HEGGIES
AUSTRALIA

REPORT 40-1143-R2

Revision 4

Conroys Gap Wind Farm
Noise Impact Assessment

PREPARED FOR

Taurus Energy
Suite 104, Pacific Highway
North Sydney, NSW 2060

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Conroys Gap Wind Farm

Noise Impact Assessment

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DOCUMENT CONTROL

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EXECUTIVE SUMMARY

Heggies Australia has completed a noise impact assessment of the proposed Conroys Gap Wind Farm.

Three alternative layouts, comprised of differing turbine types, have been assessed in accordance with the South Australian EPA *Noise Guidelines for Wind Farms (February 2003),* World Health Organisation limits and construction noise guidelines.

Noise monitoring was conducted in December 2005 and January 2006 for a two week period at six residences. A further monitoring campaign was conducted in May 2006 and the combined collected data was used to determine baseline conditions and establish indicative criteria for surrounding residential receivers.

A detailed computer noise model was used to predict wind turbine generator (WTG) noise levels for both layouts.

Layout A which includes 15 Repower MM82 (2 MW) WTG's was predicted to comply to all relevant noise criteria, SA EPA Guideline and WHO limits, at all respective receivers.

Layout B which includes 15 Vestas V90 (1.8 MW) WTG's was predicted to comply to all relevant noise criteria, SA EPA Guideline and WHO limits, at all respective receivers

Layout C, which includes 14 Suzlon S88 WTG's, was predicted to comply to WHO limits, and generally meet the SA EPA Guideline criteria at most locations. Location G42, (Riverview), is predicted to exceed the SA EPA Guideline criteria by up to approximately 2.6 dBA in the wind speed range 3-6 m/s. Location G01, (Sutton Grange), is predicted to marginally exceed the SA EPA Guideline criteria by up to approximately 1.4 dBA in the wind speed range 3-6 m/s.

These would be considered a marginal exceedance and noise monitoring at this location would be required at this location to confirm the ambient baseline noise conditions at this location.

Construction noise impact has been assessed and the 'worst case' scenario's modelled were found to be acceptable.

Blasting impact has been assessed and found to be acceptable. With a maximum MIC of up to 50 kg, the airblast overpressure is anticipated to be below the acceptable level of 115 dB Linear for existing residential locations.

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1 INTRODUCTION

Heggies Australia Pty Ltd (Heggies) have been engaged by Taurus Energy Pty Ltd as the acoustical consultants for the proposed Conroys Gap Wind Farm.

1.1 Objectives

This report describes the methodology and findings of the Noise Impact Study (NIS) and forms part of the Environmental Impact Assessment for the proposed Conroys Gap Wind Farm.

This report details the main aspects of the proposed wind farm project, the acoustic criteria, the background noise measurements and the predicted noise level at all potentially impacted receivers from the operation of the proposed wind farm.

It also addresses the acoustic impact of the wind farm during the construction phase, including blasting and transportation noise.

1.2 Methodology

1.2.1 Acceptability Limit Criteria

The methodology and acceptability limit criteria that have been applied to this study are based upon the *South Australia EPA Noise Guidelines for Wind Farms (February 2003)* (SA Guidelines). The principal acceptability limit criteria is that the wind farm $L_{A90(10\ min)}$ noise should not exceed the greater of an amenity limit of 35 dBA or the pre-existing background noise by more than 5 dBA (for any given wind speed).

The project requirements and wind farm acceptability limit criteria are discussed in more detail in **Section 6**.

1.2.2 Wind Farm Noise Level Prediction

The noise emission model used in this study to predict wind farm noise levels at sensitive receptors is based on ISO 9613 as implemented in the SoundPLAN computer noise model. The model predicts noise levels through spherical spreading and includes the effect of air absorption (as per ISO 9613), ground attenuation and shielding.

Predicted L_{Aeq} noise levels were calculated based upon sound power levels determined in accordance to the recognised standard IEC-61400-11 (*Wind Turbine Generator Systems - Part 11: Acoustic Noise Measurement Techniques*), where available, for the wind range 3 to 10 m/s.

The noise character of WTG noise emission is also assessed for any special audible characteristics, such as tonality or low frequency content, which would be deemed more annoying or offensive. If characteristics such as tonality are identified then the predicted noise level would be penalised by the addition of 5 dBA. It should be noted that the characteristic noise level modulation of WTG's, commonly referred to as 'swish', is considered to be a fundamental part of wind farm noise and is taken into account by the SA Guideline assessment procedure.

1.2.3 Ambient Noise Monitoring

In order to establish the intrusive noise limit, background noise monitoring is required to establish the pre-existing ambient noise environment as a function of wind speed. As wind speed increases the ambient noise level at most receivers generally also increases as natural sources such as wind in trees etc. begin to dominate. The variation of background noise with wind speed is usually quite site specific and related to various physical characteristics such as topographic shielding and the extent and height of exposed vegetation.

Noise monitoring is completed for a period of approximately 2 weeks and correlated to synchronous wind speed and direction data for a reference height of 10 m at the wind farm monitoring mast. The captured data is screened for validity, with data monitored during periods of rain or where the average wind speed at the microphone position likely exceeded 5 m/s being discarded from the data set. Other data that was obviously affected by external noise sources (eg. pond pumps, grass mowing, birds at dawn etc.) was also removed from the data set. A regression analysis of all valid data is used to determine a line of 'best fit' from which the noise limit is established.

1.2.4 Assessment Procedure

In general the assessment procedure contains the following steps:

1. Predict and plot the L_{Aeq} 35 dBA noise level contour from the wind farm under reference conditions. Receivers outside the contour are considered to be within acceptable wind farm noise levels.
2. Establish the pre-existing background noise level at each of the relevant assessment receivers within the L_{Aeq} 35 dBA noise level contour through background noise monitoring.
3. Predict wind farm noise levels at all relevant assessment receivers for the wind range from cut-in to approximately 10 m/s.
4. Assess the acceptability of wind farm noise at each relevant assessment receiver to the established limits.

Furthermore, where the assessment of a receiver has shown unacceptable resulting wind farm noise levels, a process of noise mitigation and alternative wind farm layouts is considered. Steps 3 and 4 were repeated until an acceptable arrangement was developed.

A brief explanation and description of acoustic terminology is included in **Appendix D.**

2 WIND TURBINE OPERATIONAL NOISE CRITERIA

2.1 Introduction

The NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) has issued information on the required inputs into the Environmental Assessment.

DIPNR highlighted a number of specific issues including an assessment of the noise impacts to be undertaken in accordance with *Wind Farms - Environmental Noise Guidelines*, from the South Australia Environment Protection Authority (February 2003).

Furthermore, DIPNR has also highlighted a number of requirements in relation to noise for the proposed Conroys Gap Wind Farm, based on the NSW Industrial Noise Policy.

2.2 SA EPA Wind Farm Noise Guidelines

The South Australia EPA Noise Guidelines for Wind Farms (SA Guidelines) recommends the following noise criteria for new wind farms,

"*The predicted equivalent noise level ($L_{Aeq,\ 10min}$), adjusted for tonality in accordance with these guidelines, should not exceed:*

- *35 dBA, or*
- *the background noise level by more than 5 dBA,*

whichever is the greater, at all relevant receivers for each integer wind speed from cut-in to rated power of the WTG."

These guidelines also provide information on measuring the background noise levels, locations and requirements on the number of valid data points to be obtained and the methodology for excluding invalid data points. It also outlines the process for determining lines of best fit for the background data, and determination of the noise limit.

The Guideline explicitly states that the "swish" or modulation noise from wind turbines is a fundamental characteristic of such turbines, however, it specifies that tonal or annoying characteristics of turbine noise should be penalised.

A 5 dBA penalty should be applied to the measured noise level if an "authorised" officer determines that tonality is an issue and that tonality should be assessed in a way acceptable to the EPA.

The Guideline does not provide an assessment for the potential of low frequency noise or infrasound, but it does state that recent turbine designs do not appear to generate significant levels of infrasound, as the earlier turbine models did.

The guideline accepts that wind farm developers commonly enter into agreements with private landowners in which they are provided compensation. The guideline is intended to be applied to premises that do not have an agreement with the wind farm developers. This does not absolve the obligations of the wind farm developer entirely as appropriate action can be taken under the *Environmental Protection Act* if a development 'unreasonably interferes' with the amenity of an area. The guideline lists that there is unlikely to be unreasonable interference if;

- a formal agreement is documented between the parties

- the agreement clearly outlines to the landowner the expected impact of the noise from the wind farm and its effect on the landowner's amenity
- the likely impact of exposure will not result in adverse health impacts (e.g. the level does not result in sleep disturbance)

The proponent Taurus Energy has discussed the possible noise implications of the various proposed turbine layouts with the involved residents whose property the turbines would be located on. These property owners have been provided copies of the Noise Assessment for their information, and have been advised that SA EPA Guidelines may be exceeded under certain turbine configurations.

It is possible that under certain turbine configurations noise levels at the residences of Ferndale, Sunnyside and Linbrook may exceed South Australian EPA Guidelines. The proponent intends to enter into noise agreements with these landowners once final selection and turbine layouts have been completed, and prior to commencement of construction. Those agreements would specify:

(a) that Taurus Energy would ensure that the properties met the World Health Organisation noise guidelines (see Section 2.4); and,

(b) Taurus would implement an adaptive management approach which could include the use of building treatments and turbine operation / management strategies if operational noise causes significant impact to the amenity of involved residents.

These noise agreements would only be required under those turbine configurations where the SA EPA Guidelines would be exceeded for that particular property

2.3 NSW Industrial Noise Policy (INP)

The NSW Department of Environment and Conservation requirements for the proposed Conroys Gap Wind Farm Environmental Assessment are based on the NSW Industrial Noise Policy.

The INP requirements include site selection for background measurements, description of the site, the equipment used, graphing of results and amenity noise criteria during each of the three periods (Day, Evening and Night) as per the Industrial Noise Policy.

The proposed site for the Conroys Gap wind farm is in a rural area and therefore the Amenity Criteria for rural residential receivers, as detailed in Table 2.1 in the NSW INP, is applicable.

The criteria vary as a function of time of day. The Day, Evening and Night Periods are defined as,

Day Period	7:00 am - 6:00 pm 8:00 am - 6:00 pm (Sundays and Public Holidays)
Evening Period	6:00 pm - 10:00 pm
Night Period	10:00 pm - 7:00 am 10:00 pm - 8:00 am (Sundays and Public Holidays)

The Amenity Criteria (L_{Aeq} level) for the residential noise sensitive locations for the Conroys Gap wind farm project are,

Day Period 50 dBA

Evening Period 45 dBA

Night Period 40 dBA

The Intrusiveness Criterion in the INP is based on the rating background level (RBL), where the Criterion is,

$$L_{Aeq,\ 15\ min} \leq \text{RBL} + 5\ \text{dBA}$$

This is almost identical to the SA Guidelines (Section 2.2), the difference being the measurement interval (15 and 10 minute) and the determination of the background noise level (rating level, based on 10th percentile of measured background levels, or using a line of best fit through the data points).

The INP states where the measured RBL is less than 30 dBA, then the RBL is considered to be 30 dBA.

In summary it is evident that the non project related residential receivers assessed under the *SA EPA Wind Farm Guideline* will generally comply to INP amenity criteria. Furthermore, intrusiveness is covered by the by the *SA EPA Wind Farm Guideline.*

2.4 World Health Organisation

As discussed in Section 2.2, the proponent intends to enter into noise agreements with the owners of project-involved residences in accordance with World Health Organisation guidelines, as it is necessary to ensure that the project does not result in an 'unreasonable interference' with the amenity of these areas or cause any adverse health affects.

The World Health Organisation (WHO) publication '*Guidelines for Community Noise'* identifies the main health risks associated with noise and derives acceptable environmental noise limits for various activities and environments.

