytime traffic volumes from Leeds Parade to the Mitchell Highway are typically 40 percent of the predicted volumes. Furthermore, the daytime percentage of heavy vehicles is typically 15 percent, compared to the predicted nominal 6 to 8 percent.
- NDR Night-time traffic volumes from Leeds Parade to the Mitchell Highway are typically 35 percent of the predicted volumes. The night-time 2008 percentage of heavy vehicles is typically 20 percent, which is similar to the predicted amount.
- NDR Daytime traffic volumes from The Escort Way Parade to the Mitchell Highway are typically 75 percent of the predicted volumes. Furthermore, the daytime percentage of heavy vehicles is typically 10 percent, which is similar to the predicted amount.
- NDR Daytime traffic volumes from The Escort Way Parade to the Mitchell Highway are typically 55 percent of the predicted volumes. The night-time 2008 percentage of heavy vehicles is typically 14 percent, compared to the predicted nominal 24 to 34 percent.

These reduced flow volumes and different percentage of heavy vehicles will typically reduce traffic noise levels (current compared to 2020 predicted) by 3 dBA north of the Mitchell Highway. South of the Mitchell Highway, slightly lower traffic noise levels of up to 1 dBA are expected.

4 AMBIENT NOISE SURVEY

Ambient noise measurements were carried out at a number of residential locations on the NDR as well as at a residence near the realigned Leeds Parade on Sheldon Crescent. The purpose of these measurements was to establish the ambient traffic noise levels at representative residences for comparison with the project design criteria as well as with the predicted noise levels. The receivers selected as measurement locations were chosen to be representative of those along the length of the completed NDR in areas both with and without noise mitigation treatments.

Measurements were conducted between 6 April 2008 and 16 April 2008 and comprised both attended and unattended noise monitoring. Traffic counting was arranged to be concurrent with the noise surveys, and consisted of the recording of individual vehicle events, thus enabling exact traffic flows to be used in calculation for comparison with the attended and unattended noise monitoring results.

4.1 Measurement Locations

Measurements were undertaken at the following representative residences and locations (**Figure 1**).

- **52 Turner Crescent**

  This residence is located between The Escort Way and the Mitchell Highway, with the rear boundary of this residence facing the NDR. This residence is generally unshielded from NDR traffic noise, although a 1.5 m boundary fence provides some attenuation of traffic noise.

- **365 Burrendong Way**

  This residence is located between the Mitchell Highway and Burrendong Way. The residence faces the NDR and is generally unshielded from NDR traffic noise.

- **11 Bilton Place**

  This residence is located between Burrendong Way and Clergate Road on the northern side of the NDR. The residence faces the NDR and is shielded by a nominal 3 m high timber noise wall, constructed as part of the project noise mitigation.

- **21 Coombes Place**

  This residence is located between Burrendong Way and Clergate Road on the southern side of the NDR. The residence faces the NDR and is shielded by a nominal 3 m high earth mound, constructed as part of the project noise mitigation.

- **140 Clergate Road**

  This residence is located between Clergate Road and Leeds Parade on the northern side of the NDR. The residence faces the NDR and is generally unshielded from the NDR, although the angle of view to NDR traffic is nominally 90 degrees due to an earth mound on the western side of Clergate Road.

- **118 Clergate Road**

  This residence is located between Clergate Road and Leeds Parade on the southern side of the NDR. The rear of the residence faces the NDR and is shielded by a nominal 3 m high earth mound, constructed as part of the project noise mitigation.

- **19 Sheldon Crescent**

  The residence is located on the re-aligned. The residence faces Leeds Parade and is generally unshielded traffic noise.

- **Reference of Calibration Location**

  Between Burrendong Way and Clergate Road and south of the intersection of Farrell Road and the NDR unattended noise measurements were conducted. This location was selected with an unshielded view of the NDR traffic as reference for noise model validation and comparison with the mitigated receivers at 11 Bilton Place and 21 Coombes Crescent.

\\SERVER\RWC\612\CAD\612Base_Noise 2a 1.DWG

REFERENCE
- Northern Distributor Road
- Cadastral Boundary
- Building
- (1) Automatic Traffic Counter Location and Identifier
- (7) Ambient Noise Monitoring Location and Identifier

SCALE 1:15 000

250 0 250 500 750 m

Base Map Source: Orange City Council

Figure 1
TRAFFIC SURVEY AND AMBIENT NOISE MONITORING LOCATIONS

Note: A colour version of this figure is available on the project CD

Unattended noise monitoring was conducted at 11 Bilton Place and 21 Coombes Crescent and the reference location, with attended monitoring at the remaining locations.

4.2 Ambient Noise Monitoring Results

The results of the attended and unattended ambient noise surveys are presented in tabular form in **Table 4** and **Table 5** respectively. Graphical results of the unattended survey are presented in **Appendix B**.

Table 4
Summary of Ambient Attended Noise Survey Results

Location	Sample Time	Noise Level (dBA) [1]				Comments
		L_{Aeq}	L_{A1}	L_{10}	L_{A90}	
52 Turner Crescent	10.08 am	48	61	49	35	Measurements at facade 30 m from NDR. Shielding by 1.5 m fence. LAmax cars 46 to 58 dBA, trucks 58 to 67 dBA
365 Burrendong Way	8.53 am	57	67	60	44	Measurements on balcony 40 m from NDR. LAmax cars 55 to 64 dBA, trucks 60 to 75 dBA
118 Clergate Road	3.02 pm	53	65	55	40	Measurements at facade 17 m from NDR 4 m noise wall. LAmax cars 47 to 62 dBA, trucks 55 to 72 dBA. Truck exhaust unshielded
140 Clergate Road	11.36 am	49	60	52	37	Measurements at facade 140 m from NDR. LAmax cars 42 to 52 dBA, trucks 52 to 70 dBA
19 Sheldon Crescent	2.27 pm	55	66	56	36	Measurements at facade 50 m from NDR. LAmax cars 48 to 53 dBA, trucks 55 to 75 dBA
Note 1: The measurement sample time was 1 hour at all locations on the NDR and 15 minutes at 19 Sheldon, being on Leeds Parade.						

Table 5 presents the results of the unattended noise monitoring conducted at 11 Bilton Place and 21 Coombes Place as well as interpolated results at the attended monitoring locations for comparison with the ECRTN based traffic noise design criteria. The interpolated L_{Aeq} results were obtained by correlating the traffic flows over the attended survey period to those of the unattended survey, as presented in **Table 3**.

4.3 Summary of Impacts

The results as presented in **Table 5** show compliance with the ECRTN criteria at all locations except 365 Burrendong Way. Note, traffic volumes during the monitoring periods are significantly lower than those used in the EIS for the 10 year after opening scenario, and noise levels would be expected in increase by up to 3 dBA as these volumes are realised. Effective traffic noise mitigation by way of barriers is reducing the noise levels at 11 Bilton Place, 21 Coombes Place and 118 Clergate Road, resulting in compliance with the ECRTN guidelines.

Table 5
Summary of Ambient L_{Aeq} Unattended Noise Survey Results

Location [2]	**Road Traffic Noise Indices – dBA**			
	Daytime (7am to 10pm)		**Night-time (10pm to 7am)**	
	Criteria $L_{Aeq(15 hour)}$	**Measured** $L_{Aeq(15 hour)}$	**Criteria** $L_{Aeq(9 hour)}$	**Measured** $L_{Aeq(9 hour)}$
52 Turner Crescent	55	46 [1]	50	41 [1]
365 Burrendong Way	55	56 [1]	50	48 [1]
11 Bilton Place	55	49	50	42
21 Coombes Place	55	50	50	44
118 Clergate Road	55	52 [1]	50	45 [1]
140 Clergate Road	55	48 [1]	50	41 [1]
	55	52 [1]	50	46 [1]

Note1: The daytime measured results were adjusted by correlating traffic flows between the measurement period and the traffic flows presented in **Table 3**. Night-time measured results are based on the predicted difference between the daytime and night-time levels.
Note 2: At all locations the noise levels were measured at 1 m from the residential facade, hence the results are "facade reflected" in accordance with the RTA guidelines.

5 NDR TRAFFIC NOISE MODEL VALIDATION

In Heggies (2004), preliminary noise modelling of the area adjacent to the NDR corridor was carried out using the UK Department of Transport's, "*Calculation of Road Traffic Noise*" (CORTN 1988) algorithms incorporated in the SoundPLAN noise modelling software. The modelling allowed for traffic volume and mix, type of road surface, vehicle speed, road gradient, ground absorption and shielding from ground topography and physical noise barriers. The algorithm output of CORTN was modified to calculate the relevant L_{Aeq} road traffic noise emission descriptors, as required.

In order to validate the noise model, a noise logger was located in an unshielded section of the completed NDR and used to measure the daytime and night-time L_{Aeq} noise levels. Concurrent with the noise logging period, traffic volume parameters including the percentage of heavy vehicles and speed were recorded. The noise logger was located approximately 60 m west of Farrell Road, and 38 m north of the NDR, between 15 April and 16 April 2008.

The results of the traffic survey were input into the noise model and the resulting predicted traffic noise levels were compared to the measured results, as presented in **Table 6**.

Table 6
Traffic Noise Model Validation Results

Location	**Road Traffic Noise Indices - dBA** [1]			
	Daytime (7am to 10pm)		**Night-time (10pm to 7am)**	
	Predicted $L_{Aeq(15 hour)}$	**Measured** $L_{Aeq(15 hour)}$	**Predicted** $L_{Aeq(9hour)}$	**Measured** $L_{Aeq(9hour)}$
North of NDR near Farrell Road	58 dBA	59 dBA	51 dBA	52 dBA

Note 1: In accordance with CORTN the presented traffic noise levels are facade corrected.

A comparison of the predicted versus measured L_{Aeq} levels shows reasonable agreement with the variations being only 1 dBA. Some variations are expected given the dependence of particular measured noise levels on road surface characteristics near the site, incidence of vehicles changing gears near the site, brake usage near the site, and localised and extraneous noise effects (eg insects and birds in trees), etc. In accordance with RTA guidelines, the model is sufficiently accurate for use.

5.1 Validation of Noise Control Measures

Noise control measures by way of a nominal 3.5 m high noise wall have been included in the NDR construction between Clergate Road and the Anson Street intersection on both the north and south sides of the NDR. The noise loggers located at 11 Bilton Place and 21 Coombes Place were located at representative residences to the north and south of the NDR respectively which were shielded by these barriers, thus mitigating the traffic noise levels.

The “validation” noise logger was located at a similar distance from the NDR as these residences, hence comparison of the noise levels presented in **Table 4** and **Table 6** will provide a realistic indication of the noise level reductions achieved. Analysis of the results shows that a noise level reduction in the order of 10 dBA has been achieved, indicating that the earth bunds/noise walls are providing attenuation in accordance with their design expectations.

6 CONCLUSION

Heggies has been engaged by Orange City Council to conduct a post-opening noise monitoring programme in the vicinity of the recently completed NDR, Orange in order to determine the adequacy of the existing noise mitigation and to validate the noise assessment undertaken as part the previous EIS. The traffic noise assessment for the EIS is contained in Heggies Report 10-3092- R2 of January 2004.

The results of the study are summarised in the following points.

- This assessment is based on the NSW Department of Environment and Climate Change’s (DECC’s) “*Environmental Criteria for Road Traffic Noise*”, May 1999 (ECRTN), which represents the NSW State Government’s current policy for road traffic noise.
- Ambient traffic noise monitoring and concurrent traffic flow measurements were conducted in April 2008. The receivers selected as measurement locations were chosen to be representative of those along the length of the completed NDR in areas both with and without noise mitigation treatments.
- The traffic noise modelling contained in the EIS was validated, based on measurements conducted in April 2008. A comparison of the predicted versus measured L_{Aeq} levels shows reasonable agreement with the variations being within 2 dBA

- Comparison of the predicted traffic noise levels, based on the 2008 traffic survey, with the measured results showed reasonable agreement, with the variations being within 2 dBA. In accordance with the RTA guidelines, the model is consequently sufficiently accurate for use.
- Analysis of the results of the validation study shows that a traffic noise level reduction in the order of 10 dBA has been achieved, indicating that the earth bunds/noise walls are providing attenuation in accordance with their design expectations.

APPENDICES

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Appendix A

Acoustic Terminology

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ACOUSTIC TERMINOLOGY USED IN THE REPORT

1 Sound Level or Noise Level

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

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

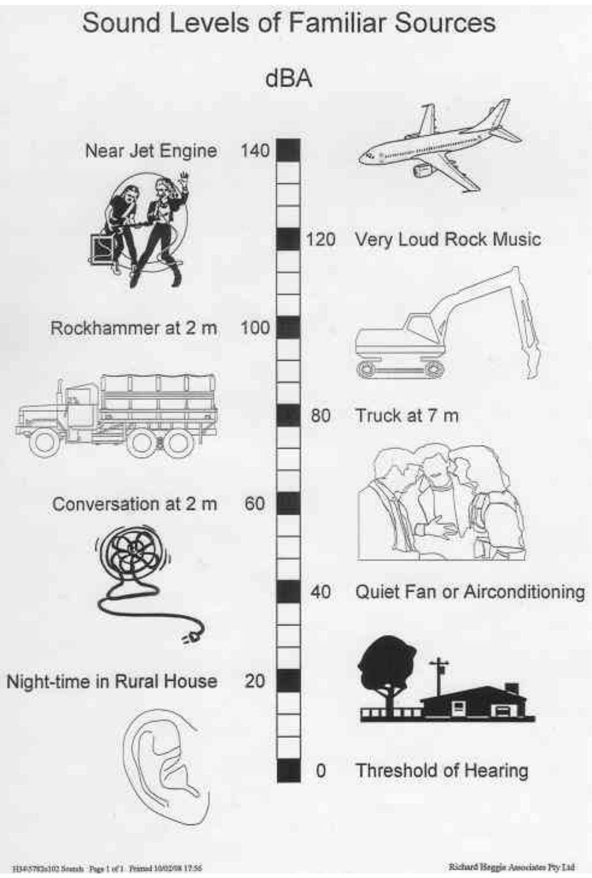
The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2×10^{-5} Pa.

2 "A" Weighted Sound Pressure Level

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

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

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



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

3 Sound Power Level

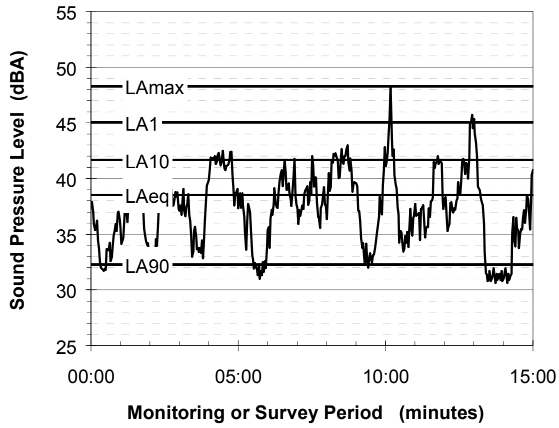
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

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

4 Statistical Noise Levels

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

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



Of particular relevance, are:

L_{Amax}	The maximum noise level during the 15 minute interval
L_{A1}	The noise level exceeded for 1% of the 15 minute interval.
L_{A10}	The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.
L_{A90}	The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.
L_{Aeq}	The A-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given monitoring location for a particular time of day. A standardised method is available for determining these representative levels. This method produces a level representing the "repeatable minimum" LA90 noise level over the daytime and night-time measurement periods, as required by the EPA. In addition the method produces mean or "average" levels representative of the other descriptors (LAeq, LA10, etc).