The appropriate guideline limits are listed in **Table 1.**

Table 1 WHO Guideline values for environmental noise in specific environments

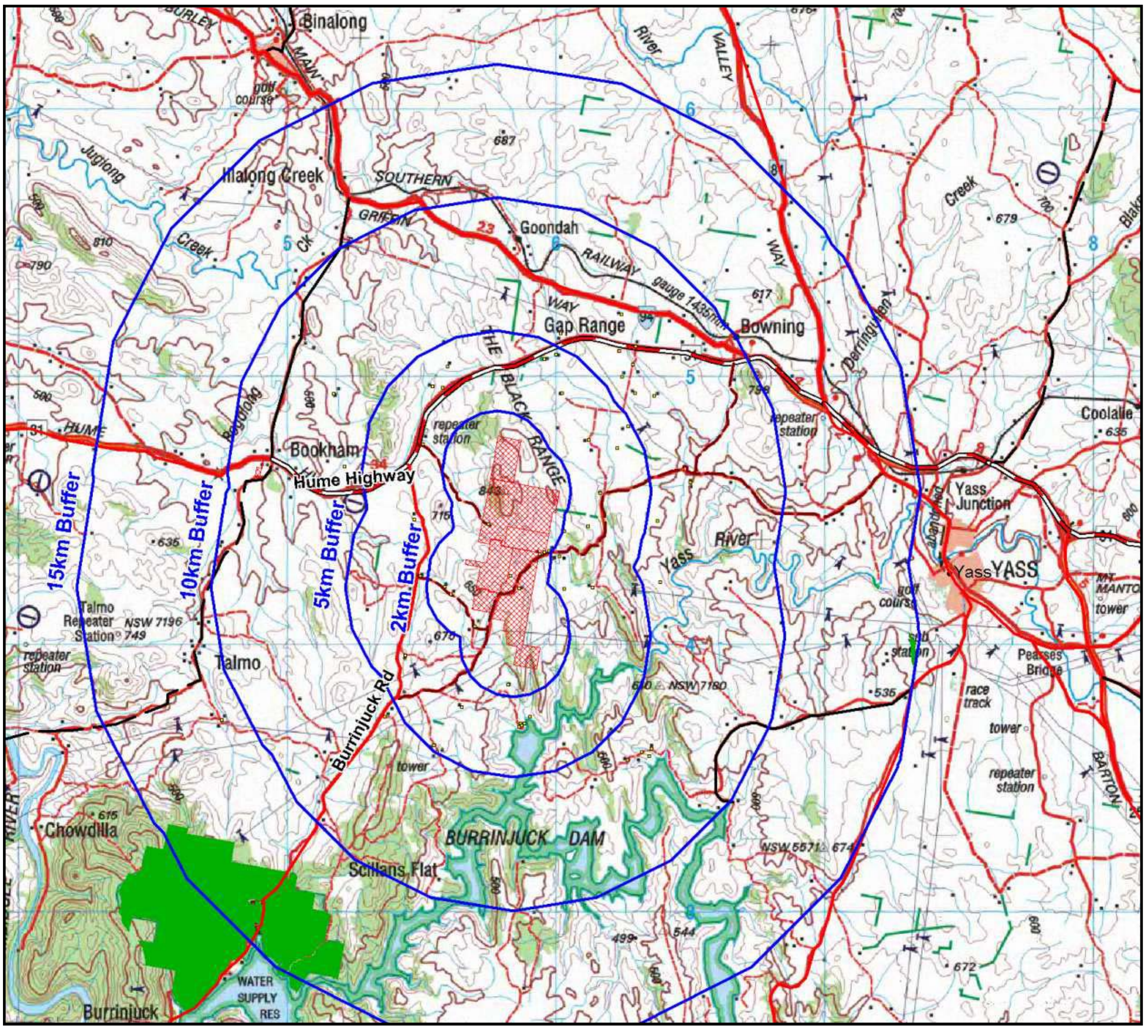
Specific Environment	**Critical Health Effect(s)**	**LAeq (dBA)**	**Time base (hours)**	**LAMax (dBA, Fast)**
Outdoor living area	Serious Annoyance, daytime & evening	55	16	-
	Moderate annoyance, daytime & evening	50	16	-
Dwelling indoors	Speech Intelligibility & moderate annoyance, daytime & evening	35	16	
Inside bedrooms	Sleep disturbance, night-time	30	8	45
Outside bedrooms	Sleep disturbance – window open, night-time	45	8	60

For the assessment of project involved residences the adopted external criteria of 45 dBA or the level given by the SA EPA Guideline criteria, where higher, will be adopted. Effectively this becomes 45 dBA or background + 5 dBA, whichever is the higher.

3 GENERAL SITE DESCRIPTION

The proposed Conroys Gap wind farm site is located approximately 16 km west of Yass in NSW, between the Hume Highway and Lake Buminjuck. The location of the proposed wind farm is shown in **Figure 1.**

Figure 1 Location of proposed Conroys Gap Wind Farm



3.1 Characteristics of the site

The proposed site incorporates the farming properties Ferndale, Sunnyside and Linbrook. These properties include residential dwellings, however, as they form part of the project consortium with agreements, they have not been subject to the formal assessment process. However, an indicative assessment has been carried out to ensure no unreasonable impact and to provide the basis of the agreements between Taurus and the site landowners.

Topographically the proposed site broadly includes a number of raised ridges / plateaus that run in an approximately north-south direction. The Hume Highway runs to the north of the site and to the south Black Range Road. The district is primarily used for agricultural (grazing) purposes.

Road traffic on the Hume Highway is relatively constant and residential dwellings close to the highway would have background noise levels dominated by road traffic. Most other properties surrounding the proposed site, including those along Black Range Road, have an ambient background noise environment that is determined by pre-dominantly natural sources which are largely wind influenced.

The prevailing wind is from the West to West-northwest and East and the district receives only marginal rainfall.

3.2 Dwelling Locations

Residential dwellings surround the proposed site and are generally located along the Hume Highway, Burrinjuck Road or Black Range Road. The assessment locations include all dwellings located within 5 km of a proposed WTG, they are indicated on the map in **Figure 2.**

The locations considered in this assessment include all dwellings located within 5 km of a proposed WTG, **Table 2** lists the on-site and off-site receiver locations and their position. Other dwellings located beyond 5 km of a proposed WTG are not considered within this assessment, primarily as WTG noise is unlikely to be audible at these distances and compliance to noise criteria more critical at closer receivers.

Figure 2 Dwelling Locations

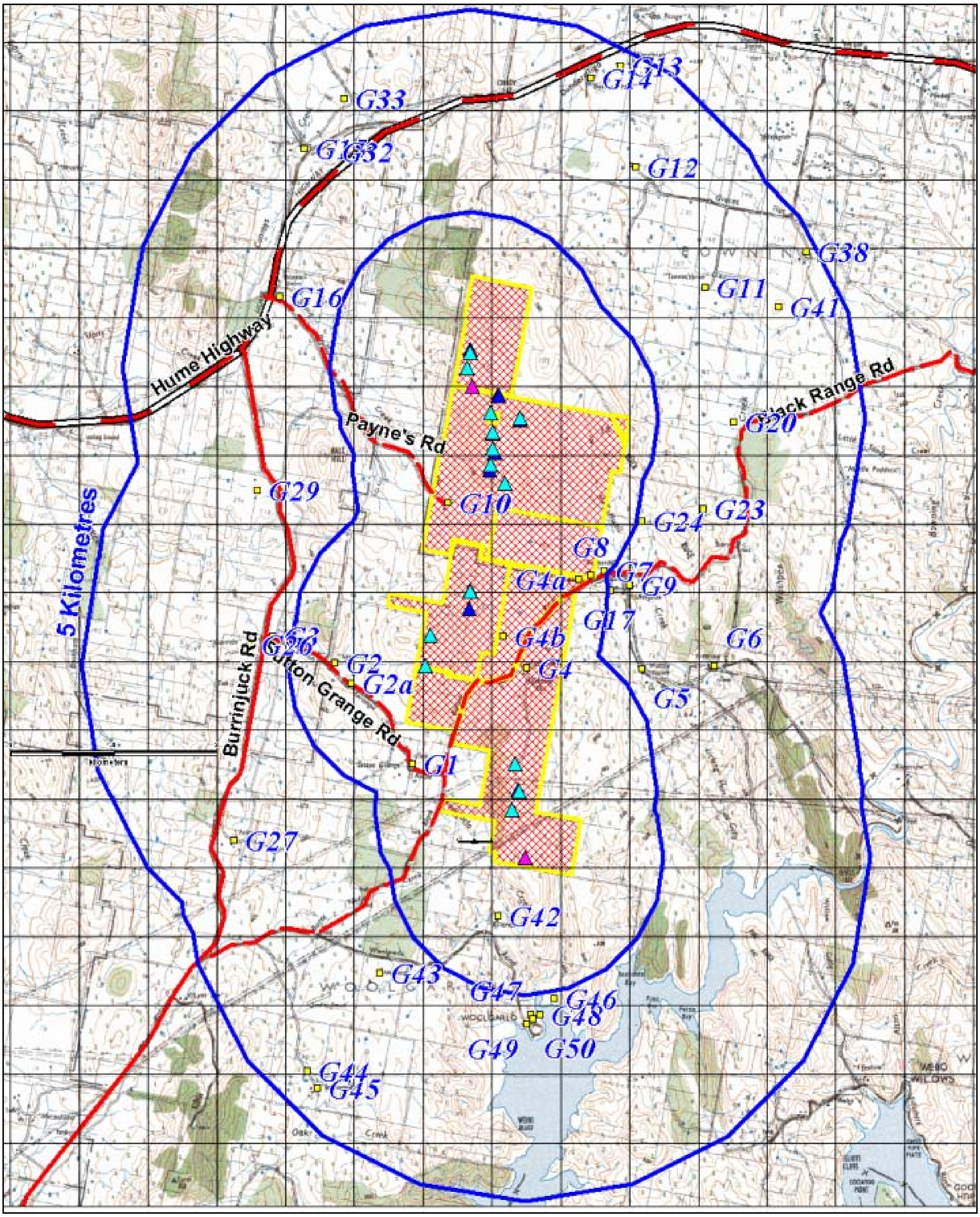


Table 2 Surrounding Receivers

Location	East (m)	North (m)	Elevation (m)
G01 Sutton Grange	656955	6140691	578
G02 Grenville	655830	6142160	561
G02a Grenville 2	656066	6141866	587
G03 Bogo	654913	6142552	534
G04 Ferndale *	658616	6142092	652
G04a Kaveney *	659368	6143377	618
G04b Proposed house *	658267	6142549	676
G05 Wattle Valley	660294	6142075	595
G06 Riverlea	661339	6142115	564
G07 Bernado	659736	6143497	609
G08 Springvale *	659548	6143435	613
G09 Sunnyside *	660108	6143295	601
G10 Linbrook *	657463	6144500	603
G11 Tannochbrae	661209	6147630	570
G12 House	660201	6149381	591
G13 Woodleigh	659983	6150849	583
G14 Bellevue Hill	659548	6150659	600
G15 Marilba	655374	6149637	552
G16 Malcom van Gelder	655027	6147494	523
G17 Ian & Una McGrath	659823	6143216	606
G18 Elvington	662442	6150000	578
G19 Rose Hill	662932	6149397	572
G20 Sreath Dubh	661622	6145660	552
G23 Jilla Colo	661185	6144412	599
G24 Yowerweena	660294	6144222	656
G26 Cooinda	654589	6142433	546
G27 Fairview	654358	6139578	608
G29 Bogo Cottage	654689	6144675	560
G32 House	655766	6149602	568
G38 Waterview	662678	6148142	584
G41 Proposed house	662272	6147338	584
G42 Riverview	658195	6138491	469
G43 Ildemere	656469	6137652	534
G44 House	655423	6136237	582
G45 Bertangles	655567	6135982	562
G46 House	659015	6137292	410
G47 House	658669	6137052	382
G48 House	658809	6137051	382
G49 House	658608	6136920	382
G50 House	658702	6136982	382

* denotes the location is involved with the project

4 PROPOSED WIND FARM LAYOUT

The proponent has developed three alternative turbine layouts for the proposed Conroys Gap Wind Farm, which are dependant upon the three alternative wind turbine types. Layout A utilises a total of 15 Repower MM82 (2 MW) WTG's, Layout B utilises a total of 15 Vestas V90 (1.8 MW) WTG's and layout C utilises a total of 14 Suzlon S88 (2.1 MW) WTG's

The alternative layouts with WTG locations are listed in **Table 3.**

Table 3 Conroys Gap proposed alternative WTG layouts

Layout A			Layout B			Layout C		
Name	**Easting**	**Northing**	**Name**	**Easting**	**Northing**	**Name**	**Easting**	**Northing**
R1	657799	6146676	V1	657797	6146725	S1	657788	6146725
R2	657750	6146446	V2	657750	6146448	S2	657752	6146452
R3	658201	6146049	V3	658205	6146052	S3	657825	6146181
R4	658089	6145805	V4	658089	6145805	S4	658085	6145813
R5	658525	6145724	V5	658526	6145702	S5	658525	6145736
R6	658125	6145513	V6	658125	6145510	S6	658125	6145542
R7	658127	6145276	V7	658150	6145225	S7	658125	6145276
R8	658097	6145049	V8	658079	6144965	S8	658091	6145014
R9	658300	6144777	V9	657796	6143224	S9	657800	6143200
R10	657799	6143205	V10	657776	6142954	S10	657225	6142568
R11	657225	6142566	V11	657225	6142566	S11	658450	6140649
R12	657150	6142126	V12	657148	6142128	S12	658503	6140304
R13	658451	6140700	V13	658451	6140700	S13	658400	6140050
R14	658501	6140303	V14	658500	6140304	S14	658599	6139325
R15	658400	6140025	V15	658400	6140026			

4.1 WTG Type and Details

The three alternative proposed wind turbines are all three bladed, upwind, pitch regulated and active yaw wind turbines. The rotor diameters vary between 82 and 90 m. They are all proposed to be mounted at a hub height of 80 m.

Table 4 summarises the relevant turbine input data used for noise level prediction.

Table 4 WTG Manufacturers Data

Wind Farm Layout	Layout A	Layout B	Layout C
Make, Model, Power	Repower MM82, 2 MW	Vestas V90, 1.8 MW	Suzlon S88, 2.1 MW
Rotor Diameter	82 m	90 m	88 m
Hub Height	80 m	80 m	80 m
Cut-in Wind Speed	3.5 m/s	4 m/s	4 m/s
Rated Wind Speed	13 m/s	13 m/s	14 m/s
Rotor Speed	8.5-17.1 rpm	8.8-14.9 rpm	15.6 rpm
Sound Power Level, $L_{WA,ref}$	104.0 dBA	102.6 dBA	106.3 dBA

Noise emission for the proposed alternative turbines has been independently tested according to International Standard IEC 61400-11 for the Repower and Vestas machines. Copies of the certification test which give the Sound Power Level variation with wind speed, frequency spectra and tonality assessment are contained in **Appendix B.**

Noise emission data for the Suzlon machines is based on manufacturer measurements and corrections for standard terrain in general accordance with IEC 61400-11. Further independent test result data for this WTG is anticipated.

5 OPERATIONAL NOISE LEVELS

5.1 Introduction

As discussed in **Section 1.2.2** a three dimensional computer noise model was used to predict L_{Aeq} noise levels from all WTGs at all surrounding residential dwellings.

The ISO 9613 noise model incorporates a 'hard ground' assumption and includes one third octave band calculated effects for air absorption, ground attenuation and topographic shielding. It is noted that ISO 9613 equations predict for average downwind propagation conditions. And also hold for average propagation under a well developed moderate ground based temperature inversion.

ISO 9613 algorithms are not as sophisticated as other standards with respect to meteorological/atmospheric effects compared to CONCAWE and NORD2000 (same algorithms as WiTuProp). It should be noted that wind and temperature inversion propagation enhancement effects are minimal for greatly elevated sources such as WTG's.

An evaluation of all standards showed that the implemented ISO 9613 model was generally more conservative (predicted higher noise levels) than predictions from the CONCAWE (worst case Category 5) or NORD2000 (worst case wind propagation). The only exception were for receivers located at considerable distance from WTG's, where noise levels were typically less than 20 dBA. At these locations impacts and compliance are not an issue. In summary the implemented ISO 9613 model, was the most conservative noise model to use for all nearby potentially impacted assessment locations.

This is supported by other similar investigations. (Reference: _Wind Turbine Generator Noise Prediction - Comparison of Computer Models_, *Tickell, Ellis, Bastasch, Proceedings of ACOUSTICS 2004)*

The estimated accuracy of the prediction model is approximately ±3 dBA.

Whilst $L_{A90(10\ min)}$ noise levels are used for compliance monitoring, the assessment utilises predicted L_{Aeq} noise levels, as prescribed by SA Guidelines, and therefore infer a degree of conservatism which assists in other uncertainties in the noise prediction and assessment process.

5.2 Wind Turbine Noise Levels

For indicative purposes the WTG noise levels from the proposed wind farm were calculated for the reference wind condition of 8 m/s at all surrounding residential receivers. The resulting WTG noise levels are listed in **Table 5** for all layouts at 8 m/s wind speed, measured at the reference height of 10 metres, which is the condition that WTG sound power levels are typically quoted.

Predicted noise contour plots resulting from proposed Layout A is depicted in **Figure 3,** Layout B is depicted in **Figure 4** and Layout C is shown in **Figure 5.**

Furthermore, noise levels from the proposed wind farm were calculated for all integer wind speeds in the range of 4 to 10 m/s at all surrounding assessment receivers within 5 km of a turbine. Whilst the rated wind speed of the WTG's is typically 13 - 14 m/s, published manufacturers sound power level test data (IEC 61400-11) has only been generated as high as 10 m/s. It should be noted that noise produced by WTG's begins to 'plateu off' at higher wind speeds and because of the higher masking background noise level at higher wind speeds, noise impacts and compliance are a non issue at these speeds. The covered wind range sufficiently covers the most noise critical operational conditions.

The predicted levels are displayed on the assessment graphs presented in **Appendix A1, Appendix A2** and **Appendix A3**.

Table 5 WTG LAeq noise level (dBA) at V_{ref} = 8 m/s

Receiver / Property	Layout A Repower MM82	Layout B Vestas V90	Layout C Suzlon S88
G01 Sutton Grange	36.7	32.4	37.6
G02 Grenville	34.7	30.3	33.6
G02a Grenville 2	36.5	32.4	35.3
G03 Bogo	30.9	25.4	30.1
G04* Ferndale	38.3	34.6	39
G04a* Kaveney	35.9	31.2	36.2
G04b* Proposed house	40.5	38.6	41.4
G05 Wattle Valley	33.4	28.2	34
G06 Riverlea	27.6	22.7	27.7
G07 Bernado	35.5	30.4	35.7
G08* Springvale	35.4	30.4	35.6
G09* Sunnyside	34.3	29	34.3
G10* Linbrook	41.3	36.8	42.3
G11 Tannochbrae	28.4	22.6	29.2
G12 House	20.5	14.5	20.8
G13 Woodleigh	21.3	15.3	21.6
G14 Bellevue Hill	20.5	14.5	20.8
G15 Marilba	20.8	14.9	21.1
G16 Malcom van Gelder	31.1	25.4	31.9
G17 Ian & Una McGrath	35	29.9	35.1
G18 Elvington	23.7	17.2	22.6
G19 Rose Hill	23.8	17.3	22.7
G20 Sreath Dubh	22.9	16.9	23
G23 Jilla Colo	24.1	18.2	24.2
G24 Yowerweena	34.7	29.1	34.7
G26 Cooinda	31	25.8	30.5
G27 Fairview	28.1	22.6	28.2
G29 Bogo Cottage	27.8	23	27.5
G32 House	28.2	22.2	28.8
G33 House	27.4	21.4	27.7
G38 Waterview	25.3	19.4	24.9
G41 Proposed house	27	20.6	26.8
G42 Riverview	33.4	28.7	38.8
G43 Ildemere	28.7	23.2	30.4
G44 House	24.7	18.9	25.5
G45 Bertangles	21	15.4	19.7
G46 House	20.3	14.8	28.7
G47 House	27	21.5	30.4
G48 House	27	21.5	30.4
G49 House	26.7	21.1	29.9
G50 House	27.1	21.5	30.3

* denotes the location is involved with the project

Predicted noise contour plots resulting from proposed Layout A is depicted in **Figure 3,** Layout B is depicted in **Figure 4** and layout C depicted in **Figure 5.**