5 Tonality

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

6 Impulsiveness

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

7 Frequency Analysis

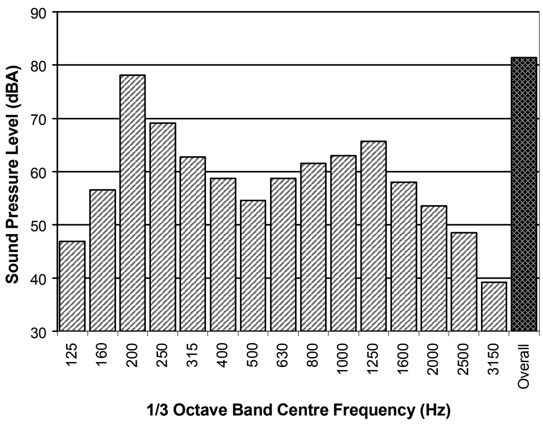
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

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

Frequency analysis can be in:

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

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



8 Vibration

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

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

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

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

9 Human Perception of Vibration

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

10 Over-Pressure

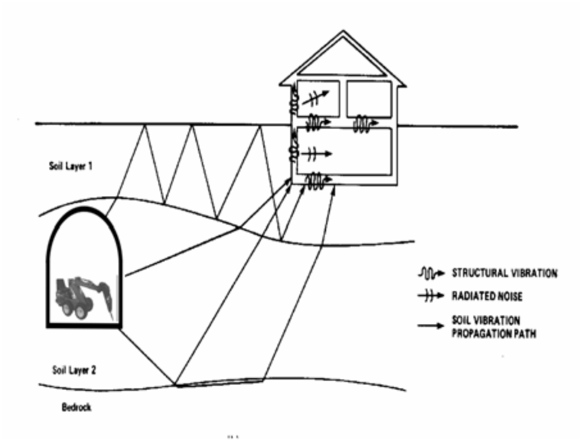
The term "over-pressure" is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

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

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

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

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



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

Appendix B

Statistical Noise Levels

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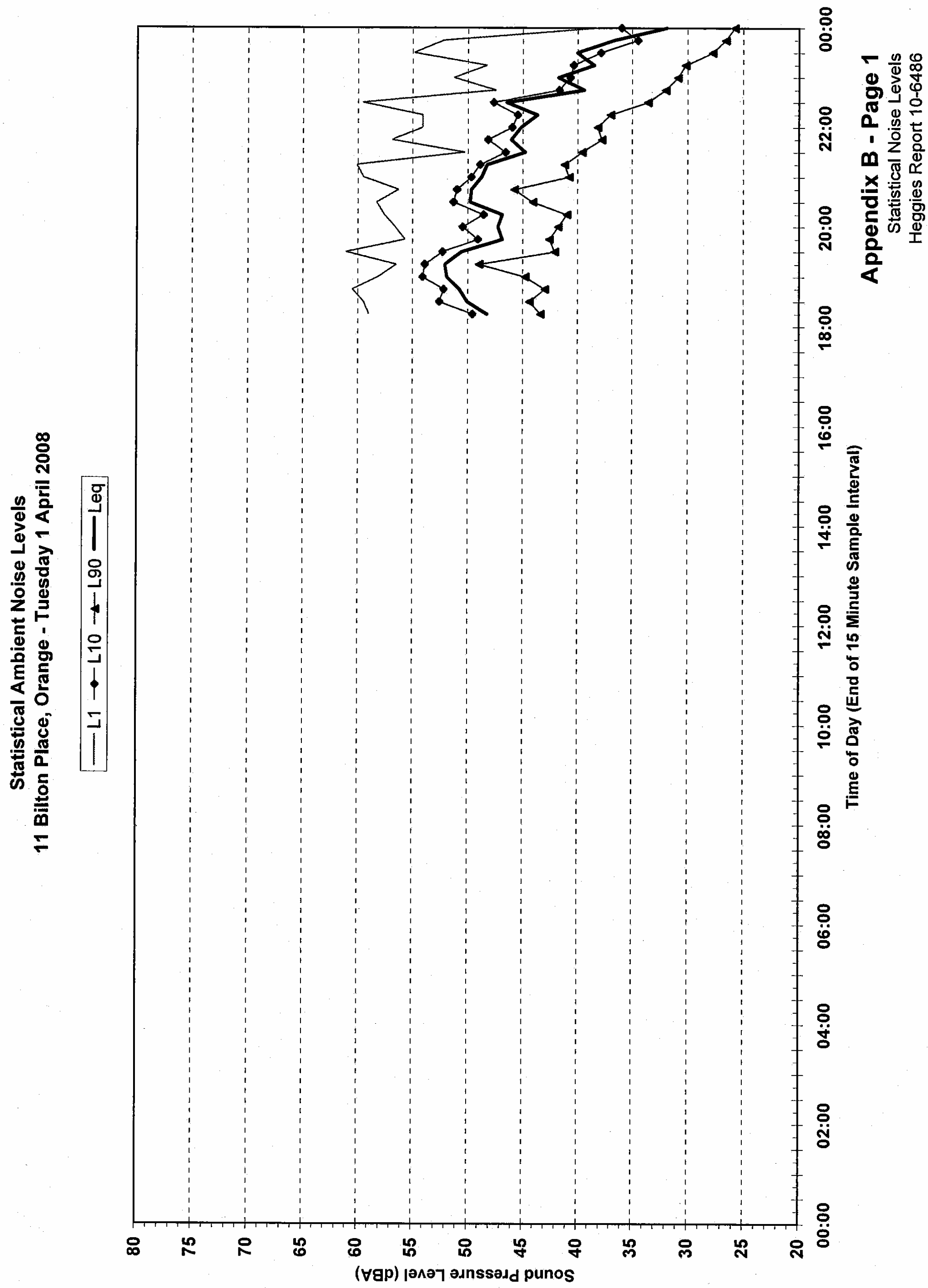
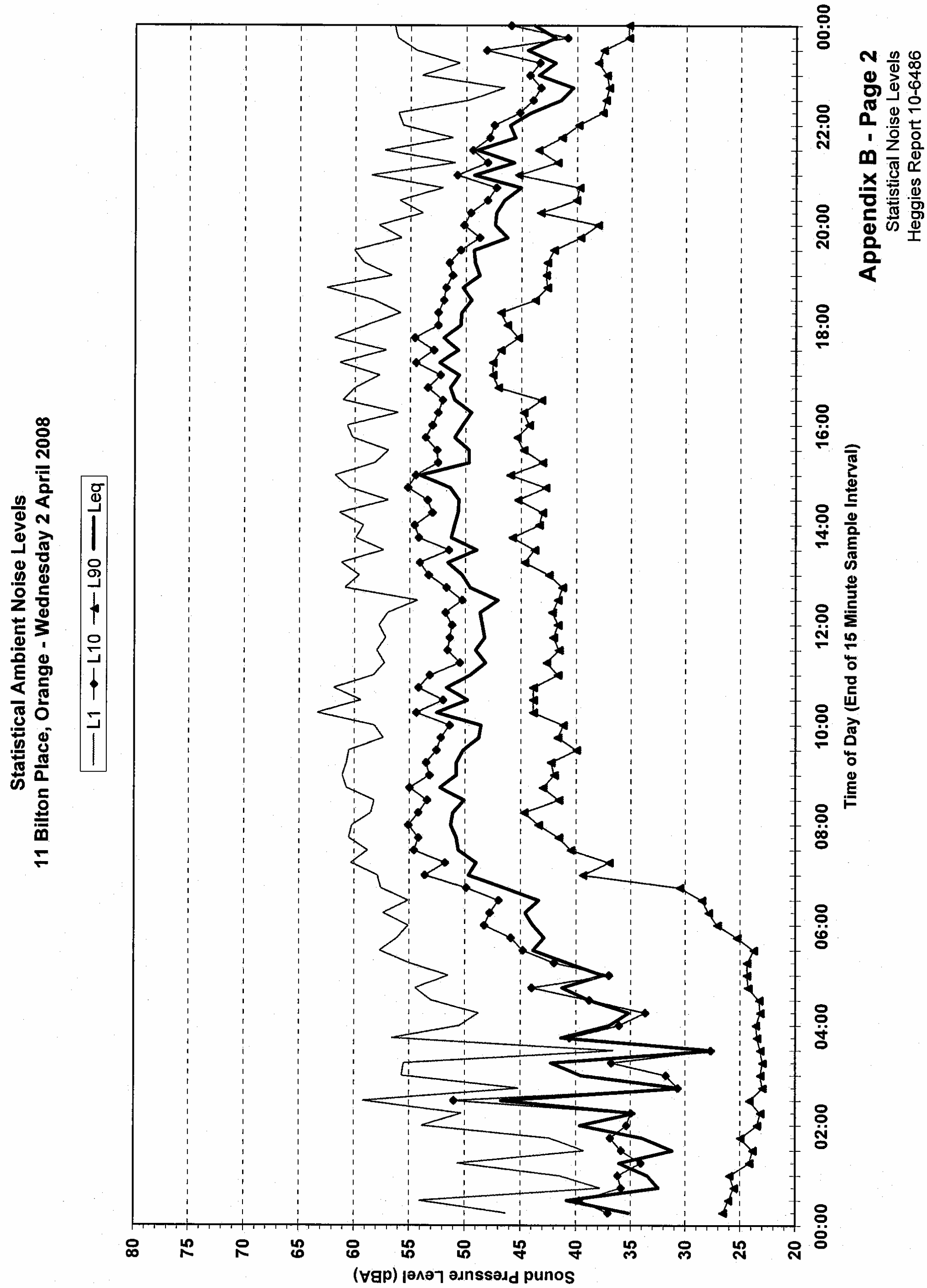

Statistical Ambient Noise Levels
11 Bilton Place, Orange - Tuesday 1 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
Time of Day (End of 15 Minute Sample Interval)
Appendix B - Page 1
Statistical Noise Levels
Heggies Report 10-6486



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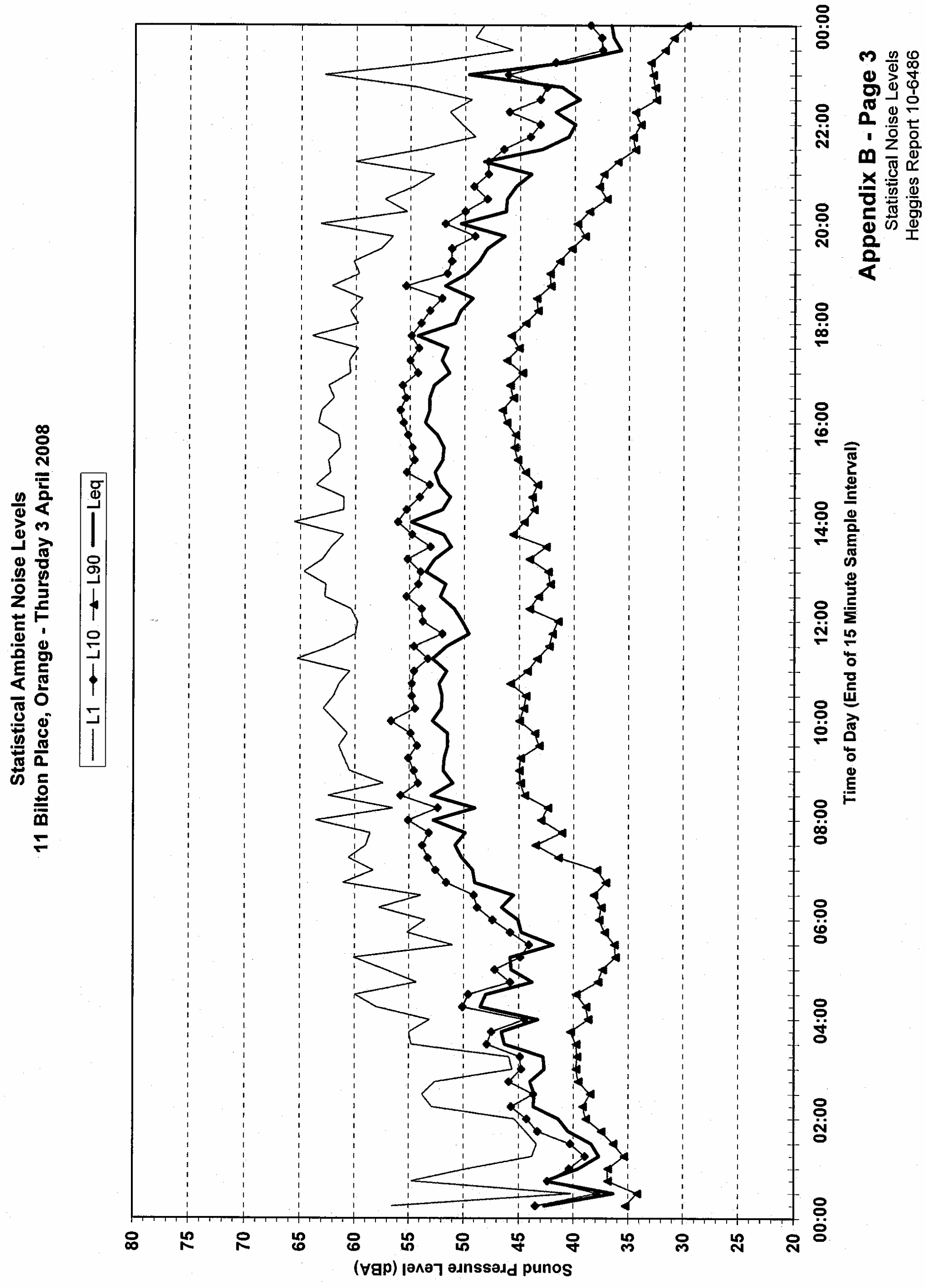
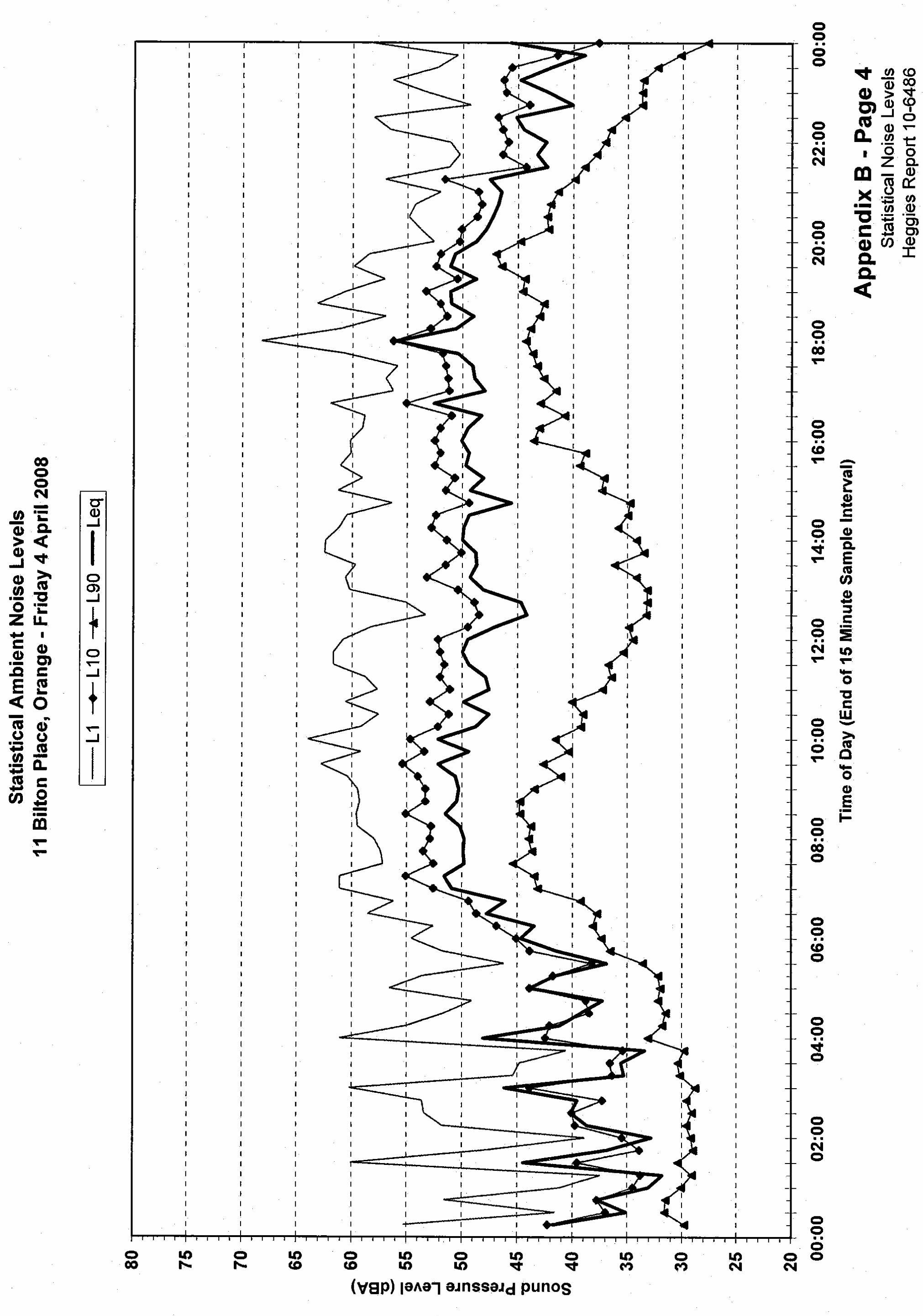
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Thursday 3 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 3
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Friday 4 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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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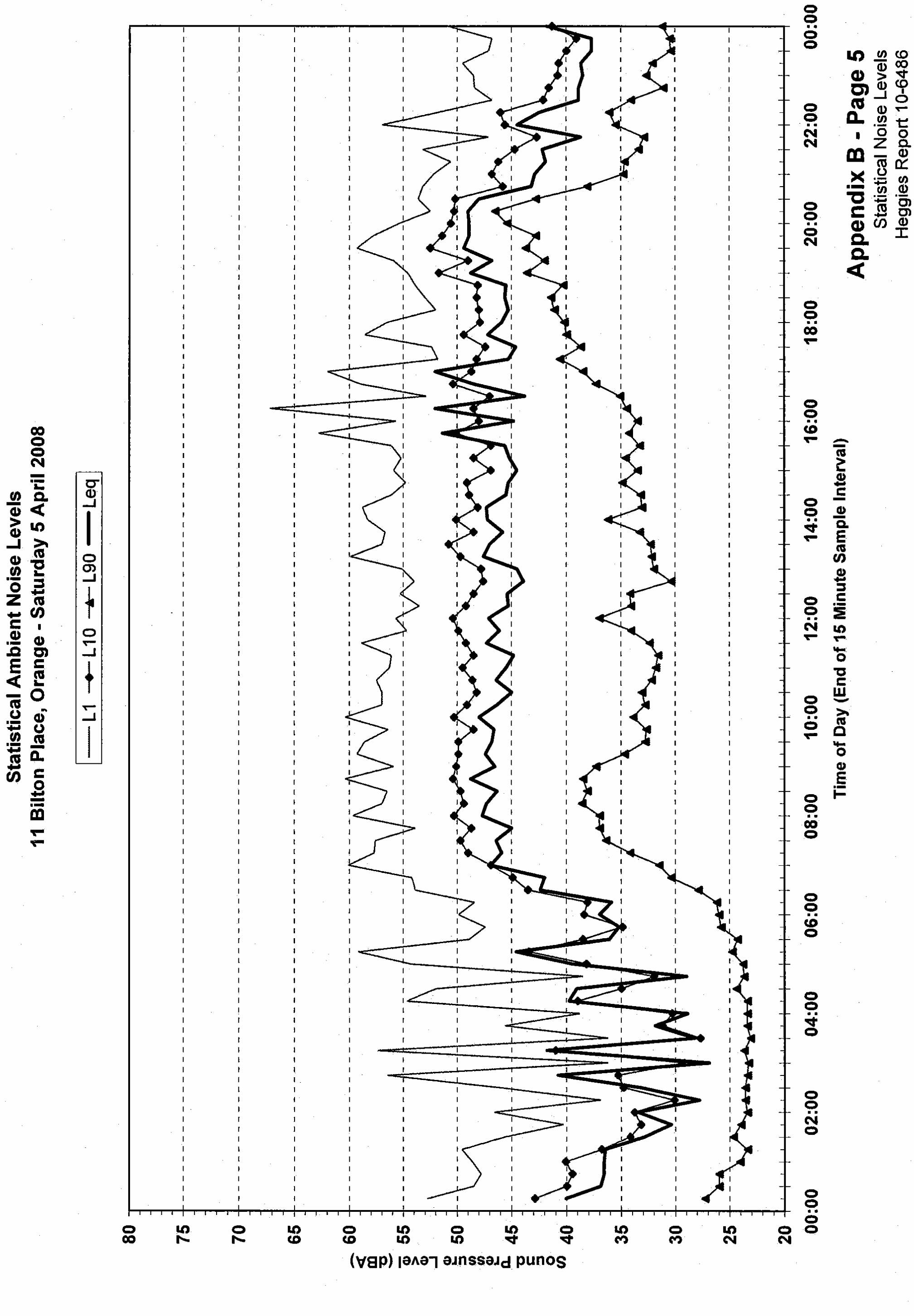
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Saturday 5 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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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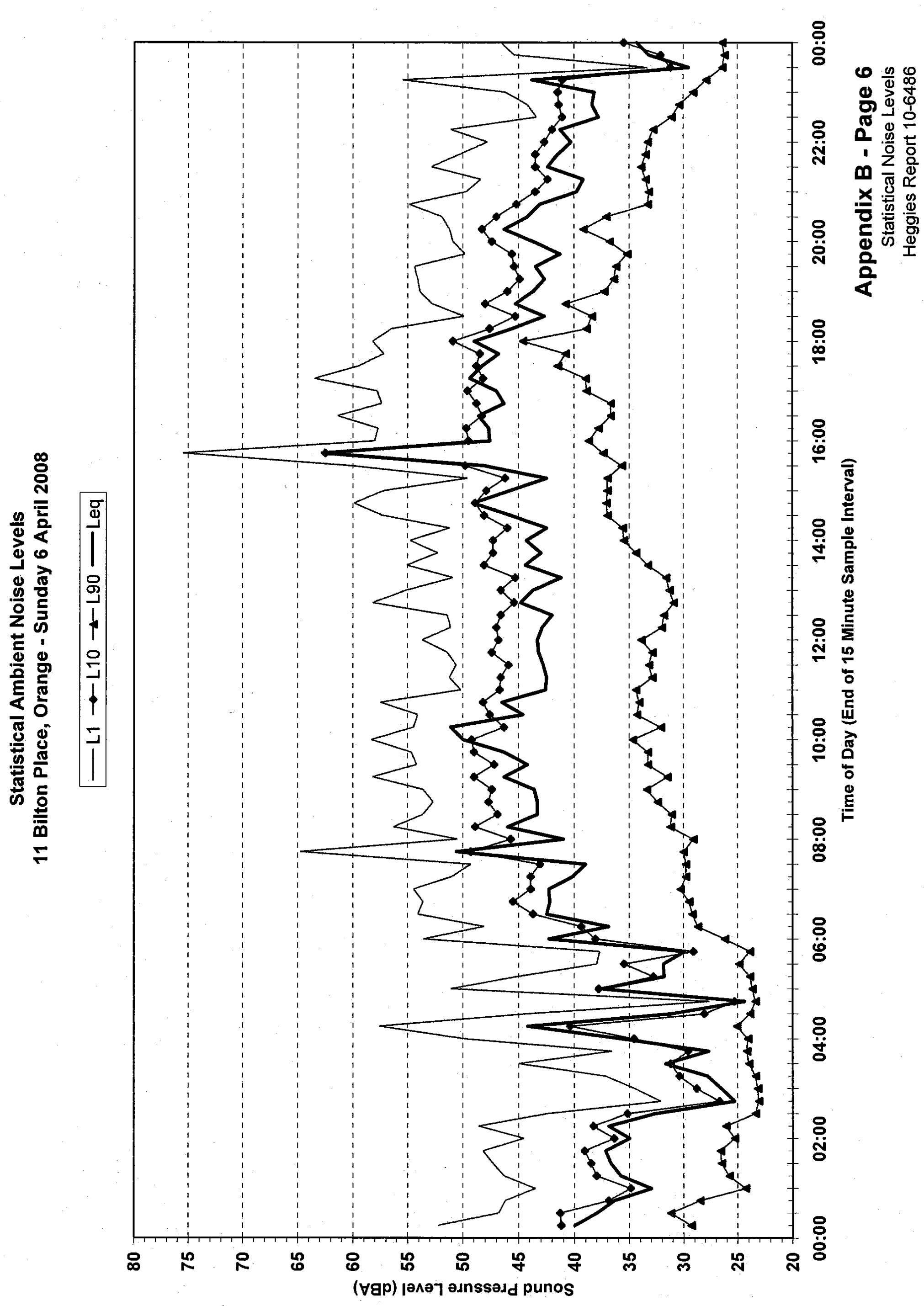
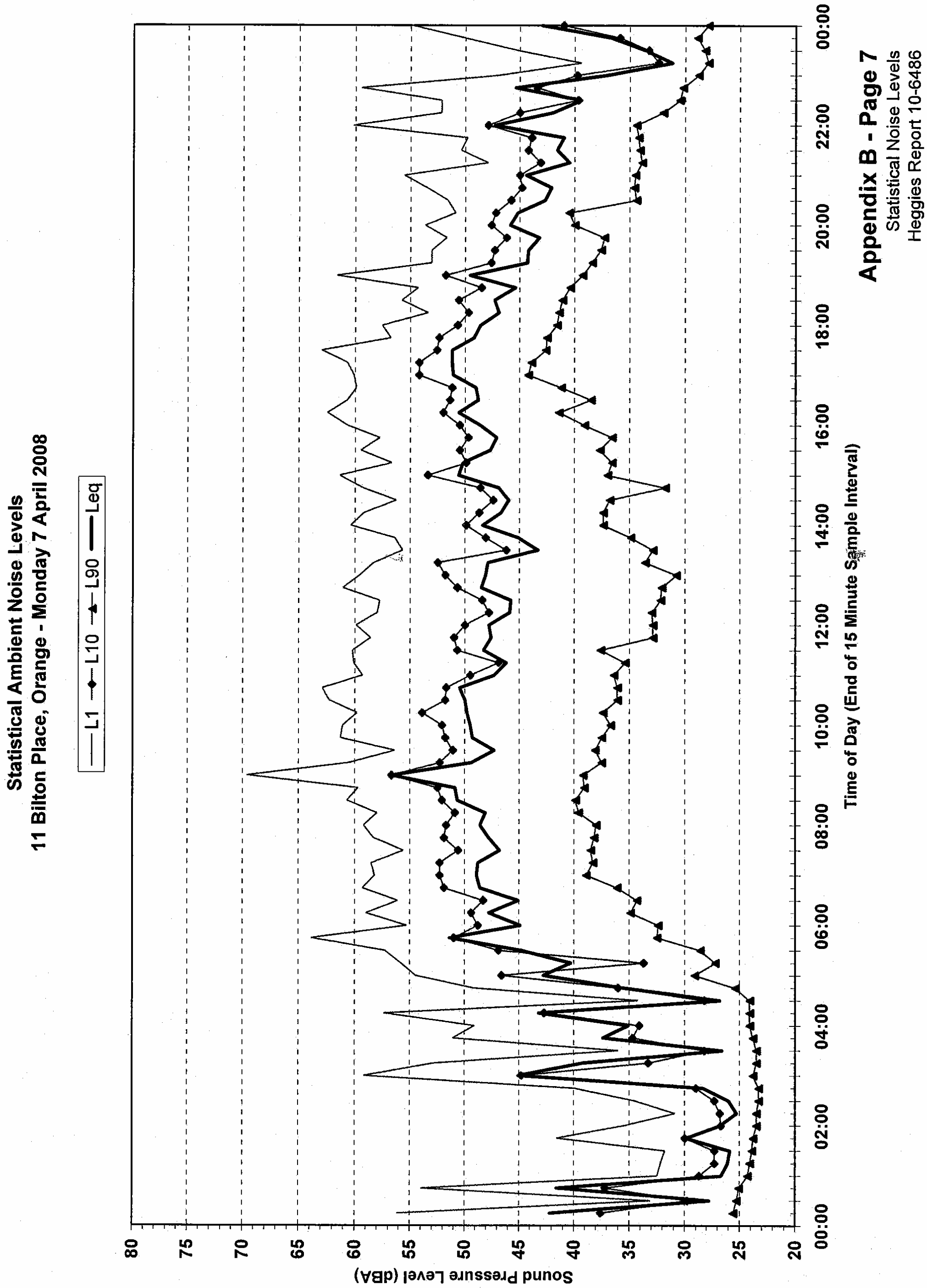
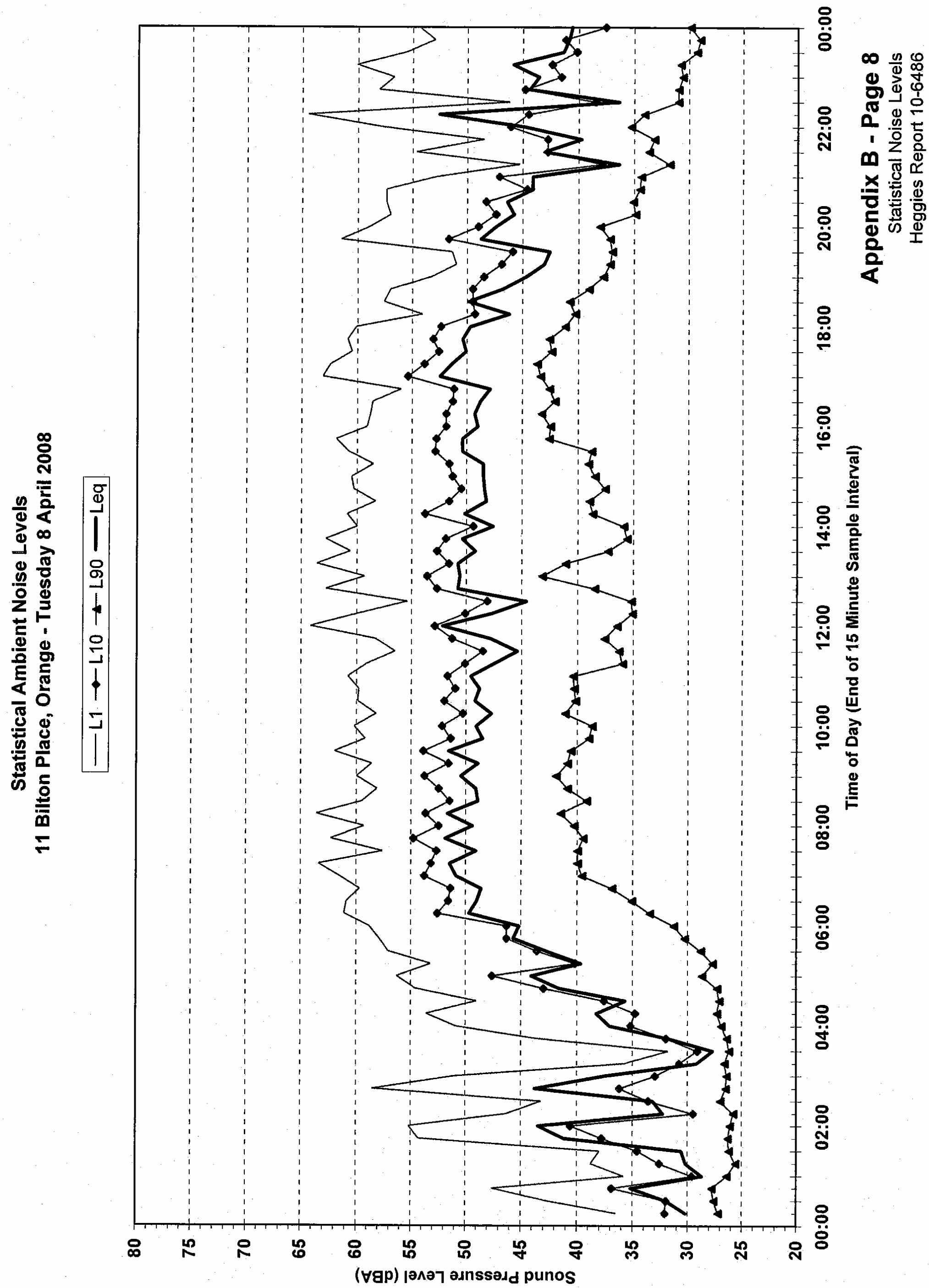
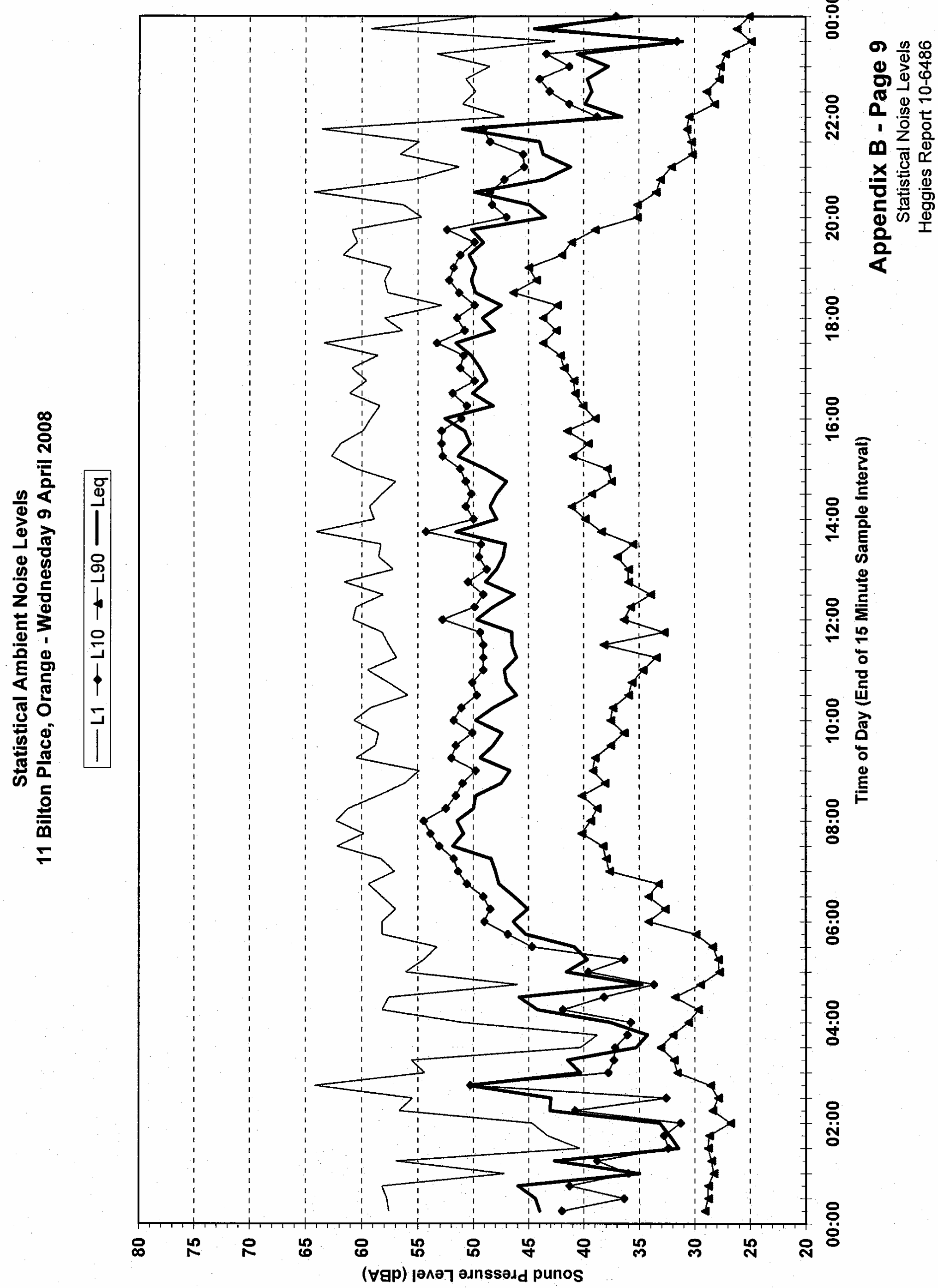
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Sunday 6 April 2008
L1 L10 L90 Leq
Sound Pressure Level (dBA)
80 75 70 65 60 55 50 45 40 35 30 25 20
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)
Appendix B - Page 6
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Monday 7 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 7
Statistical Noise Levels
Heggies Report 10-6486