Figure 3 Layout A - WTG L_{Aeq} Noise Contour Map at V_{ref} = 8 m/s

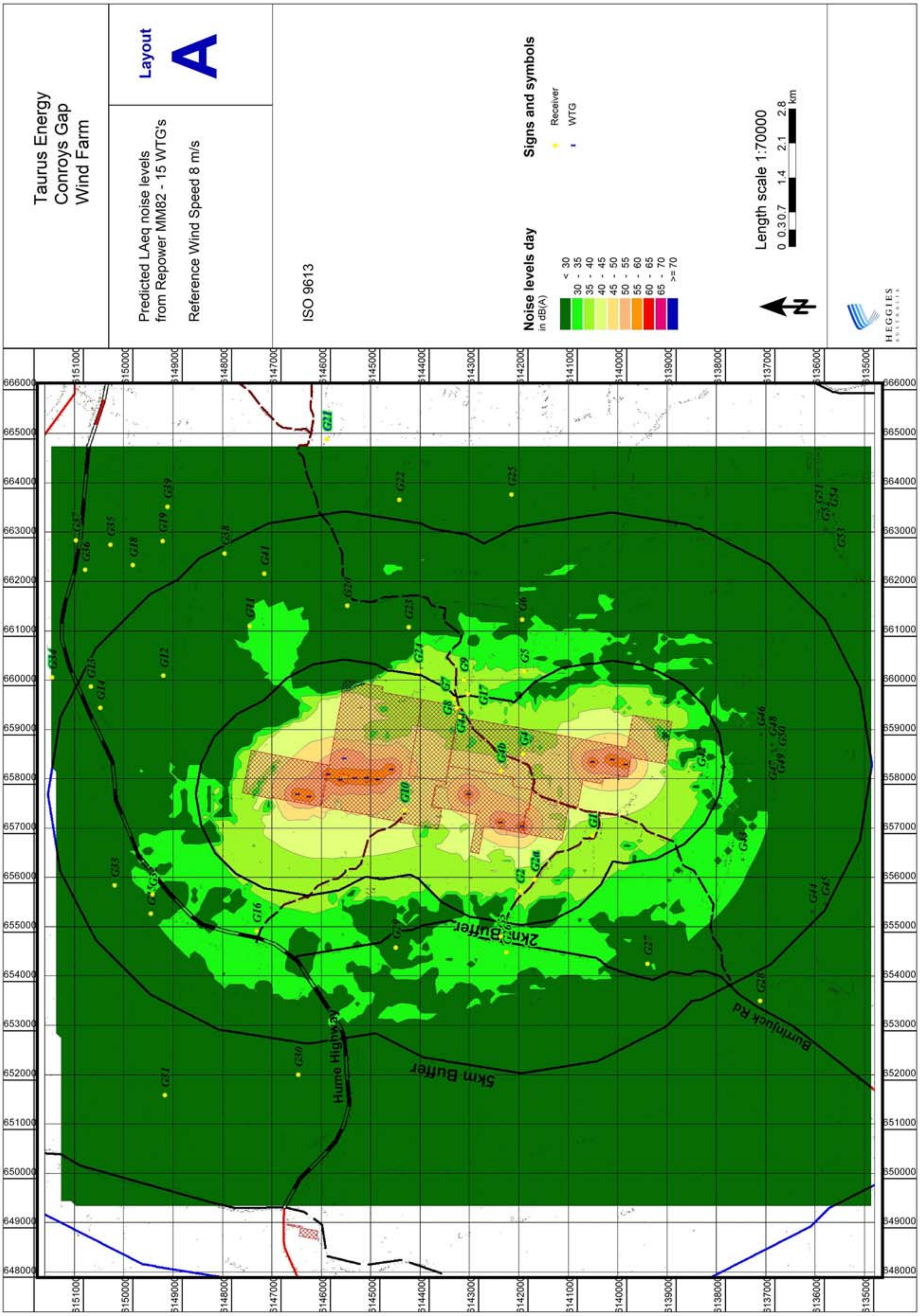


Figure 4 Layout B - WTG LAeq Noise Contour Map at V_{ref} = 8 m/s

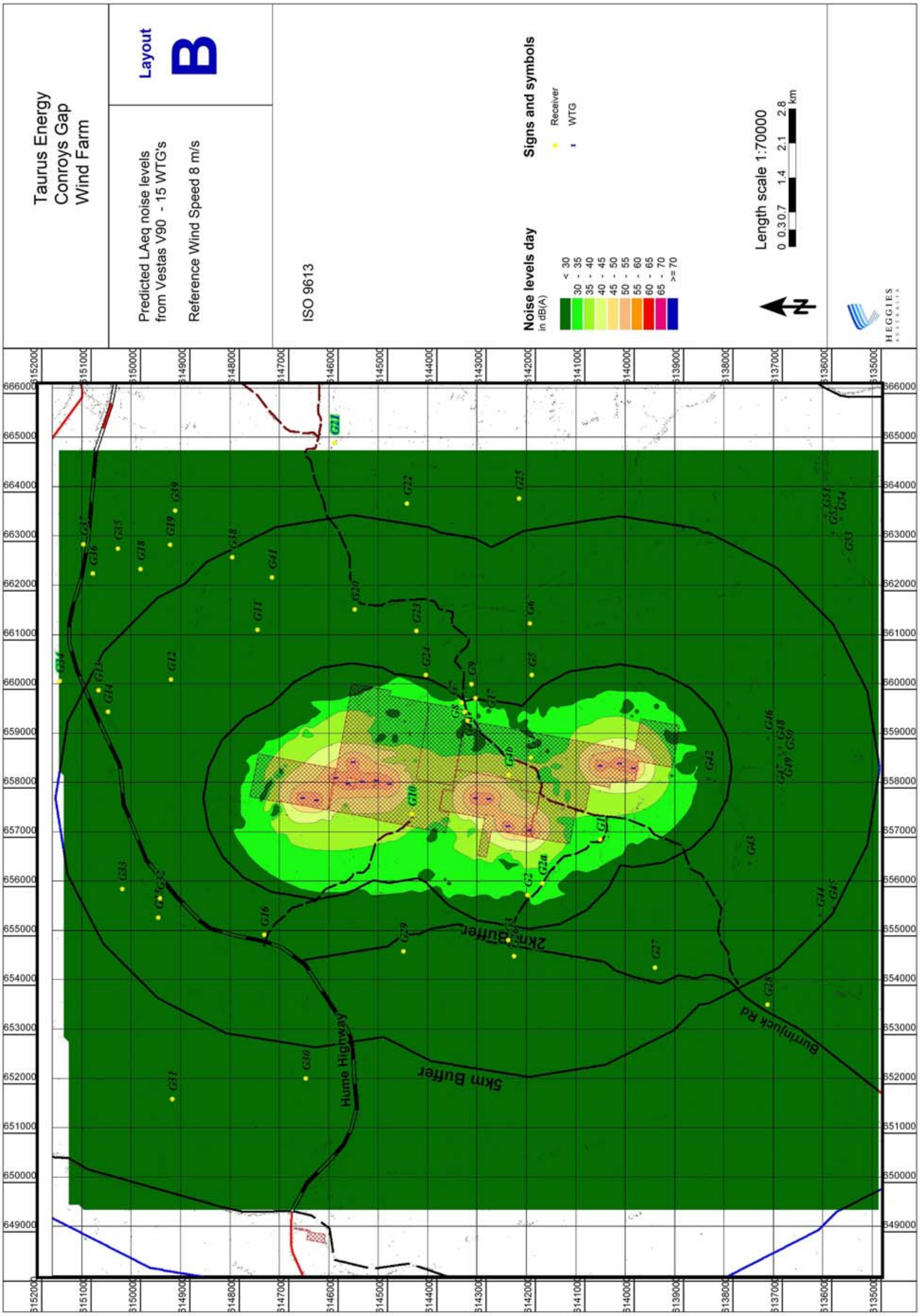
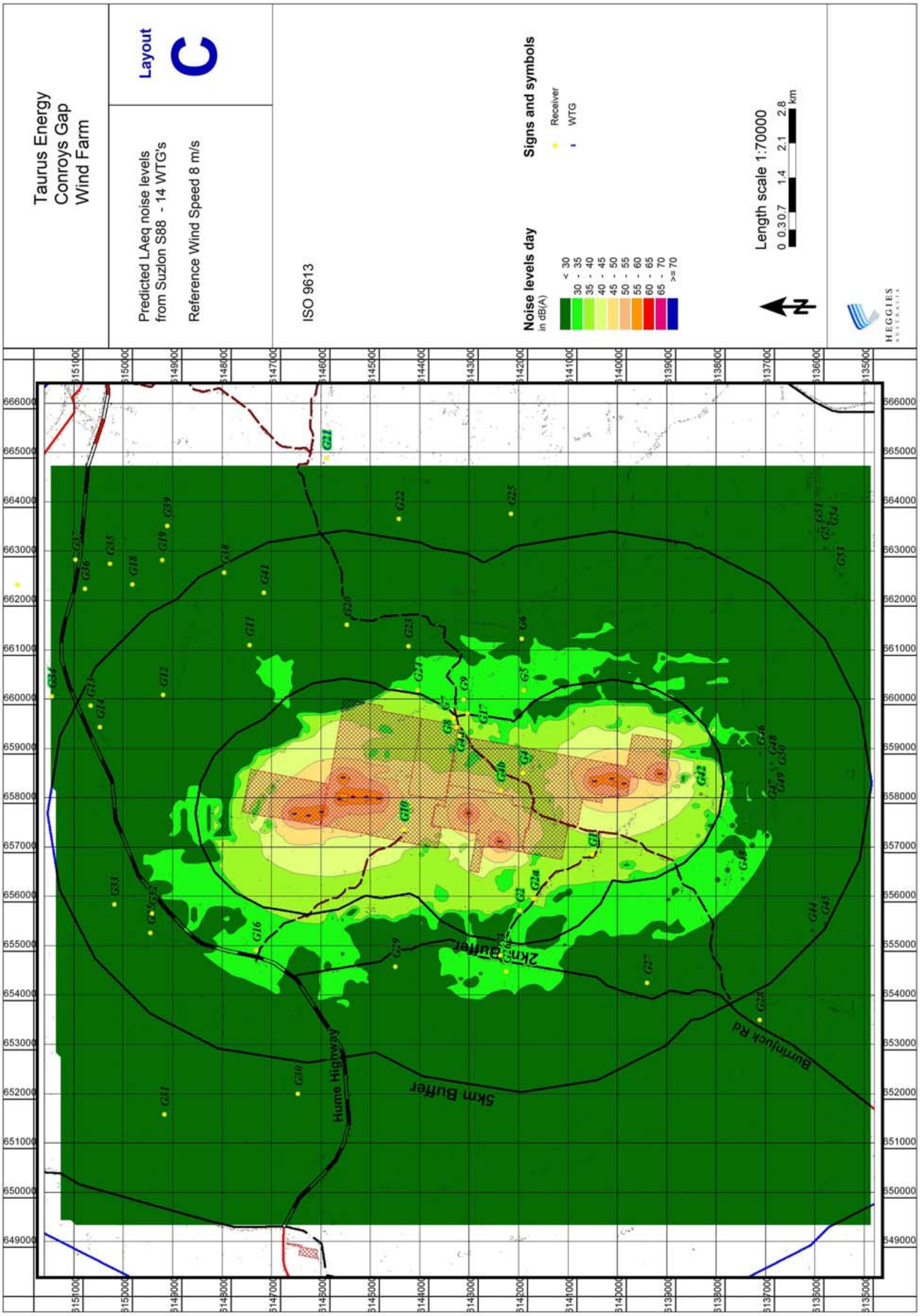


Figure 5 Layout C - WTG LAeq Noise Contour Map at V_{ref} = 8 m/s



5.3 Transformer Noise Levels

Subject to final agreement with Transgrid, the preferred location for the wind farm substation is at the centre of the site where the existing 132 kV line crosses the proposed site, approximately 1500 metres south-east of the closest residential receiver, which is Location G01, Sutton Grange.

The proposed location of the substation is at GDA94 E658389 N6139998.

The substation transformers may possibly be enclosed by blast protection walls in which case they will also serve as noise walls.

The substation would ‘step up’ the voltage from the incoming 22 or 33 kV voltage to the 132 kV voltage of the transmission line using a single 30-50 MVA transformer.

Australian Standard AS 2374 Part 6 1994: “Power Transformers – Determination of Transformer and Reactor Sound levels” indicates that a transformer of this capacity may produce sound power levels up to 98 dBA. The dominant frequency of such a transformer is 100 Hz.

Predicted noise levels from the transformer installation are expected to be less than 22 dBA at the most exposed receiver location, Location G01 Sutton Grange, which is below the existing ambient background and predicted future WTG levels and as such will not effect the compliance assessment of the proposed wind farm.

6 BACKGROUND LEVELS AND NOISE LIMITS

6.1 Measurement Locations

The locations for the background noise measurements were chosen based on the potential for acoustic impact to the nearest receivers, as recommended by Table 3.1 of the NSW INP. The SA Guidelines recommend that the measurement locations should be located at least 5 metres from a reflecting surface (other than the ground) and locations within 20 metres of a residence are generally appropriate.

Monitoring equipment was generally placed in the vicinity of the residence at a suitable location that would be protected from the prevailing wind direction in order to protect the microphone from wind induced noise effects. Care was taken not to place the equipment in locations that would be affected by extraneous noise sources.

Background noise monitoring locations were selected based on the predicted wind farm noise level from the preliminary 15 turbine base layout at reference conditions. Many of the potentially adversely affected locations have been monitored. Generally a selected monitoring location was used to provide an indicative background for nearby locations in that vicinity. The relative proximity of some receiver locations to one another and their similar wind exposure and surrounding trees meant that background noise monitoring was conducted at only one of the locations and the result was considered indicative of the adjacent locations.

A number of receivers are located in proximity to the Hume highway. Whilst they have been grouped with a measurement location that is geographically similar it is noted that their ambient background level is likely to be higher than that measured or indicated elsewhere.

It is anticipated that further baseline background noise monitoring will be conducted before project commissioning.

A total of 7 locations were monitored around the proposed wind farm site. These are listed in **Table 6** below.

Table 6 Measurement Locations

Location	Address	Indicative of	Similar Characteristic for wind induced noise
G11	Tannochbrae	G11, G12, G13**, G14**, G15**, G16**, G18, G19, G32**, G33**, G38, G41	geographic proximity, exposure to wind, proximity to Hume Hwy.
G10	Linbrook	G10*, G29	exposure to wind
G02	Grenville	G02, G02a, G03, G26, G27	geographic proximity, exposure to wind
G04*	Ferndale	G01, G04*, G04a*, G04b*, G42, G43, G45, G46, G47, G48, G49, G50,	geographic proximity, exposure to wind
G17	McGrath	G05, G06, G07, G08*, G09*, G17	geographic proximity, exposure to wind
G24	Yowerweena	G20, G23, G24	geographic proximity, exposure to wind
G01	Sutton Grange	G01,	Measurement to examine similarity to G04

* denotes the location is involved with the project

** denotes the location is located close to Hume highway and would anticipate ambient background conditions to be higher than monitored

At each location noise monitoring equipment was placed in the vicinity of the residence and the position of the monitoring equipment was documented with photographs.

A weather station was placed at location G10, capable of measuring wind speed, direction, rainfall, temperature and humidity. Furthermore meteorological data for the monitoring period was sourced from the nearest Bureau of Meteorology station in Yass. This data was used to identify and exclude any data during rain periods, which may have affected the background noise levels.