Statistical Ambient Noise Levels
11 Bilton Place, Orange - Tuesday 8 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 8
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Wednesday 9 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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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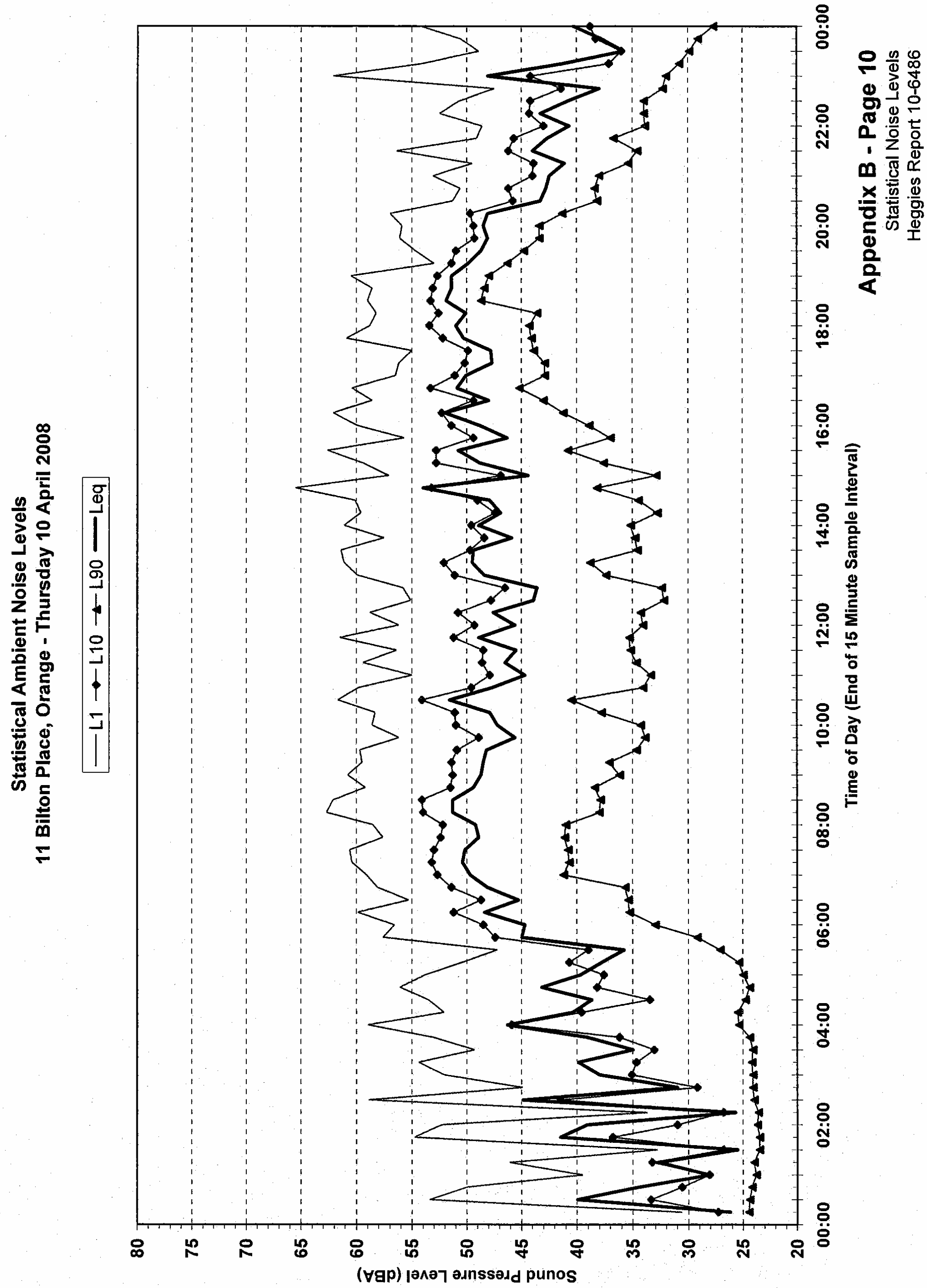
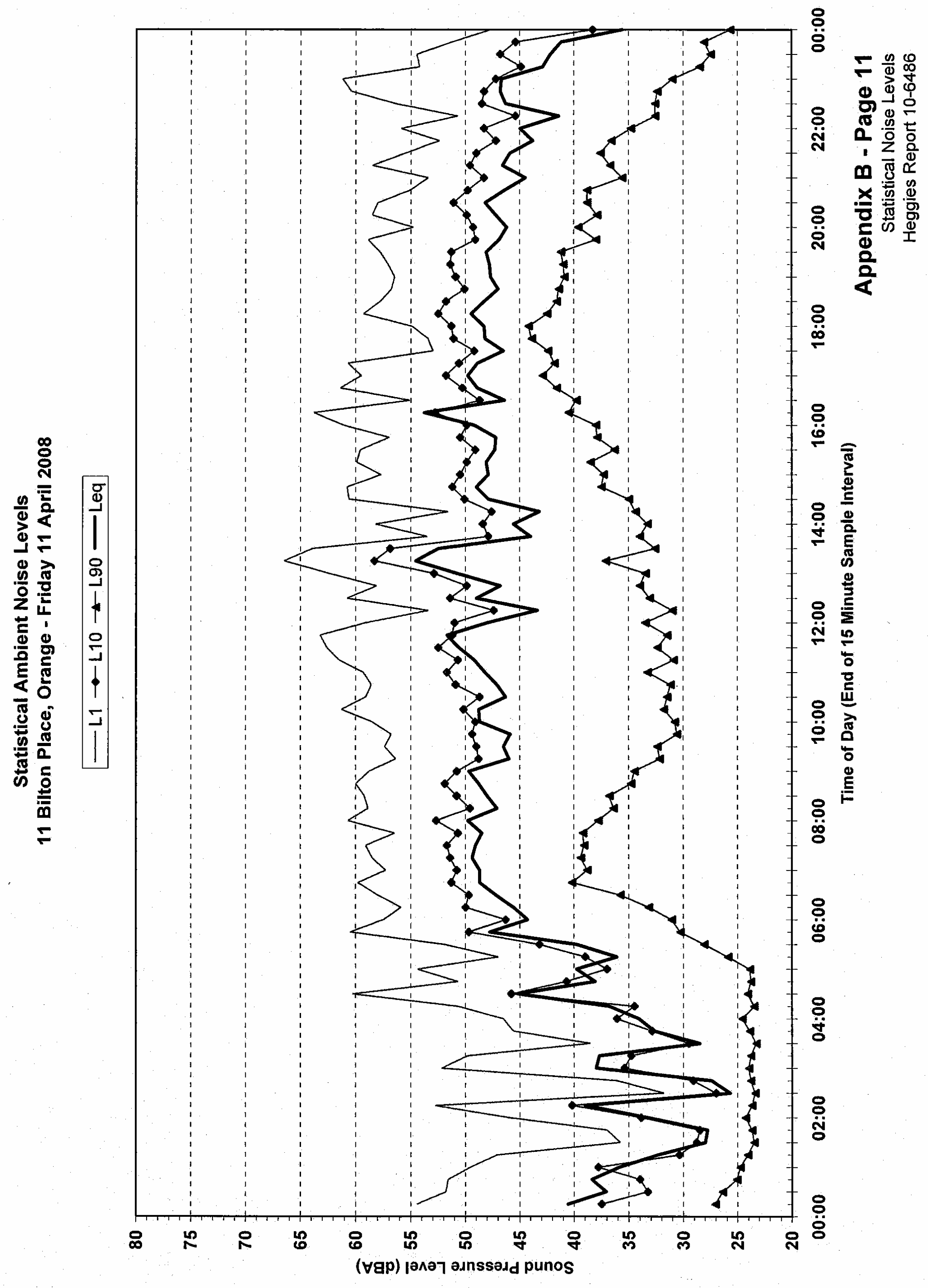
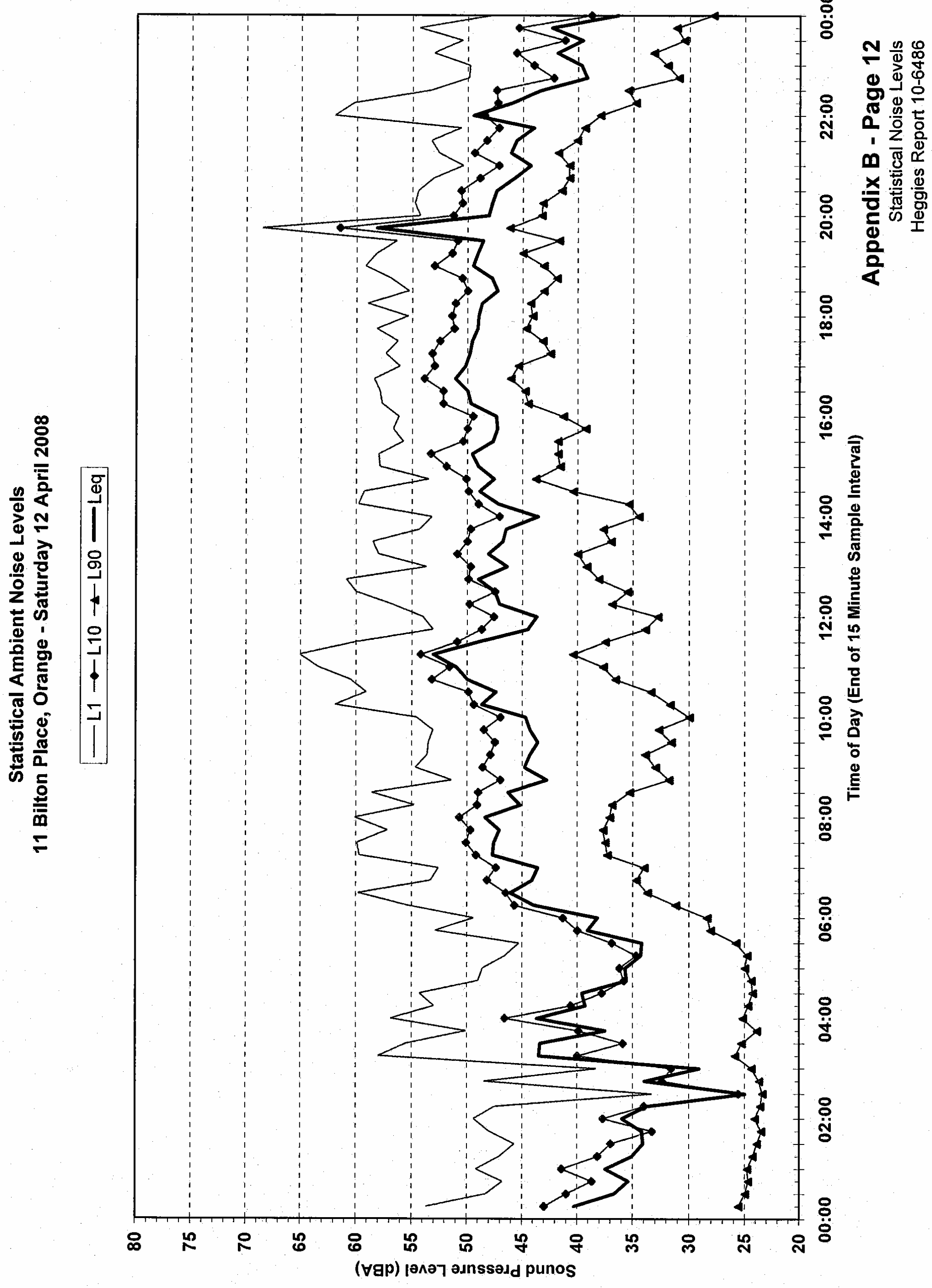
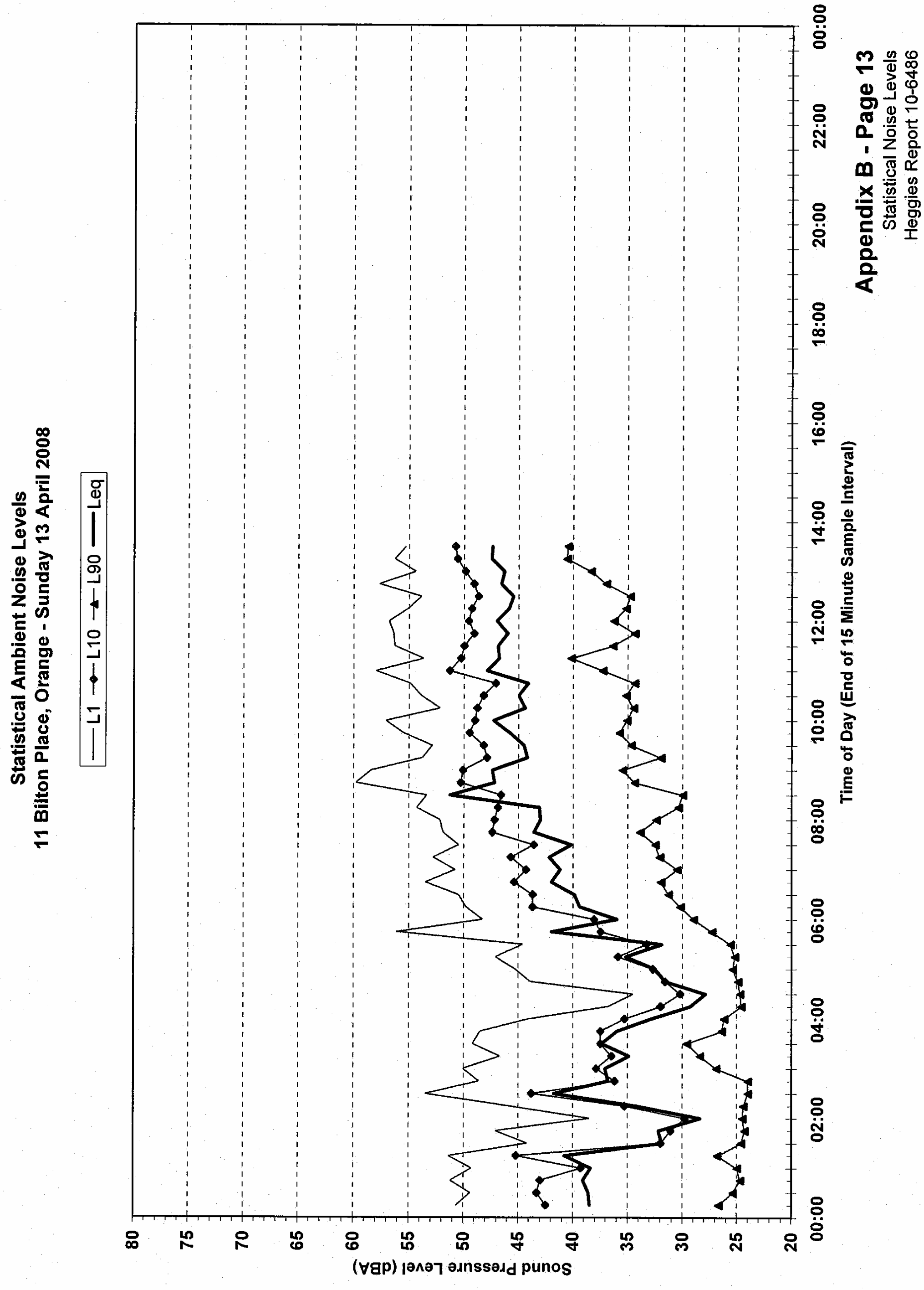
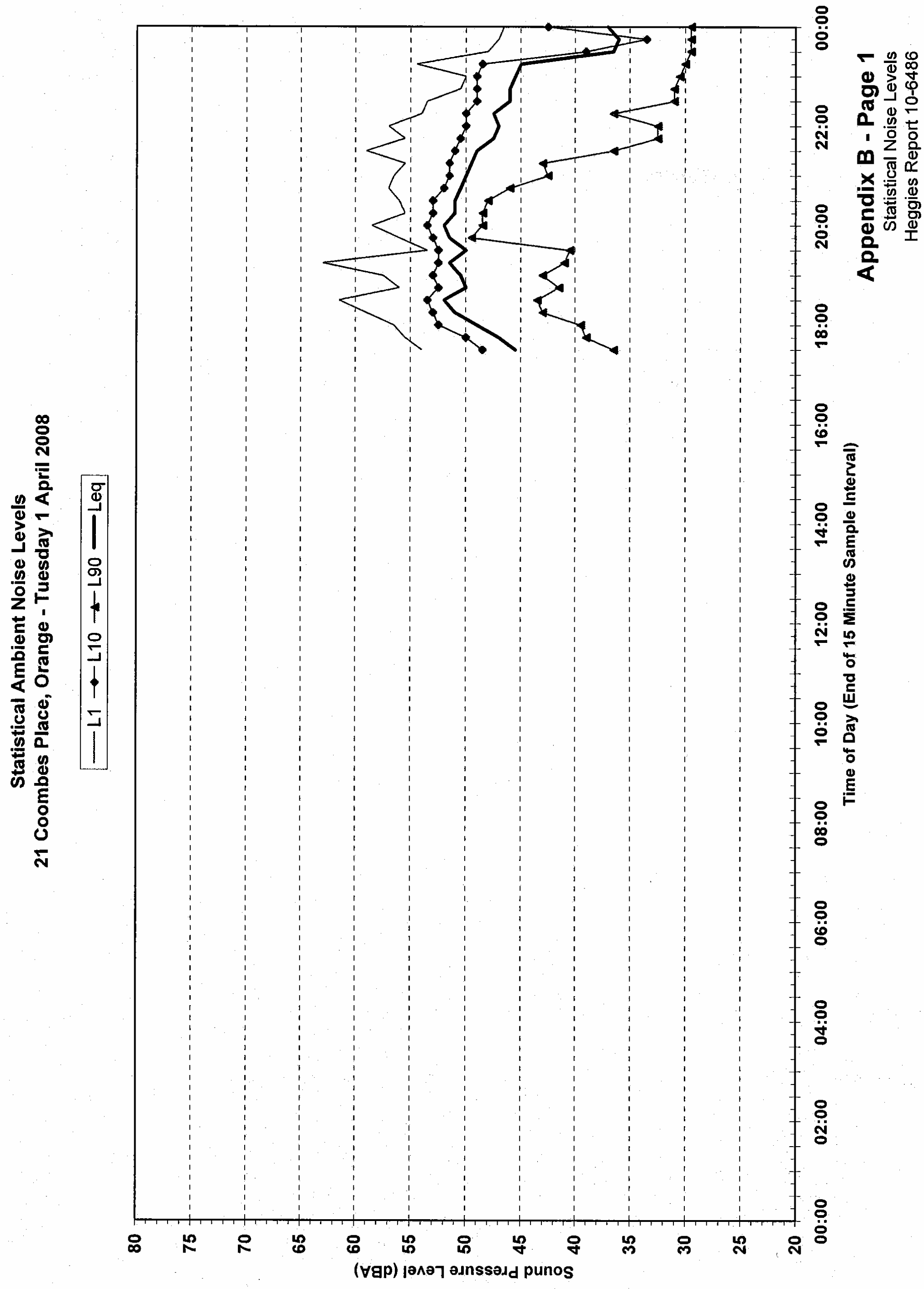
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Thursday 10 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 10
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Friday 11 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 11
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Saturday 12 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 12
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
11 Bilton Place, Orange - Sunday 13 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 13
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
21 Coombes Place, Orange - Tuesday 1 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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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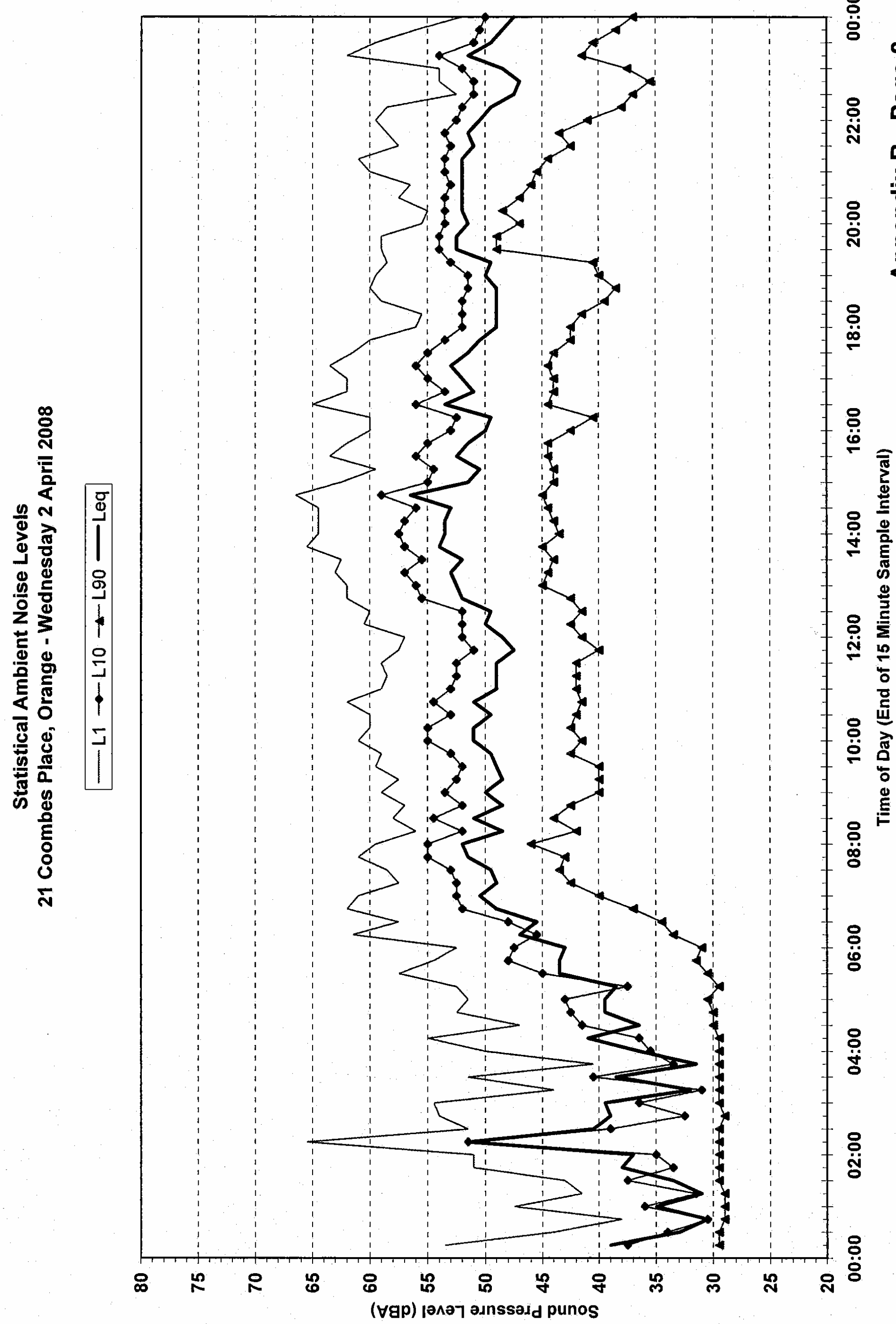
Statistical Noise Levels
Heggies Report 10-6486



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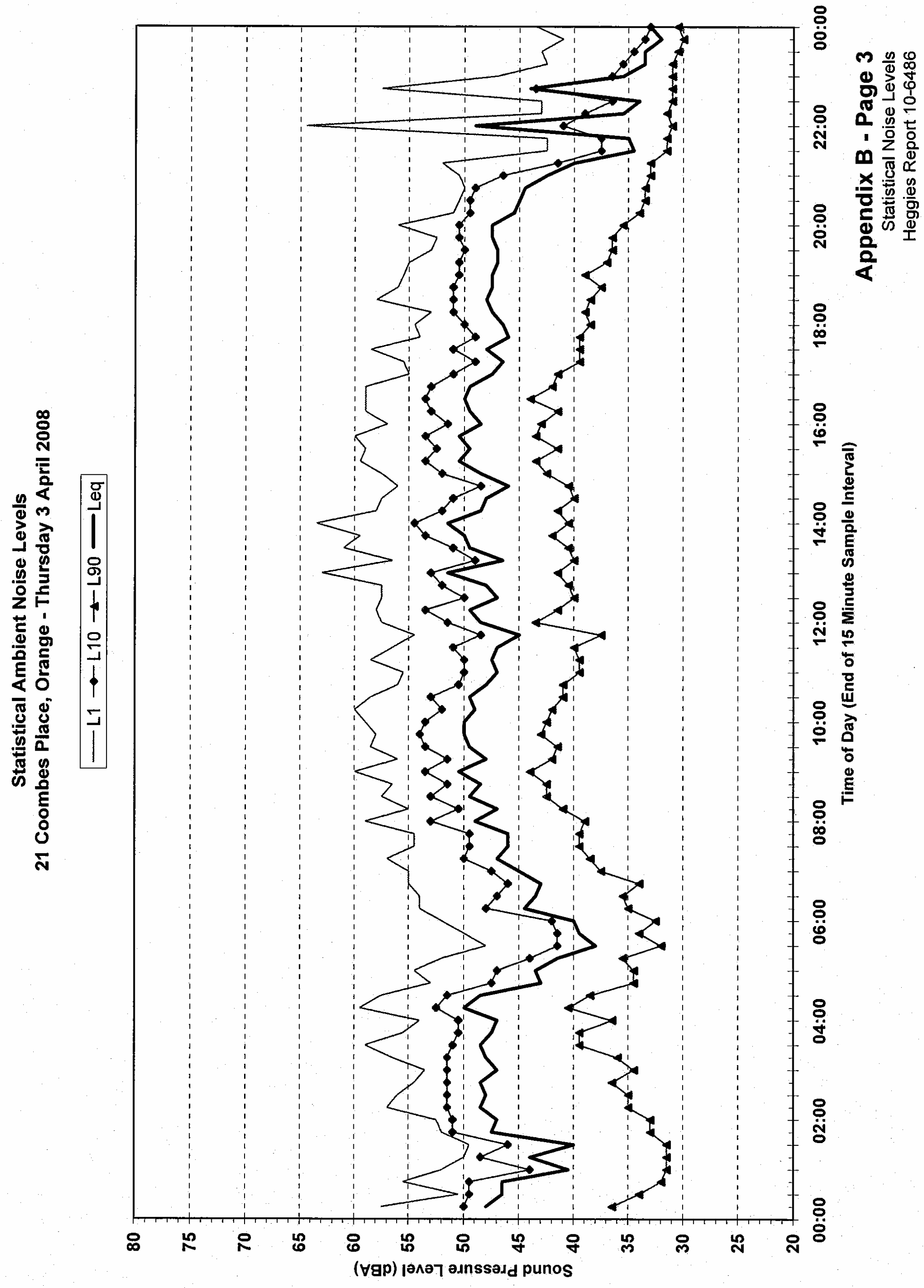
Statistical Noise Levels
Heggies Report 10-6486