The measured data for rain confirmed that the monitoring periods were generally dry and as a result only a small amount of data points were rejected due to rain.

The SA Guidelines require measurements to be conducted in 10 minute intervals, while the NSW INP request 15 minute interval data. Given that almost all wind data, including the wind farm site monitored data, is in 10 minute intervals, this period was used for all measurements.

Noise monitoring for six baseline sites was conducted from the period 24th November through to 7th December 2005. Unfortunately during this period the wind monitoring tower was inoperable and as a consequence the measured noise data was unsuitable for assessment purposes.

The noise monitoring was re-conducted during the period 13th December through to 28th December 2005, concurrently with wind data collection. Noise monitoring for most sites continued through to only the 23rd of December when battery capacity of the loggers was exhausted. Location G04 was monitored during the period 11th to the 28th of January 2006, as equipment breakage had interrupted the previous monitoring campaign.

A further pair of noise monitoring campaigns was conducted between 15th May and 1st June 2006. During this period low wind speed conditions were experienced (~ 50% below 3 m/s). The data collected during this mid year monitoring was used to supplement monitoring data from the earlier campaign in December.

Due to a property transfer location G11 Tannochbrae was uninhabited during the May 2006 monitoring and as no resident was available to grant access to this property. The smaller data set collected during December 2005 was used solely for this location.

Location G01 Sutton Grange was monitored during May 2006, as a result of the low wind speeds experienced only 918 valid data points was collected. During this period background noise levels were compared with data collected at G04 Ferndale. The comparison of data collected at both locations showed that the noise level versus wind trend at G04 was lower than measured at G01. It is acknowledged that at low wind speeds this is partially attributed the higher noise floor of the equipment located at G01, however, it is clear that at higher wind speeds the average baseline noise level at G04 is several dBA lower than at G01. This comparison serves to confirm that the use of G04 baseline criteria curve for G01 is suitable as it is likely more conservative.

Similarly after 6 weeks of monitoring at locations G17 and G24 a combination of equipment failures, and wind conditions below 3 m/s, have resulted in less than 2000 valid data points. It should be noted that the assessment of locations that are characterised by the monitoring data from G17 and G24 are in all instances compliant, and in the case of Layout A and Layout B have a significant margin of compliance (2-5 dBA)

A summary of the noise monitoring campaigns are included in **Table 7.**

The specific equipment used at each site, site descriptions including photographs and data obtained are shown in the following sections.

The local noise data is correlated to the wind speed at a reference wind data location. It is usual for this location to be at 10 metres above ground level. The reference wind tower at the proposed Conroys Gap Wind Farm has wind monitoring equipment located at 10 metres, 30 metres and 50 metres above ground level.

Table 7 Monitoring campaign summary

Location	Address	Monitoring period	Comment
G11	Tannochbrae	24/11/05 - 07/12/05	Wind monitoring non-functional
		13/12/05-22/12/05	Noise monitoring period shortened by flat logger battery
G10	Linbrook	24/11/05 - 07/12/05	Wind monitoring non-functional
		13/12/05-23/12/05	Noise monitoring period shortened by flat logger battery
		15/05/06 - 23/05/06	Significant period of low wind speeds
		25/05/06 - 01/06/06	Significant period of low wind speeds
G02	Grenville	24/11/05 - 07/12/05	Wind monitoring non-functional
		13/12/05-23/12/05	Noise monitoring period shortened by flat logger battery
		15/05/06 - 22/05/06	Significant period of low wind speeds
		24/05/06 - 01/06/06	Significant period of low wind speeds
G04	Ferndale	24/11/05 - 07/12/05	Wind monitoring non-functional
		13/12/05-24/12/05	Noise logger microphone damaged
		11/01/06 - 28/01/06	Full period
		15/05/06 - 22/05/06	Significant period of low wind speeds
		25/05/06 - 01/06/06	Significant period of low wind speeds
G17	McGrath	24/11/05 - 07/12/05	Wind monitoring non-functional
		13/12/05-23/12/05	Noise monitoring period shortened by flat logger battery
		16/05/06 - 22/05/06	Logger failure
		25/05/06 - 01/06/06	Significant period of low wind speeds
G24	Yowerweena	24/11/05 - 07/12/05	Wind monitoring non-functional
		13/12/05-20/12/05	Noise monitoring period shortened by flat logger battery
		16/05/06 - 22/05/06	Logger failure
		24/05/06 - 30/05/06	Significant period of low wind speeds
G01	Sutton Grange	16/05/06 - 22/05/06	Significant period of low wind speeds
		25/05/06 - 01/06/06	Significant period of low wind speeds

6.2 Measurement Details

The monitoring period, equipment type and serial number of the noise logger are summarised in **Table 8**.

The SA Guidelines require a set of approximately 2,000 valid data points. All data points below the cut-in wind speed of the proposed turbines and any adversely affected data (rain, external extraneous noise sources etc.) should be excluded. The cut-in wind speed for the proposed turbines is 3-4 m/s. The number of valid data points for each location is also shown in **Table 8**.

The measured background noise levels (L_{A90}) are then plotted against the reference wind tower wind speed to obtain a background versus wind speed characteristic for each location.

The line of best fit for the data set is then determined, as required by the SA Guideline using a linear, second order (quadratic) or third order (cubic) polynomial. The Guideline requires that the correlation coefficient for each line type be reported and the one with the highest correlation coefficient used. As required, the R^2 value, which is a measure of the correlation coefficient for each of the three type of line of best fit are also shown. At each location the cubic polynomial gave the highest correlation and was therefore used for the line of best fit. The SA Guideline does not specify a minimum acceptable correlation coefficient.

Table 8 Measurement Details for each Location

Measurement Location	**Measurement Period (2005)**	**Noise Logger**	**No. of monitoring intervals**	**No. of valid data points**	**Correlation Coefficient (R^2)**		
					Linear	**Quad.**	**Cubic**
G11 Tannochbrae	13/12/05 - 22/12/05	Acoustic Research Laboratories (ARL) Type 1, EL-316 (#16203530)	1461	1174	0.397	0.423	0.44
G10* Linbrook	13/12/05 - 23/12/05 15/05/06 - 01/06/06	Type 2, EL-215 (#. 194631) Type 2, EL-215 (#. 194591)	3370	2186	0.129	0.166	0.180
G02 Grenville	13/12/05 - 23/12/05 15/05/06 - 01/06/06	Type 1, EL-316 (#16203506) Type 2, EL-215 (#.193410)	3559	2531	0.159	0.260	0.308
G04* Ferndale	11/01/06-28/01/06 15/05/06 - 01/06/06	Type 1, EL-316 (#16004013) Type 1, EL-316 (#16301472)	4394	2597	0.364	0.368	0.371
G17 McGrath	13/12/05 - 23/12/05 25/05/06 - 01/06/06	Type 1, EL-316 (#16302490) Type 2, EL-215 (#. 194626)	2554	1798	0.475	0.491	0.495
G24 Yowerweena	13/12/05-20/12/05 22/05/06 - 30/05/06	Type 2, EL-315(#.15203514) Type 2, EL-215 (#. 194592)	2021	1355	0.720	0.776	0.795

* denotes the location is involved with the project

The Rating Background Level (RBL) for each location during each time period is shown in **Table 9,** for each monitoring campaign, as per the DIPNR requirements.

Table 9 RBL for each Period at each Location

	Rating Background Level (dBA)								
Campaign	**November 2005**			**December 2005**			**May 2005**		
Location	**Day**	**Evening**	**Night**	**Day**	**Evening**	**Night**	**Day**	**Evening**	**Night**
G11 Tannochbrae	35.1	35.2	34.8	35.4	30.5	26.1			
G10* Linbrook	34.0	31.0	30.7	32.0	28.8	27.5	30.0	31.1	32.5
G02 Grenville	36.9	34.1	32.6	39.6	27.4	26.3	34.8	28.0	34.3
G04* Ferndale	30.8	34.3	30.0	29.7	28.5	25.3	30.7	22.5	23.5
G17 McGrath	30.8	31.0	30.6	30.9	28.6	25.7	26.0	25.5	25.5
G24 Yowerweena	31.5	30.5	30.2	31.1	28.1	27.2	27.0	27.5	28.0
G01 Sutton Grange							31.0	26.3	26.8

* denotes the location is involved with the project

The entire set of noise logger results, showing the measured L_{A90}, L_{Aeq} and L_{A10} noise levels, together with wind speed, are shown in **Appendix C.**

The horizontal distance between each of the assessment locations and the all WTG's for the proposed Layout A wind farm is shown in **Table 10.**

Table 10 Distance Between the Assessment Location and WTG's for Layout A

Assess.	Distance to WTG (km)														
Locatio	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
G01	6.04	5.81	5.50	5.24	5.27	4.96	4.73	4.51	4.30	2.65	1.89	1.45	1.50	1.59	1.59
G02	4.93	4.70	4.55	4.29	4.47	4.06	3.87	3.67	3.60	2.23	1.45	1.32	3.00	3.25	3.34
G02a	5.11	4.88	4.70	4.43	4.58	4.19	3.98	3.78	3.67	2.19	1.35	1.12	2.66	2.89	2.97
G03	5.03	4.82	4.80	4.55	4.81	4.37	4.21	4.05	4.05	2.96	2.31	2.28	3.99	4.23	4.31
G04*	4.66	4.44	3.98	3.75	3.63	3.46	3.22	3.00	2.70	1.38	1.47	1.47	1.40	1.79	2.08
G04a*	3.65	3.47	2.92	2.74	2.49	2.47	2.27	2.10	1.76	1.58	2.29	2.55	2.83	3.19	3.49
G04b*	4.15	3.93	3.50	3.26	3.19	2.97	2.73	2.51	2.23	0.81	1.04	1.19	1.86	2.26	2.53
G05	5.23	5.06	4.49	4.33	4.06	4.07	3.87	3.70	3.36	2.74	3.11	3.14	2.30	2.52	2.79
G06	5.77	5.62	5.03	4.92	4.58	4.68	4.51	4.37	4.04	3.70	4.14	4.19	3.22	3.37	3.61
G07	3.72	3.56	2.98	2.84	2.53	2.58	2.40	2.26	1.92	1.96	2.68	2.93	3.08	3.42	3.72
G08*	3.68	3.51	2.94	2.78	2.51	2.52	2.33	2.17	1.83	1.76	2.48	2.73	2.95	3.30	3.60
G09*	4.09	3.94	3.35	3.22	2.90	2.98	2.80	2.67	2.34	2.31	2.97	3.18	3.08	3.40	3.69
G10*	2.20	1.97	1.72	1.45	1.62	1.21	1.02	0.84	0.88	1.34	1.95	2.39	3.93	4.32	4.57
G11	3.54	3.66	3.40	3.61	3.29	3.74	3.88	4.04	4.07	5.59	6.44	6.84	7.46	7.81	8.11
G12	3.62	3.82	3.89	4.15	4.02	4.39	4.60	4.82	4.98	6.63	7.44	7.87	8.86	9.24	9.53
G13	4.71	4.94	5.12	5.39	5.33	5.65	5.87	6.10	6.30	7.95	8.73	9.17	10.26	10.65	10.94
G14	4.35	4.58	4.80	5.07	5.04	5.34	5.57	5.79	6.01	7.66	8.42	8.86	10.02	10.41	10.70
G15	3.83	3.98	4.57	4.70	5.02	4.96	5.16	5.34	5.67	6.87	7.31	7.72	9.45	9.84	10.08
G16	2.89	2.92	3.49	3.50	3.92	3.68	3.81	3.92	4.25	5.11	5.40	5.77	7.61	7.99	8.19
G17	4.01	3.84	3.26	3.12	2.82	2.86	2.67	2.52	2.18	2.02	2.68	2.89	2.87	3.20	3.49
G18	5.71	5.89	5.80	6.05	5.80	6.23	6.40	6.59	6.67	8.23	9.08	9.49	10.12	10.47	10.76
G19	5.81	5.96	5.80	6.03	5.74	6.18	6.33	6.50	6.54	8.04	8.90	9.29	9.78	10.12	10.41
G20	3.96	3.95	3.44	3.54	3.10	3.50	3.52	3.58	3.44	4.54	5.38	5.70	5.89	6.20	6.49
G23	4.07	3.99	3.40	3.40	2.97	3.25	3.18	3.15	2.91	3.60	4.37	4.64	4.61	4.91	5.20
G24	3.50	3.38	2.78	2.71	2.32	2.52	2.41	2.35	2.07	2.69	3.49	3.78	3.98	4.31	4.60
G26	5.32	5.11	5.11	4.86	5.13	4.69	4.54	4.38	4.39	3.30	2.64	2.58	4.23	4.45	4.51
G27	7.89	7.66	7.53	7.26	7.43	7.03	6.83	6.63	6.53	5.00	4.14	3.78	4.24	4.21	4.07
G29	3.70	3.54	3.77	3.58	3.98	3.54	3.49	3.43	3.61	3.44	3.30	3.54	5.47	5.80	5.95
G32	3.56	3.73	4.31	4.45	4.76	4.72	4.93	5.11	5.45	6.71	7.19	7.60	9.30	9.69	9.93
G33	4.13	4.32	4.87	5.04	5.31	5.32	5.54	5.74	6.07	7.40	7.91	8.33	9.99	10.38	10.63
G38	5.09	5.21	4.94	5.15	4.81	5.26	5.38	5.53	5.52	6.94	7.80	8.17	8.56	8.88	9.18
G41	4.52	4.61	4.27	4.46	4.08	4.53	4.63	4.76	4.73	6.09	6.95	7.31	7.66	7.98	8.27
G42	8.19	7.97	7.56	7.31	7.24	7.02	6.79	6.56	6.29	4.73	4.19	3.78	2.22	1.84	1.55
G43	9.12	8.89	8.57	8.31	8.33	8.03	7.80	7.57	7.36	5.71	4.97	4.53	3.64	3.34	3.06
G44	10.71	10.47	10.20	9.93	9.98	9.66	9.43	9.21	9.01	7.36	6.58	6.14	5.39	5.10	4.82
G45	10.92	10.69	10.41	10.14	10.18	9.87	9.64	9.41	9.21	7.56	6.79	6.35	5.53	5.22	4.94
G46	9.46	9.24	8.79	8.56	8.45	8.27	8.03	7.81	7.52	6.04	5.57	5.18	3.45	3.05	2.80
G47	9.66	9.44	9.01	8.77	8.67	8.48	8.24	8.02	7.73	6.21	5.70	5.30	3.65	3.26	2.98
G48	9.68	9.45	9.02	8.78	8.68	8.49	8.25	8.03	7.74	6.24	5.74	5.34	3.67	3.27	3.00
G49	9.79	9.56	9.14	8.90	8.80	8.61	8.37	8.14	7.86	6.34	5.81	5.41	3.78	3.38	3.11
G50	9.74	9.51	9.08	8.84	8.74	8.55	8.31	8.09	7.81	6.29	5.78	5.37	3.73	3.33	3.06