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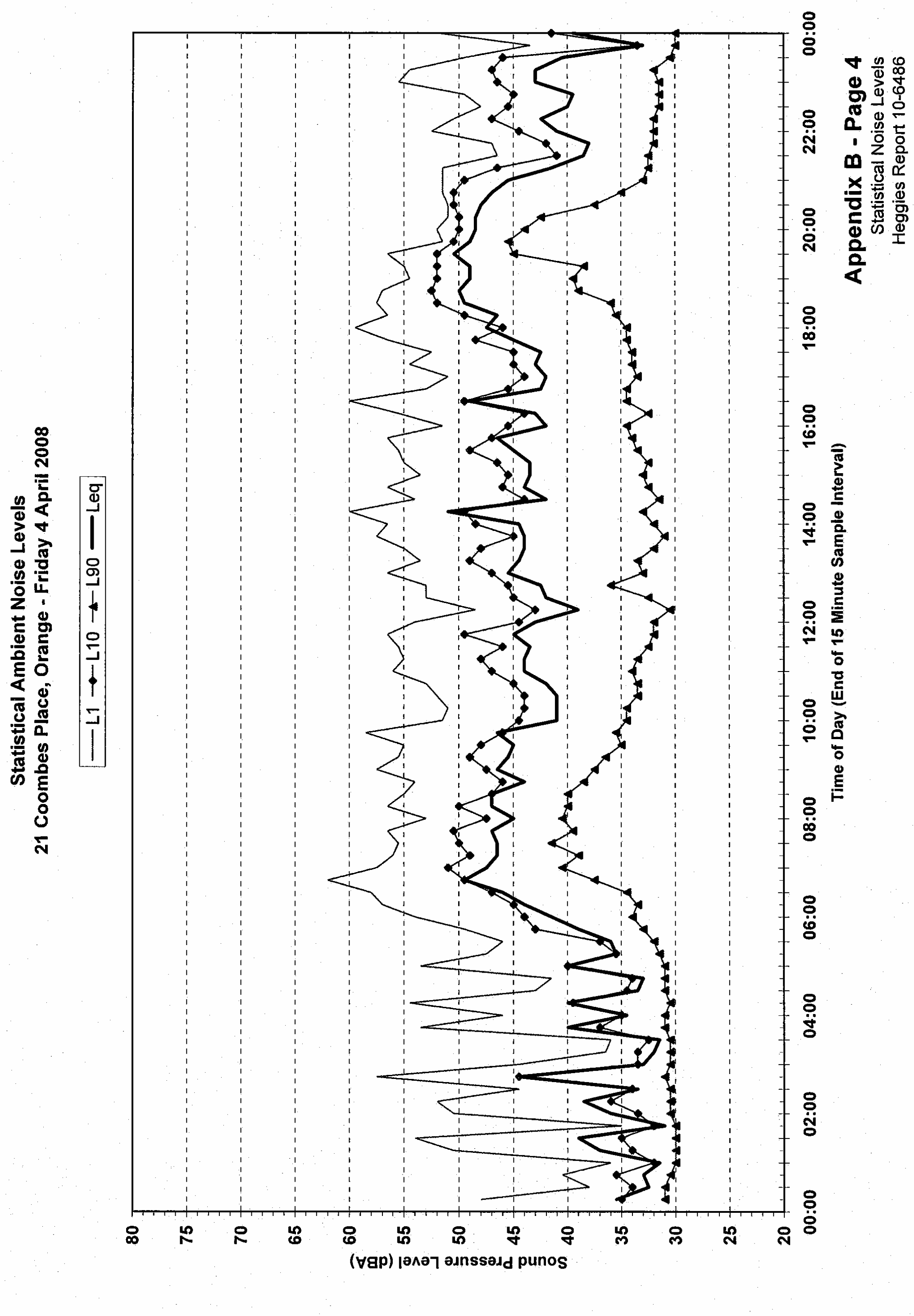
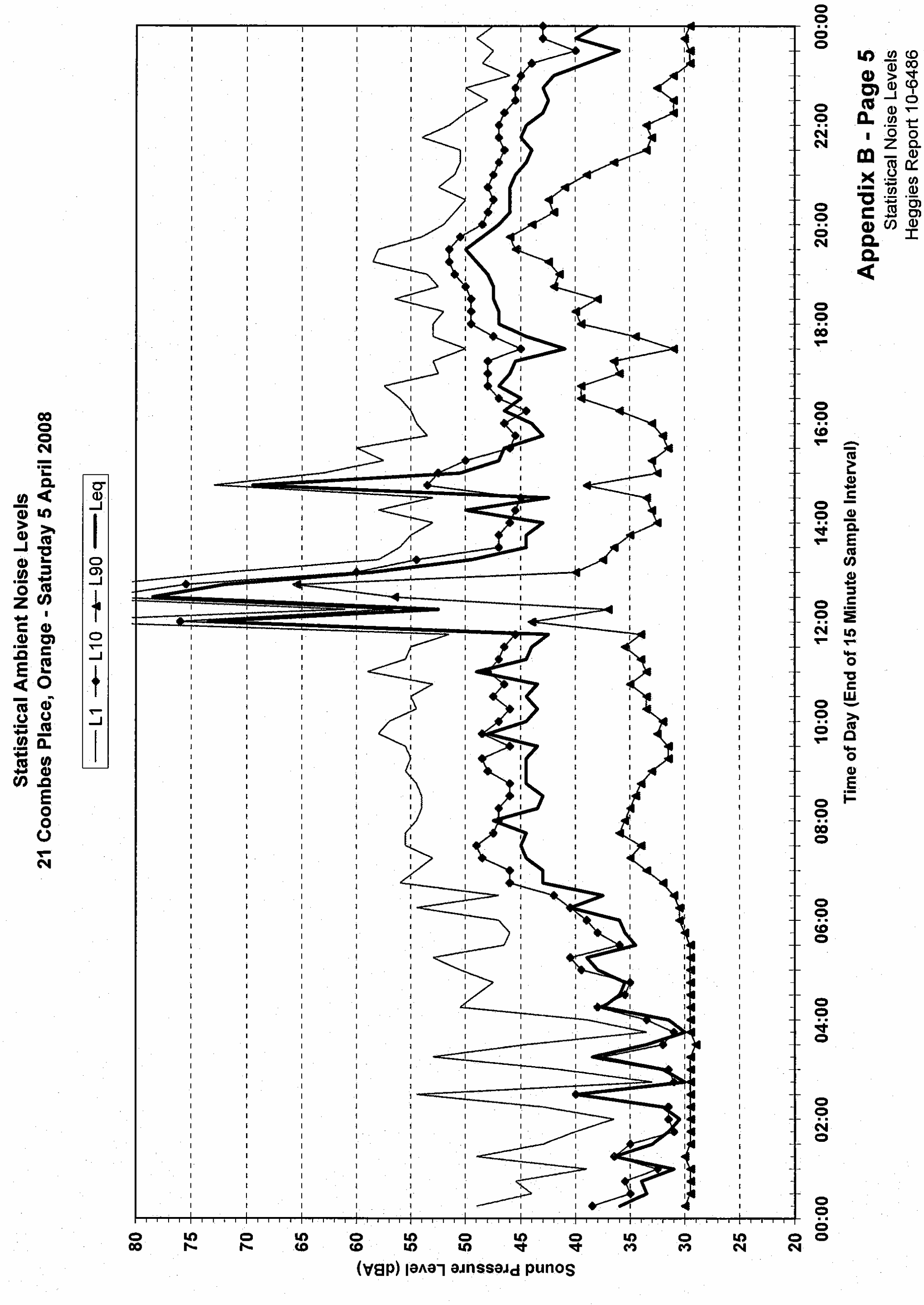
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
21 Coombes Place, Orange - Friday 4 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
Time of Day (End of 15 Minute Sample Interval)
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
Appendix B - Page 4
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
21 Coombes Place, Orange - Saturday 5 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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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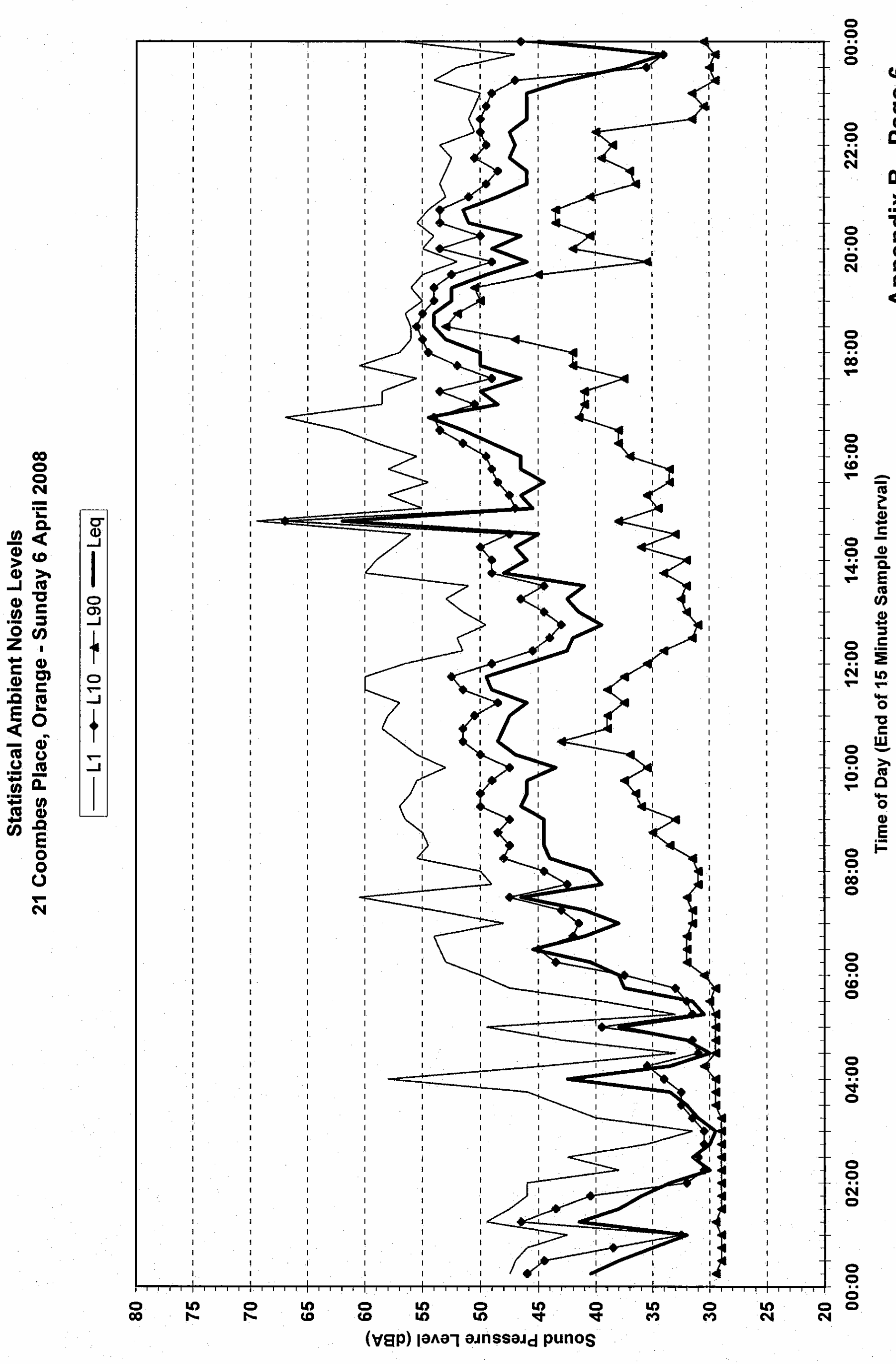
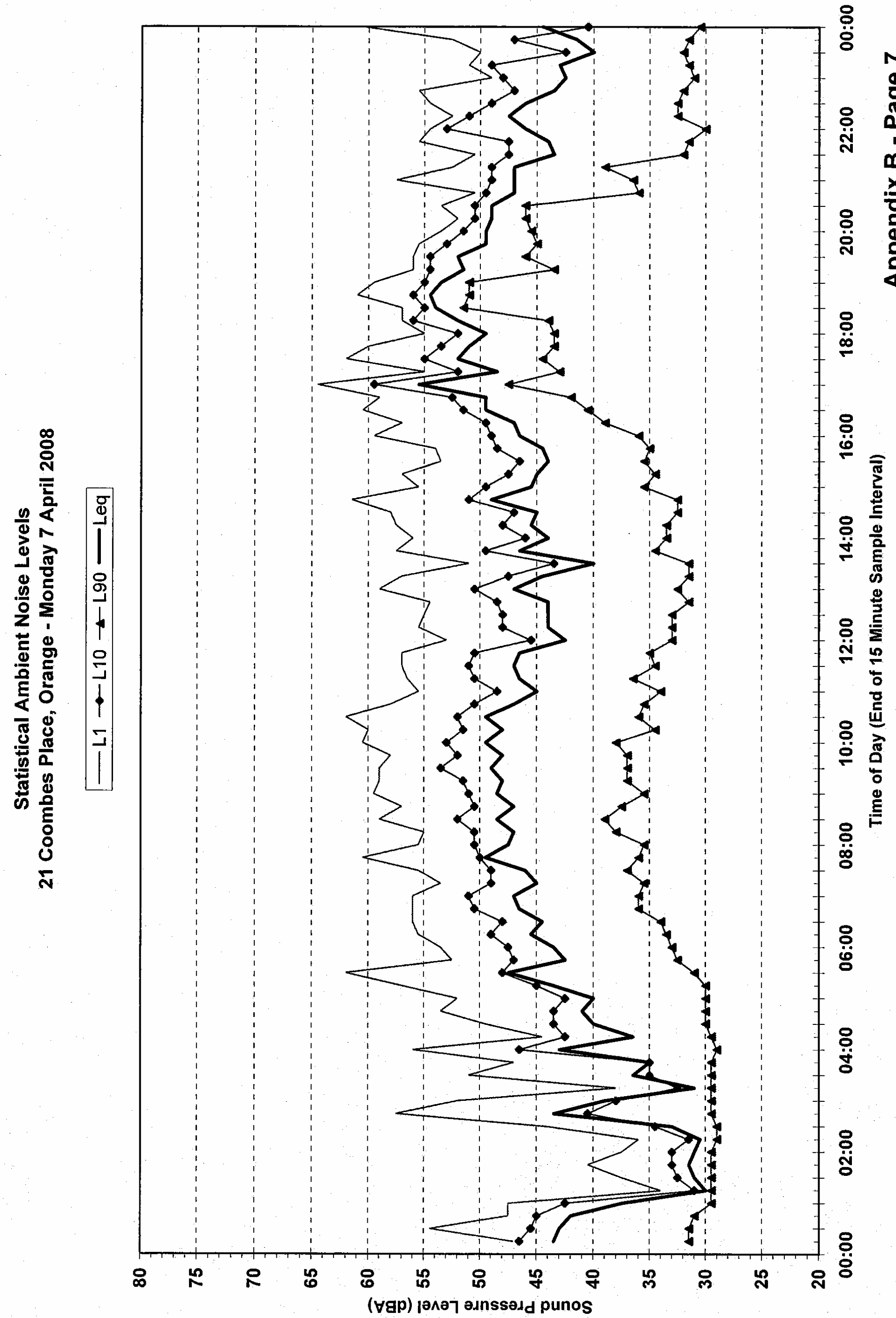
Statistical Noise Levels
Heggies Report 10-6486



Appendix B - Page 6
Statistical Noise Levels
Heggies Report 10-6486



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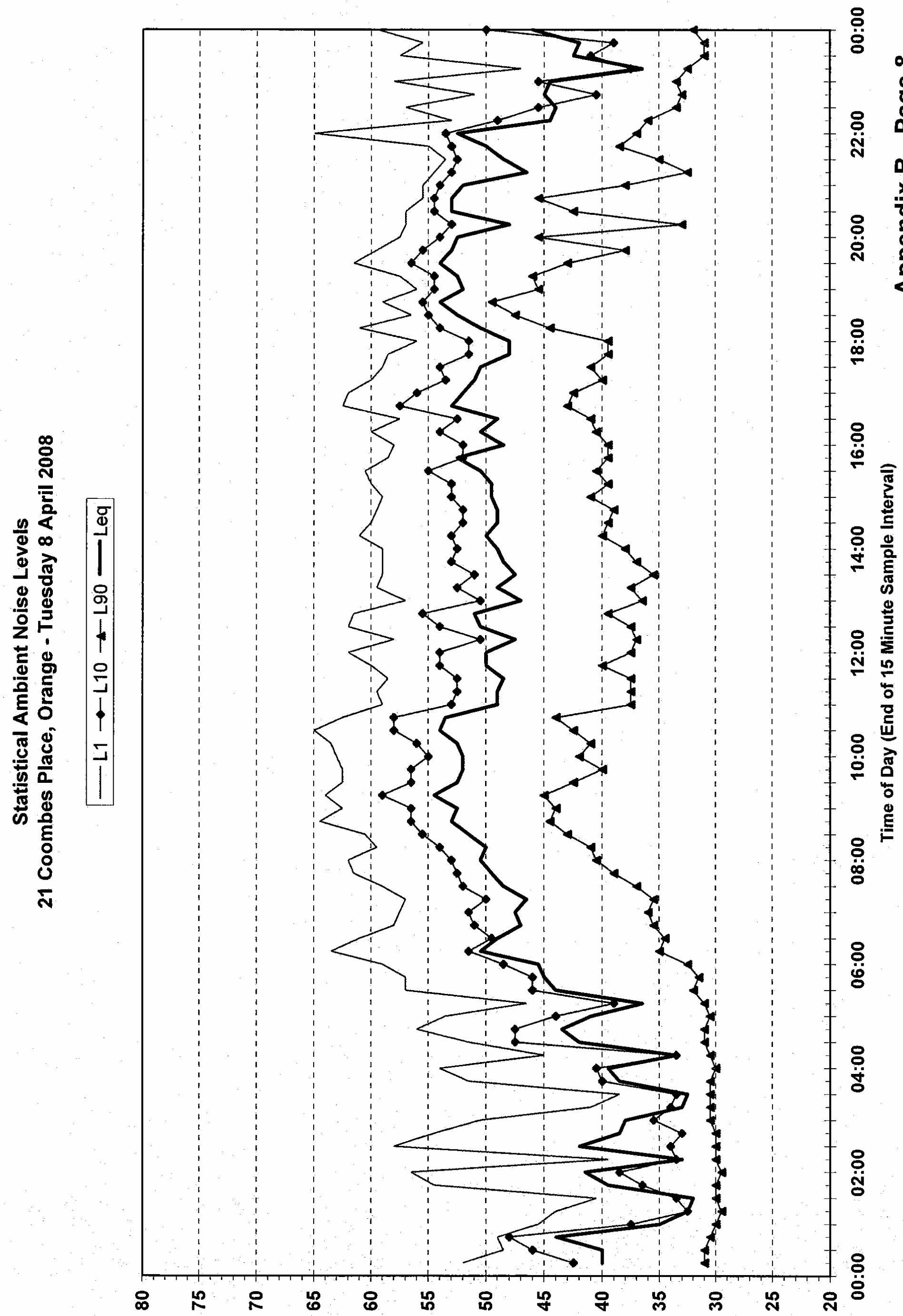
Statistical Noise Levels
Heggies Report 10-6486



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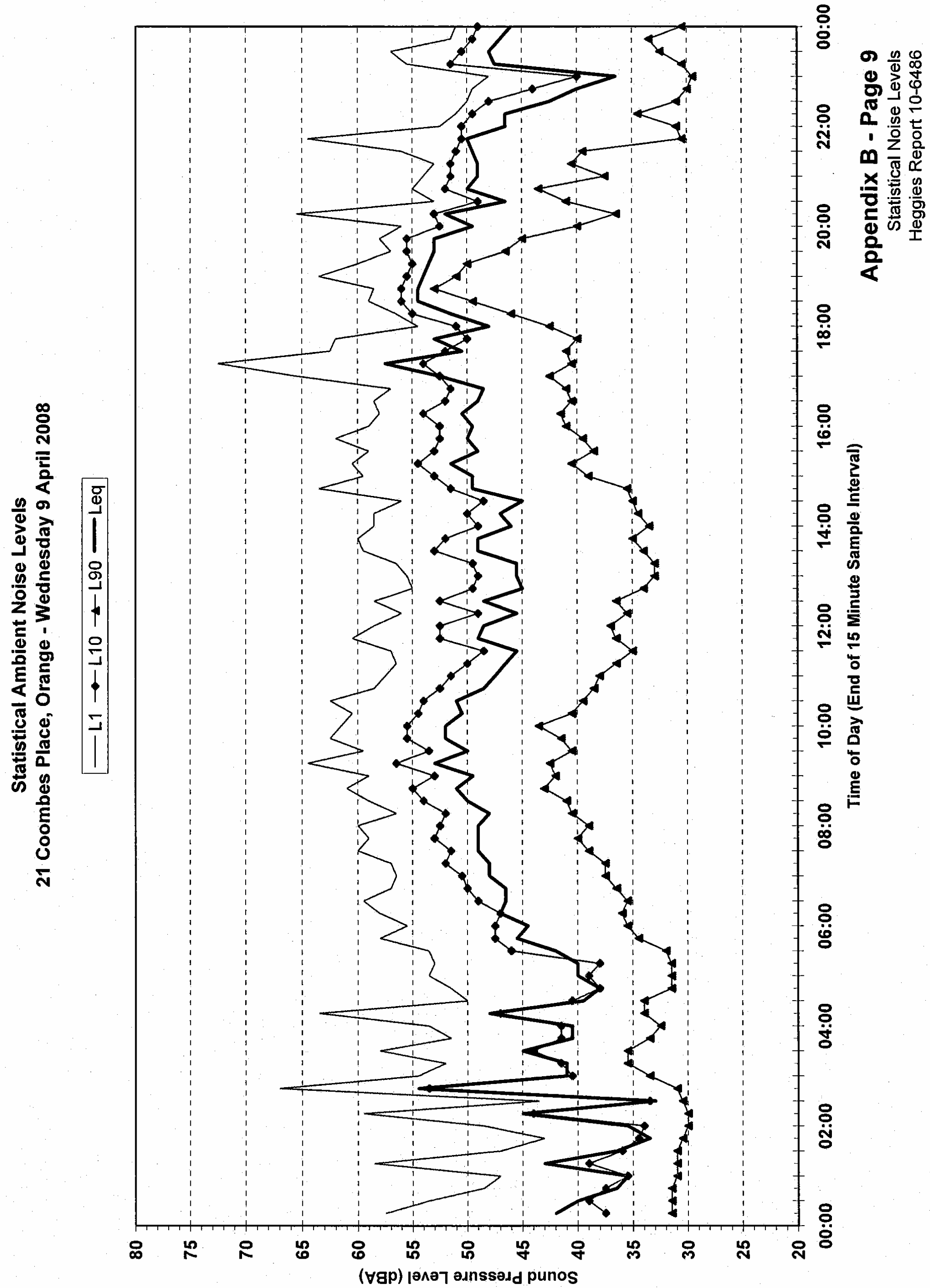
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
21 Coombes Place, Orange - Wednesday 9 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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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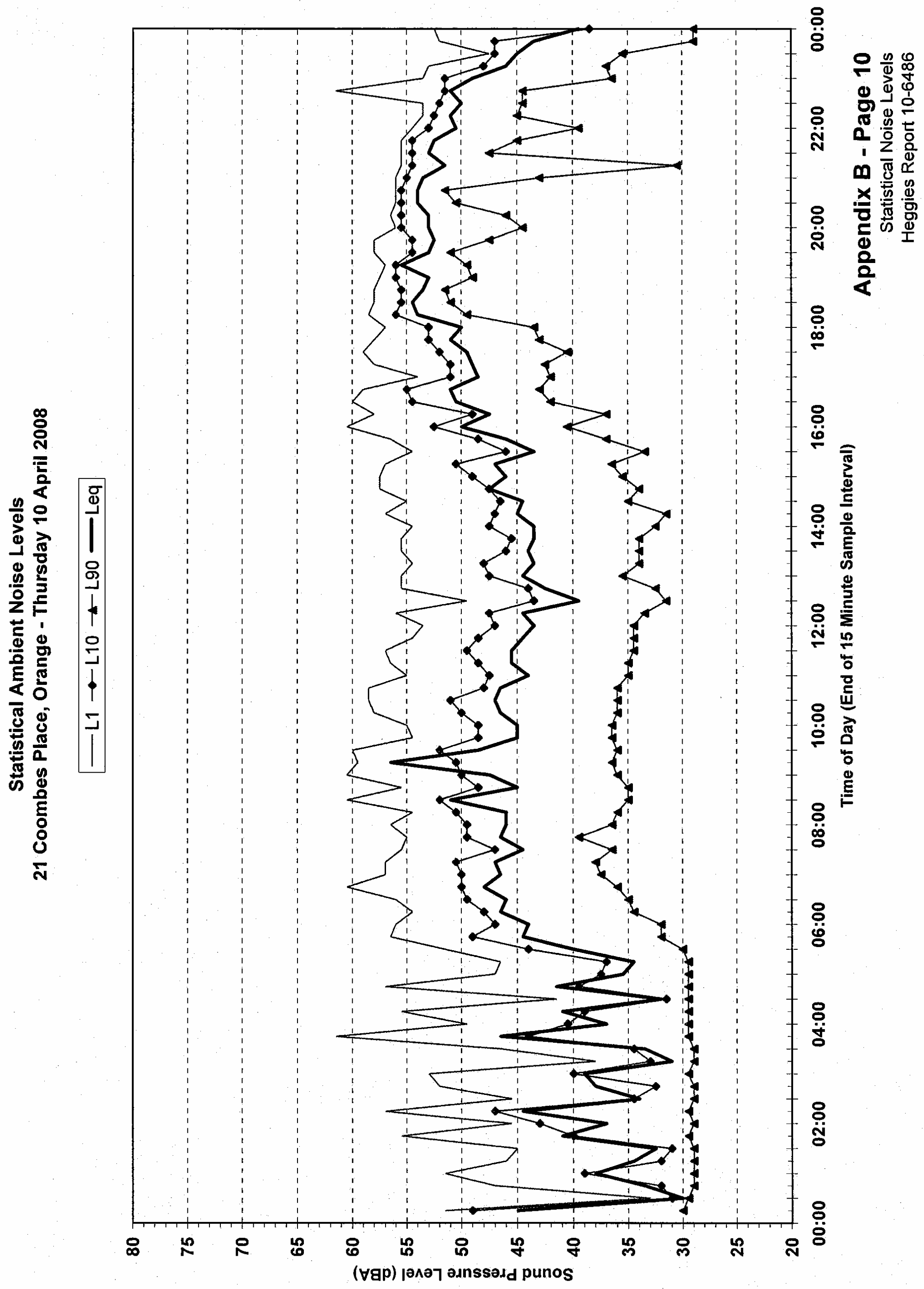
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
21 Coombes Place, Orange - Thursday 10 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
Time of Day (End of 15 Minute Sample Interval)
00:00
02:00
04:00
06:00
08:00
10:00
12:00
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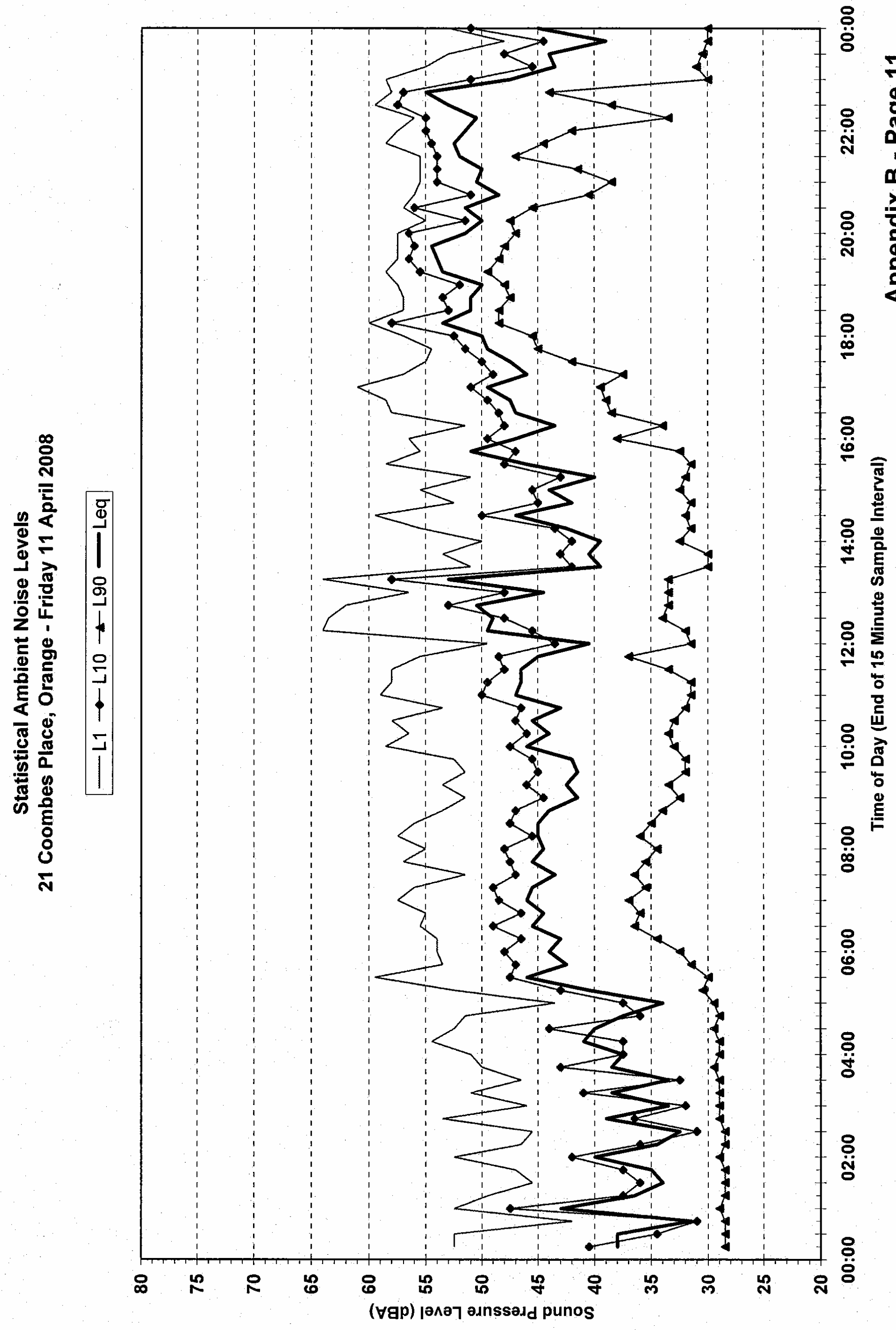
16:00
18:00
20:00
22:00
00:00
Appendix B - Page 10
Statistical Noise Levels
Heggies Report 10-6486