* denotes the location is involved with the project

The horizontal distance between each of the assessment locations and the all WTG's for the proposed Layout B wind farm is shown in **Table 11.**

Table 11 Distance between the assessment location and WTG's for Layout B

Assess. Location	Distance to WTG (km)														
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
G01	6.09	5.81	5.51	5.24	5.25	4.96	4.69	4.42	2.67	2.41	1.89	1.45	1.50	1.59	1.59
G02	4.97	4.70	4.56	4.29	4.45	4.06	3.84	3.60	2.24	2.10	1.45	1.32	3.00	3.25	3.34
G02a	5.16	4.88	4.70	4.43	4.56	4.19	3.95	3.70	2.20	2.03	1.35	1.11	2.66	2.89	2.97
G03	5.07	4.82	4.80	4.55	4.79	4.37	4.20	3.98	2.96	2.89	2.31	2.27	3.99	4.23	4.31
G04*	4.71	4.44	3.98	3.75	3.61	3.45	3.17	2.92	1.40	1.20	1.47	1.47	1.40	1.79	2.08
G04a*	3.70	3.47	2.92	2.74	2.47	2.47	2.21	2.05	1.58	1.65	2.29	2.55	2.83	3.19	3.49
G04b*	4.20	3.93	3.50	3.26	3.16	2.96	2.68	2.42	0.82	0.64	1.04	1.20	1.86	2.26	2.53
G05	5.28	5.06	4.49	4.33	4.04	4.06	3.81	3.64	2.75	2.67	3.11	3.15	2.30	2.52	2.79
G06	5.81	5.63	5.03	4.92	4.56	4.67	4.45	4.33	3.71	3.66	4.14	4.19	3.22	3.37	3.61
G07	3.77	3.56	2.98	2.84	2.51	2.58	2.35	2.21	1.96	2.03	2.68	2.93	3.08	3.42	3.72
G08*	3.73	3.51	2.94	2.78	2.49	2.52	2.27	2.12	1.76	1.84	2.48	2.73	2.95	3.30	3.60
G09*	4.14	3.94	3.35	3.22	2.88	2.97	2.75	2.63	2.31	2.36	2.97	3.18	3.08	3.40	3.69
G10*	2.25	1.97	1.72	1.45	1.60	1.21	1.00	0.77	1.32	1.58	1.95	2.39	3.93	4.32	4.57
G11	3.53	3.66	3.39	3.61	3.30	3.74	3.89	4.11	5.57	5.80	6.44	6.84	7.46	7.81	8.11
G12	3.58	3.82	3.88	4.15	4.04	4.39	4.63	4.90	6.61	6.87	7.44	7.87	8.86	9.24	9.53
G13	4.67	4.93	5.12	5.39	5.35	5.65	5.91	6.18	7.93	8.20	8.73	9.17	10.26	10.65	10.94
G14	4.31	4.58	4.80	5.07	5.06	5.34	5.61	5.88	7.64	7.91	8.42	8.86	10.02	10.41	10.69
G15	3.79	3.98	4.57	4.70	5.04	4.96	5.21	5.40	6.86	7.10	7.31	7.72	9.45	9.84	10.08
G16	2.87	2.92	3.49	3.50	3.93	3.68	3.86	3.96	5.09	5.31	5.40	5.77	7.61	7.98	8.19
G17	4.05	3.84	3.27	3.12	2.80	2.85	2.61	2.47	2.03	2.06	2.68	2.89	2.87	3.20	3.49
G18	5.68	5.88	5.79	6.05	5.81	6.23	6.42	6.66	8.22	8.45	9.08	9.49	10.12	10.47	10.76
G19	5.79	5.96	5.79	6.03	5.75	6.18	6.35	6.57	8.03	8.25	8.90	9.29	9.78	10.12	10.41
G20	3.97	3.95	3.44	3.54	3.10	3.50	3.50	3.61	4.54	4.70	5.38	5.70	5.89	6.20	6.49
G23	4.10	3.99	3.40	3.40	2.96	3.25	3.14	3.16	3.59	3.71	4.37	4.64	4.61	4.91	5.20
G24	3.54	3.38	2.78	2.71	2.31	2.52	2.37	2.34	2.69	2.82	3.49	3.78	3.98	4.31	4.60
G26	5.36	5.11	5.12	4.86	5.12	4.69	4.52	4.31	3.30	3.23	2.64	2.58	4.23	4.45	4.51
G27	7.93	7.66	7.53	7.26	7.41	7.03	6.80	6.55	5.01	4.80	4.14	3.78	4.24	4.21	4.07
G29	3.72	3.54	3.78	3.58	3.97	3.54	3.50	3.40	3.43	3.53	3.30	3.54	5.47	5.80	5.95
G32	3.52	3.73	4.31	4.45	4.78	4.72	4.98	5.18	6.69	6.94	7.19	7.60	9.30	9.69	9.93
G33	4.09	4.31	4.87	5.04	5.33	5.32	5.59	5.81	7.38	7.64	7.91	8.33	9.99	10.38	10.63
G38	5.08	5.21	4.94	5.15	4.82	5.26	5.39	5.59	6.93	7.14	7.80	8.17	8.56	8.88	9.17
G41	4.52	4.61	4.27	4.46	4.09	4.53	4.63	4.82	6.08	6.28	6.95	7.31	7.66	7.98	8.27
G42	8.24	7.97	7.56	7.31	7.22	7.02	6.73	6.47	4.75	4.48	4.19	3.78	2.22	1.84	1.55
G43	9.17	8.89	8.58	8.31	8.31	8.03	7.76	7.49	5.73	5.46	4.97	4.53	3.64	3.34	3.06
G44	10.75	10.47	10.20	9.93	9.96	9.66	9.39	9.12	7.38	7.12	6.58	6.14	5.39	5.10	4.82
G45	10.97	10.69	10.41	10.14	10.16	9.87	9.60	9.33	7.58	7.31	6.79	6.35	5.53	5.22	4.94
G46	9.51	9.24	8.80	8.56	8.42	8.27	7.98	7.73	6.06	5.80	5.57	5.18	3.45	3.06	2.80
G47	9.71	9.44	9.01	8.77	8.65	8.48	8.19	7.93	6.23	5.97	5.70	5.30	3.65	3.26	2.99
G48	9.73	9.46	9.02	8.78	8.66	8.49	8.20	7.95	6.26	5.99	5.74	5.34	3.67	3.27	3.00
G49	9.84	9.57	9.14	8.90	8.78	8.60	8.32	8.06	6.36	6.09	5.81	5.41	3.78	3.39	3.11
G50	9.78	9.51	9.08	8.84	8.72	8.55	8.26	8.01	6.31	6.04	5.78	5.38	3.73	3.33	3.06

* denotes the location is involved with the project

The horizontal distance between each of the assessment locations and the all WTG's for the proposed Layout **C** wind farm is shown in **Table 12**.