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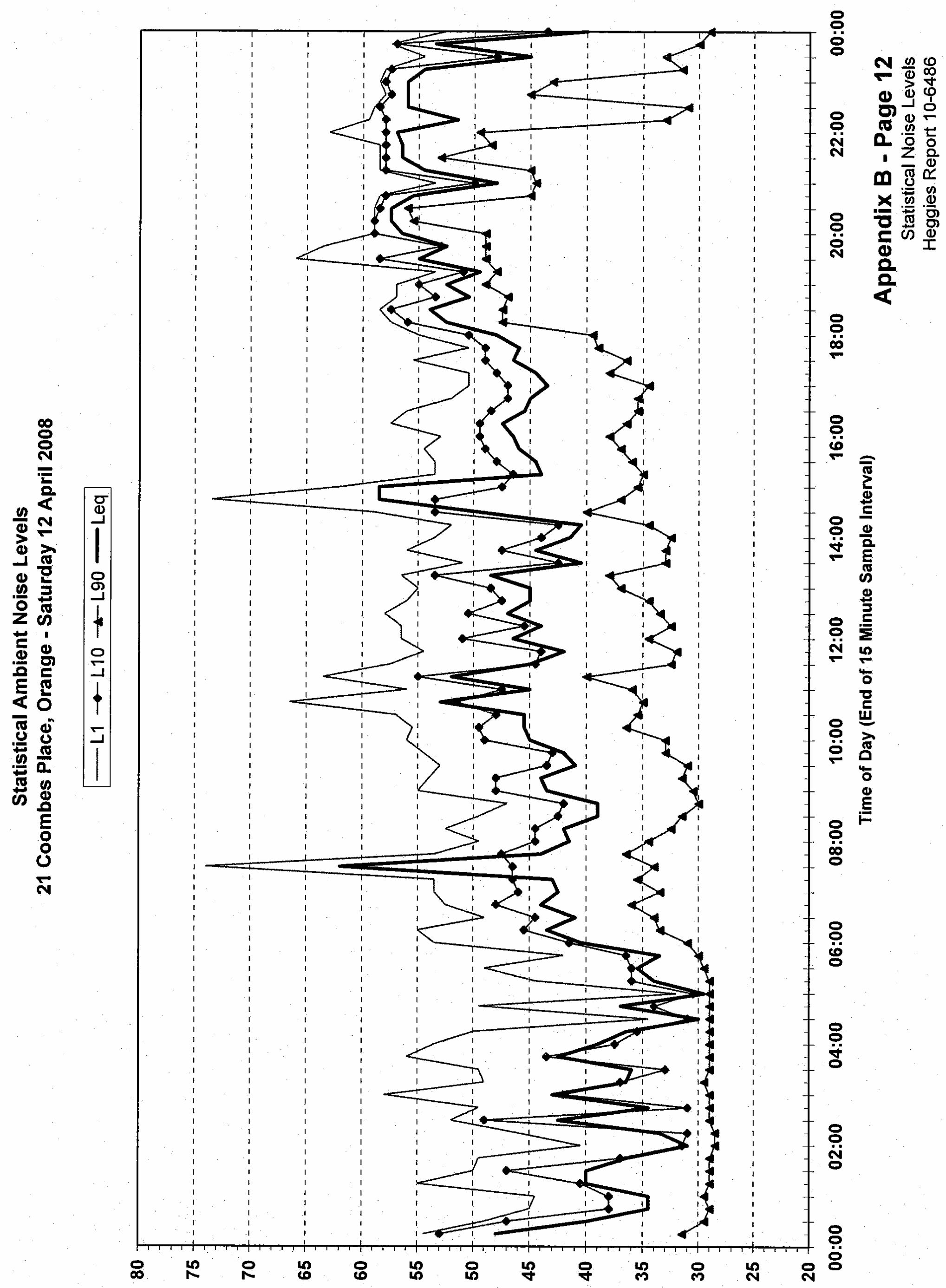
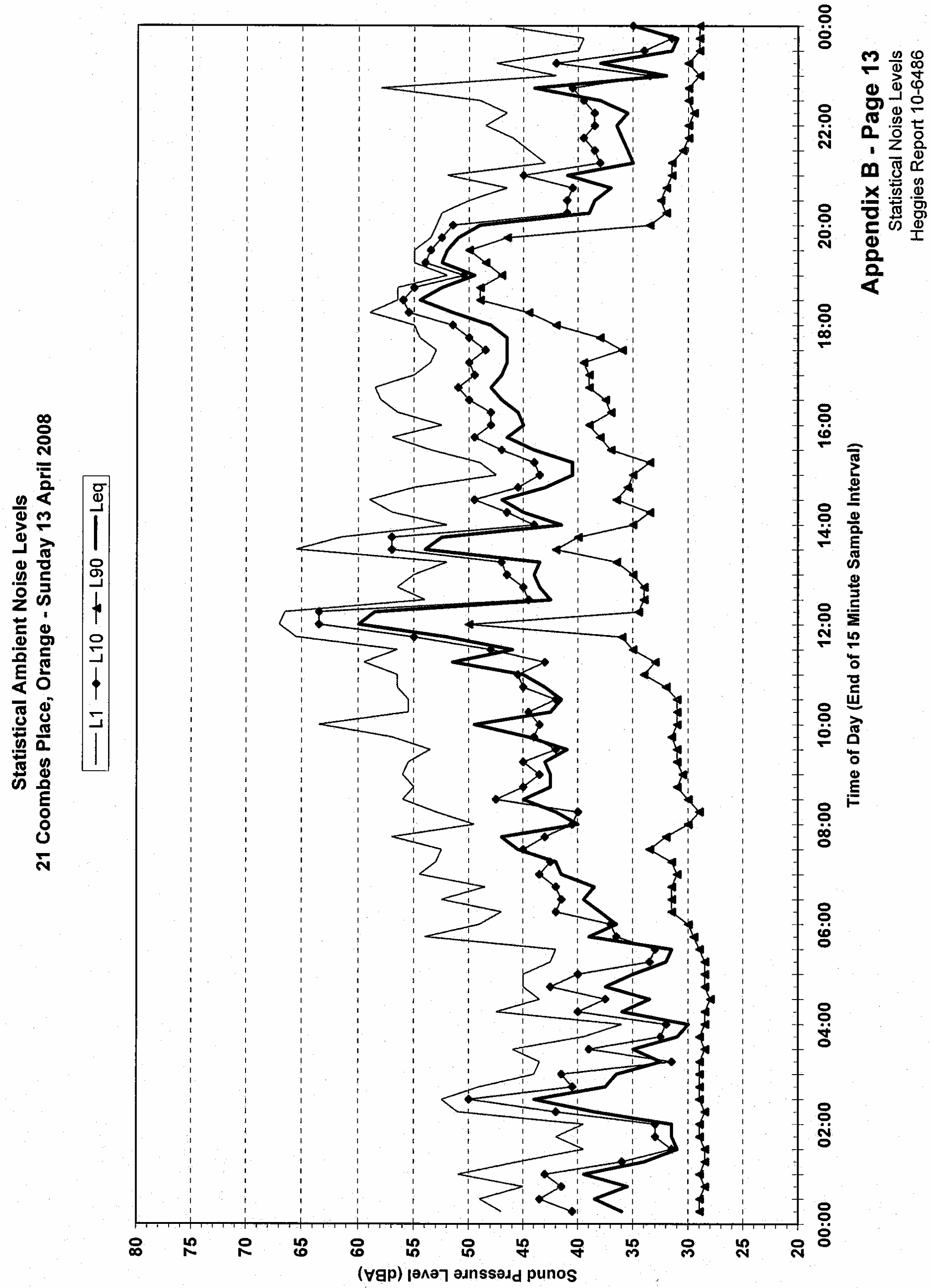
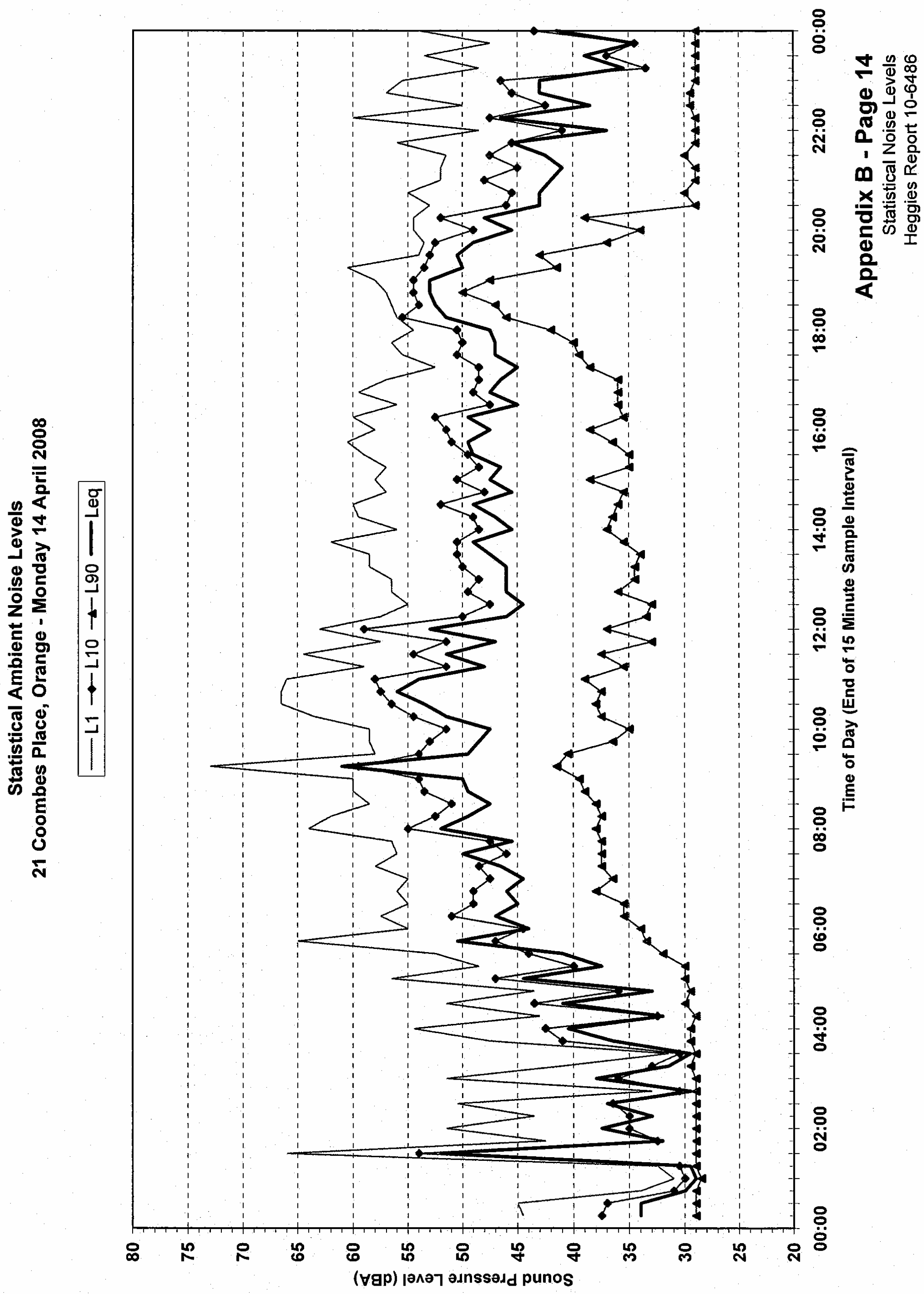
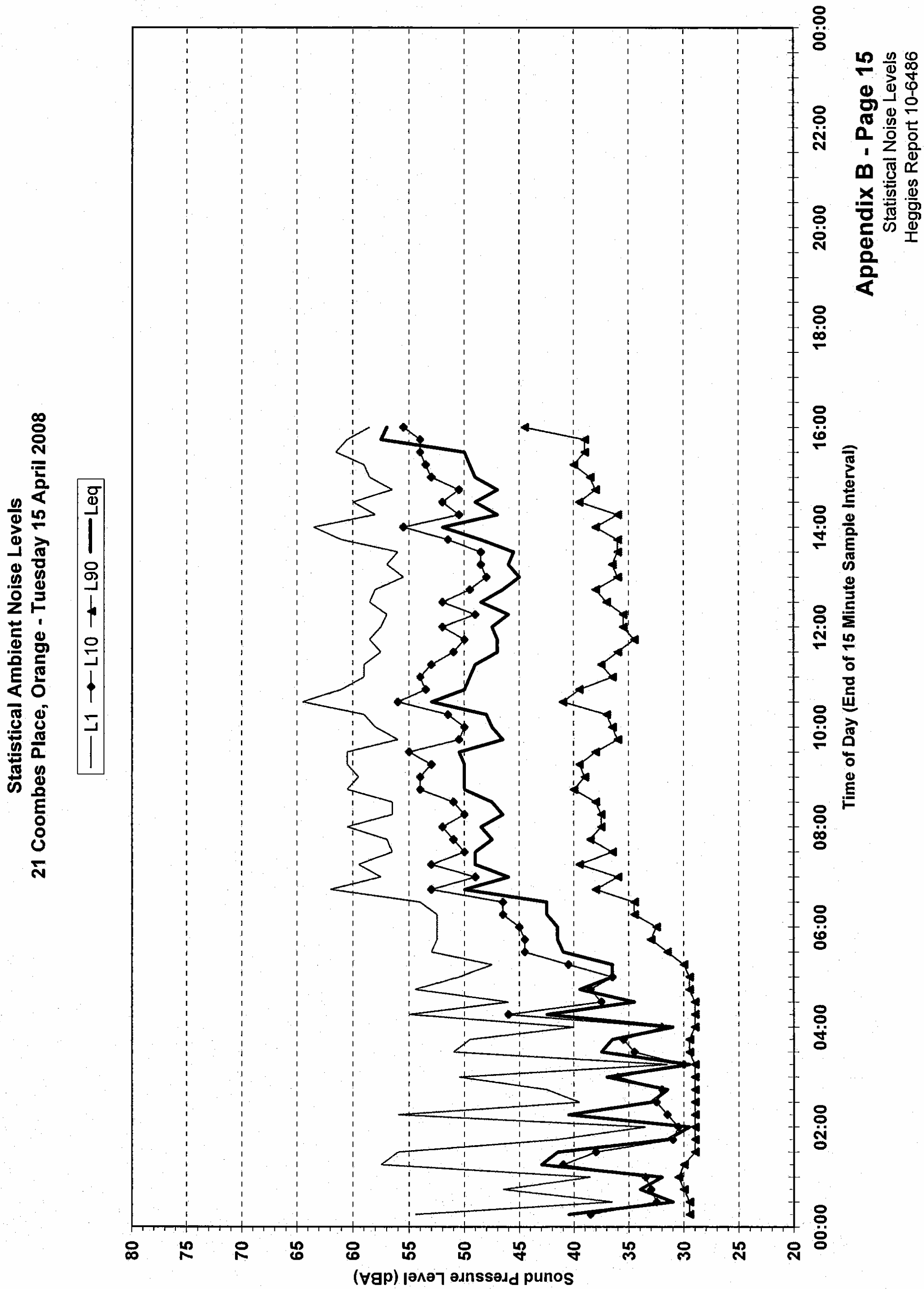
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
21 Coombes Place, Orange - Saturday 12 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 12
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
21 Coombes Place, Orange - Sunday 13 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 13
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
21 Coombes Place, Orange - Monday 14 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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)
Appendix B - Page 14
Statistical Noise Levels
Heggies Report 10-6486


Statistical Ambient Noise Levels
21 Coombes Place, Orange - Tuesday 15 April 2008
L1
L10
L90
Leq
Sound Pressure Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
25
20
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 10-6486