Table 12 Distance between the assessment location and WTG's for Layout C

Assess. Location	Distance to WTG (km)													
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
G01	6.09	5.82	5.56	5.25	5.28	4.99	4.73	4.47	2.65	1.90	1.50	1.60	1.58	2.14
G02	4.97	4.70	4.49	4.29	4.48	4.09	3.87	3.64	2.23	1.45	3.02	3.25	3.33	3.96
G02a	5.16	4.89	4.66	4.43	4.59	4.21	3.98	3.74	2.19	1.36	2.68	2.90	2.96	3.59
G03	5.07	4.82	4.65	4.55	4.81	4.39	4.21	4.02	2.96	2.31	4.02	4.24	4.29	4.90
G04*	4.71	4.44	4.17	3.76	3.65	3.48	3.22	2.97	1.38	1.47	1.45	1.79	2.05	2.77
G04a*	3.70	3.47	3.20	2.75	2.51	2.50	2.27	2.08	1.58	2.29	2.88	3.19	3.47	4.12
G04b*	4.20	3.94	3.66	3.27	3.20	3.00	2.73	2.47	0.80	1.04	1.91	2.26	2.50	3.24
G05	5.28	5.06	4.79	4.34	4.07	4.09	3.87	3.67	2.74	3.11	2.33	2.52	2.77	3.23
G06	5.82	5.63	5.37	4.93	4.59	4.70	4.51	4.35	3.70	4.14	3.24	3.36	3.59	3.91
G07	3.77	3.56	3.29	2.84	2.55	2.60	2.40	2.24	1.96	2.68	3.12	3.42	3.70	4.32
G08*	3.73	3.51	3.24	2.79	2.52	2.54	2.33	2.15	1.76	2.48	2.99	3.30	3.57	4.22
G09*	4.14	3.94	3.68	3.23	2.91	3.00	2.80	2.65	2.31	2.97	3.12	3.39	3.67	4.25
G10*	2.25	1.97	1.72	1.45	1.63	1.23	1.02	0.81	1.34	1.95	3.98	4.32	4.55	5.30
G11	3.54	3.65	3.68	3.61	3.29	3.72	3.88	4.07	5.59	6.44	7.51	7.81	8.08	8.71
G12	3.59	3.82	3.99	4.15	4.01	4.36	4.60	4.85	6.63	7.43	8.91	9.23	9.50	10.18
G13	4.67	4.93	5.14	5.38	5.32	5.62	5.87	6.13	7.95	8.73	10.31	10.65	10.91	11.61
G14	4.31	4.57	4.80	5.06	5.03	5.31	5.57	5.83	7.66	8.42	10.07	10.41	10.67	11.37
G15	3.78	3.97	4.24	4.69	5.01	4.93	5.16	5.36	6.88	7.31	9.50	9.84	10.05	10.80
G16	2.87	2.92	3.09	3.49	3.91	3.66	3.81	3.94	5.11	5.39	7.65	7.99	8.17	8.92
G17	4.06	3.84	3.58	3.13	2.83	2.88	2.67	2.50	2.02	2.68	2.91	3.20	3.47	4.08
G18	5.69	5.88	5.99	6.04	5.79	6.21	6.40	6.62	8.23	9.08	10.17	10.47	10.74	11.35
G19	5.80	5.96	6.04	6.03	5.73	6.16	6.33	6.53	8.05	8.90	9.83	10.11	10.39	10.96
G20	3.98	3.95	3.83	3.54	3.10	3.50	3.52	3.59	4.55	5.38	5.93	6.20	6.47	7.02
G23	4.11	3.99	3.80	3.40	2.97	3.26	3.18	3.15	3.60	4.37	4.65	4.91	5.18	5.71
G24	3.54	3.38	3.15	2.72	2.33	2.54	2.41	2.34	2.70	3.49	4.02	4.31	4.58	5.18
G26	5.35	5.11	4.95	4.86	5.14	4.71	4.54	4.35	3.30	2.64	4.25	4.46	4.49	5.07
G27	7.93	7.67	7.46	7.26	7.44	7.05	6.83	6.59	5.00	4.14	4.23	4.21	4.07	4.25
G29	3.72	3.54	3.48	3.58	3.98	3.54	3.49	3.42	3.44	3.30	5.51	5.80	5.93	6.63
G32	3.52	3.72	3.99	4.44	4.75	4.70	4.93	5.14	6.72	7.18	9.35	9.69	9.91	10.66
G33	4.08	4.31	4.59	5.03	5.30	5.29	5.54	5.77	7.40	7.90	10.04	10.38	10.61	11.36
G38	5.09	5.21	5.23	5.15	4.80	5.24	5.38	5.55	6.94	7.80	8.60	8.88	9.15	9.72
G41	4.53	4.61	4.60	4.46	4.08	4.52	4.63	4.78	6.09	6.94	7.70	7.98	8.25	8.81
G42	8.24	7.97	7.70	7.32	7.25	7.05	6.79	6.52	4.73	4.19	2.17	1.84	1.57	0.93
G43	9.17	8.89	8.64	8.32	8.34	8.06	7.80	7.54	5.71	4.97	3.59	3.34	3.08	2.71
G44	10.75	10.48	10.23	9.94	9.99	9.69	9.43	9.17	7.36	6.58	5.35	5.10	4.84	4.43
G45	10.97	10.70	10.45	10.15	10.19	9.90	9.64	9.38	7.56	6.79	5.49	5.23	4.96	4.51
G46	9.51	9.25	8.97	8.57	8.46	8.30	8.03	7.78	6.03	5.57	3.40	3.06	2.83	2.08
G47	9.71	9.44	9.17	8.78	8.68	8.51	8.24	7.98	6.21	5.70	3.60	3.26	3.01	2.27
G48	9.73	9.46	9.18	8.79	8.69	8.52	8.25	7.99	6.23	5.74	3.62	3.27	3.03	2.28
G49	9.84	9.57	9.29	8.91	8.82	8.64	8.37	8.11	6.33	5.81	3.73	3.39	3.14	2.40
G50	9.79	9.52	9.24	8.85	8.76	8.58	8.31	8.06	6.28	5.78	3.68	3.33	3.08	2.35

* denotes the location is involved with the project

6.3 Location G11 - Tannochbrae

The property of Tannochbrae is located directly to the North East of the proposed wind farm. The homestead residence is surrounded by a well established garden with flat grassy plains to the east of the site. The measurement location was on the eastern boundary fenceline of the house and grazing paddocks. The monitoring location is shown in **Figure 6.**

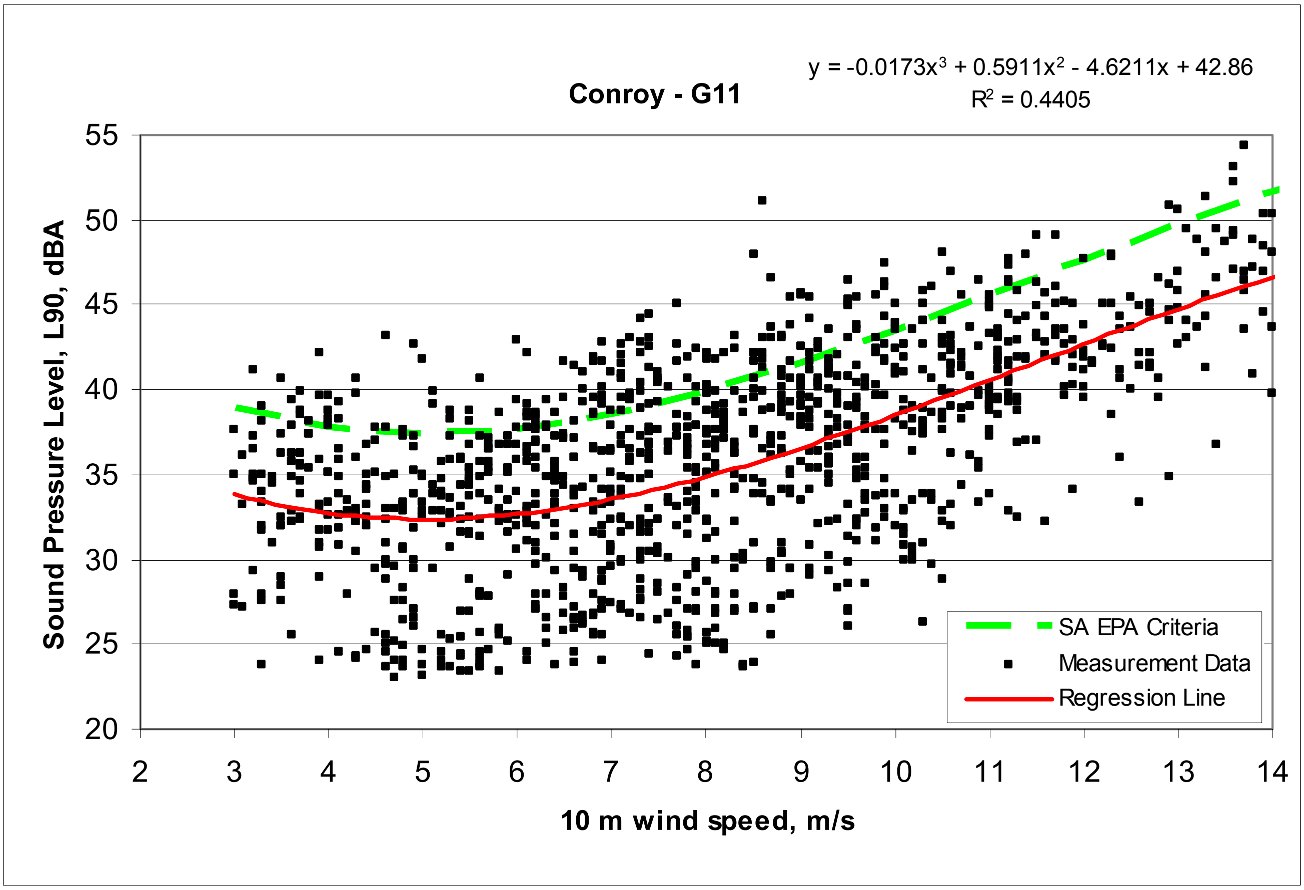
Figure 6 Tannochbrae Measurement Location

The results of the background noise monitoring taken in December 2005, showing the data points, line of best fit and the Noise Criteria Curve are shown in **Figure 7.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix C2**. High noise levels during the dawn period were a feature of this location and likely a result of birds**.**

The 'average' background level, determined for construction noise impact assessment purposes, was 39.9 dBA.

Figure 7 Background Noise Measurements and Noise Criteria Curve - Tannochbrae



6.4 Location G10 - Linbrook

The property of Linbrook is nestled between two ridgelines to the west that form part of proposed wind farm. The measurement location is shown in **Figure 8.**

Figure 8 Linbrook Measurement Location

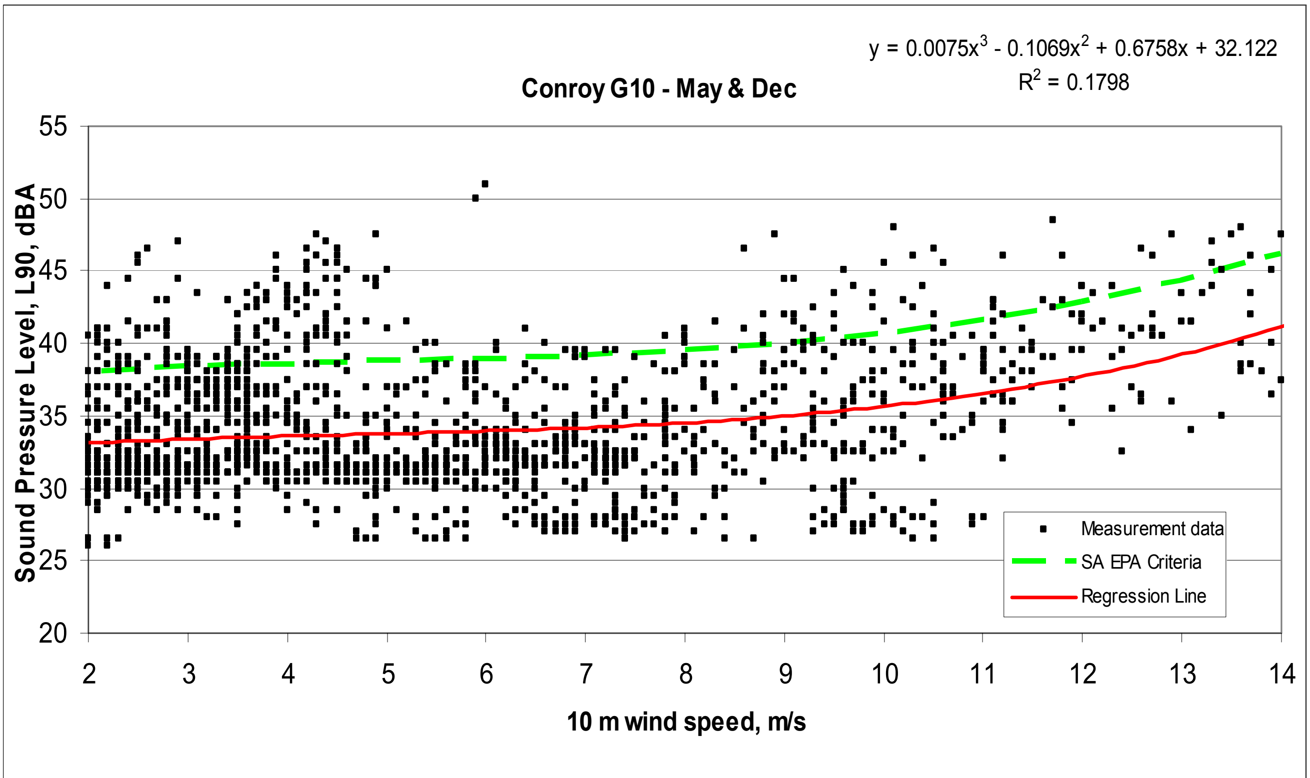
A weather station was placed at this location to measure local wind speed and rain fall during the monitoring period.

The results of the background noise monitoring during the December 2005 and May 2006 campaigns, showing the combined data points, line of best fit and the Noise Criteria Curve are shown in **Figure 9.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix C1.**

The 'average' background level, determined for construction noise impact assessment purposes, was 35.3 dBA.

Figure 9 Background Noise Measurements and Noise Criteria Curve - Linbrook



6.5 Location G02 - Grenville

The residence of Grenville is located directly to the South West of the proposed wind farm. A number of large well established trees grow beside the house yard area. The measurement location is shown in **Figure 10.**

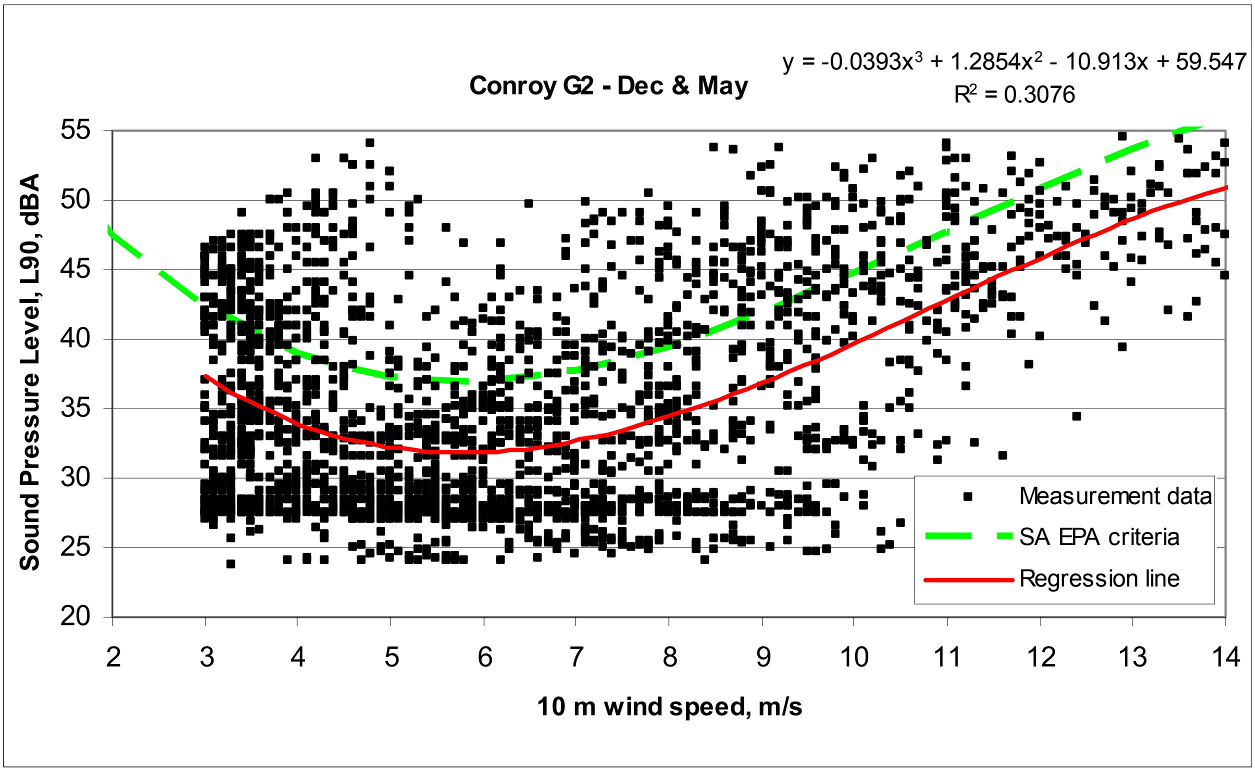
Figure 10 Grenville Measurement Location

The results of the background noise monitoring during the December 2005 and May 2006 campaigns, showing the combined data points, line of best fit and the Noise Criteria Curve are shown in **Figure 11.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix C3**. Higher noise levels during the dawn period were a feature of this location and likely a result of birds**.**

The 'average' background level, determined for construction noise impact assessment purposes, was 40.1 dBA.

Figure 11 Background Noise Measurements and Noise Criteria Curve - Grenville



6.6 Location G04 - Ferndale

The property of Ferndale is located to the South East of the proposed wind farm. Monitoring at this location was repeated during the period 11th January 2006 through to 28th January 2006 as the equipment had suffered a breakage which then compromised the measurement data collected in December. The residence is shown in **Figure 12.**

Figure 12 Ferndale Measurement Location

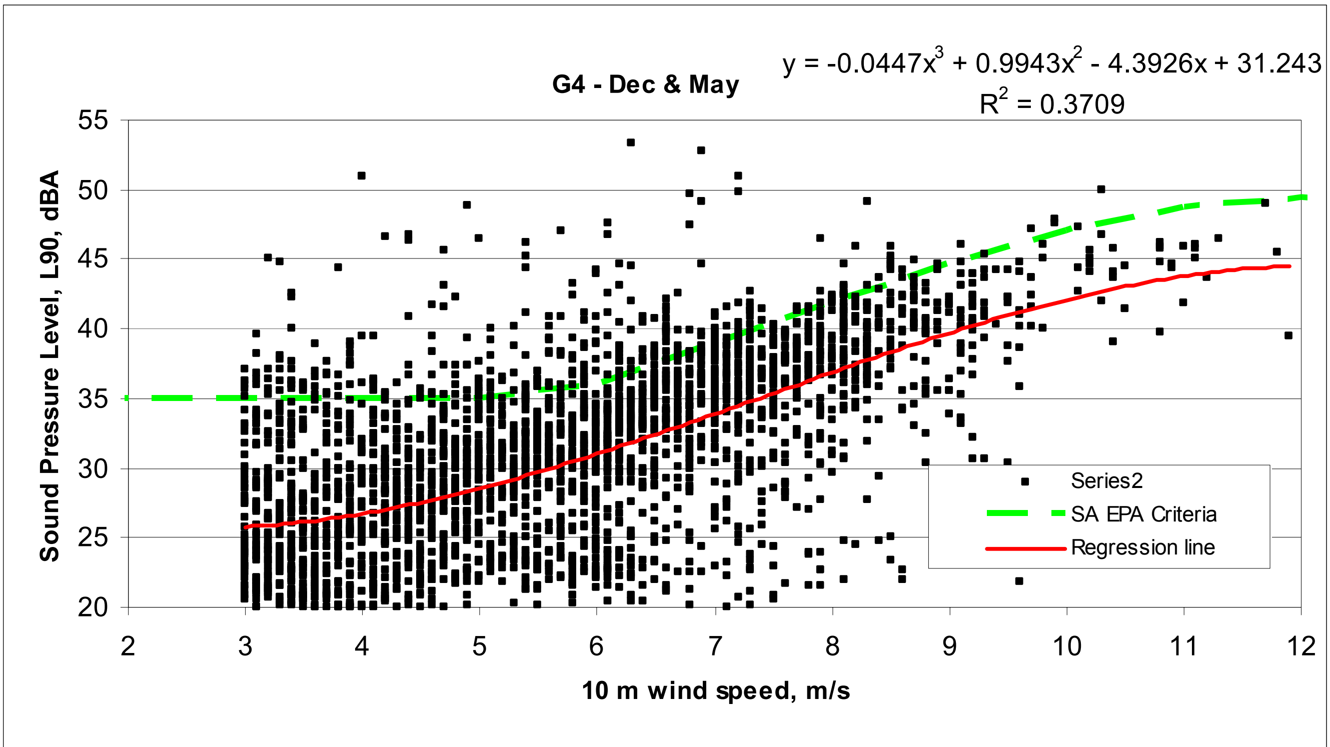
The final measurement location was established to the western edge of the entrance driveway as the original position was exposed to noise from a local pond pump.

The results of the background noise monitoring at this location during January and May 2006, showing the data points, line of best fit and the Noise Criteria Curve are shown in **Figure 13.**

Graphically represented noise statistical indices, are presented in **Appendix C4.**

The 'average' background level was 32.7 dBA.

Figure 13 Background Noise Measurements and Noise Criteria Curve - Ferndale



6.7 Location G17 - McGrath

The McGrath residence is located directly to the East of the proposed wind farm. The house has a westerly aspect. The measurement location is shown in **Figure 14.**

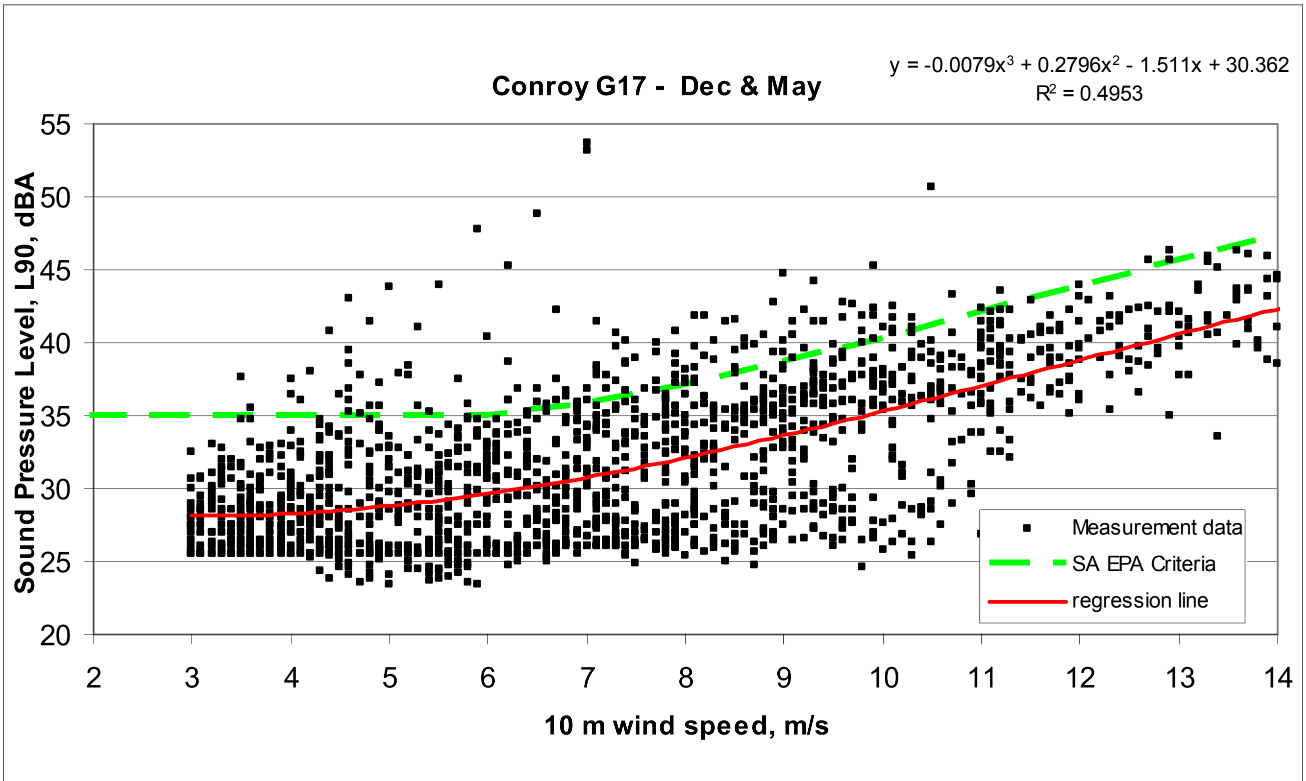
Figure 14 McGrath Measurement Location

The results of the background noise monitoring during the December 2005 and May 2006 campaigns, showing the combined data points, line of best fit and the Noise Criteria Curve are shown in **Figure 15.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix C5.**

The 'average' background level was 34.2 dBA.

Figure 15 Background Noise Measurements and Noise Criteria Curve - McGrath



6.8 Location G24 - Yowerweena

The Yowerweena residence is located directly to the East of the proposed wind farm. The house has a westerly aspect. The measurement location is shown in **Figure 16.**

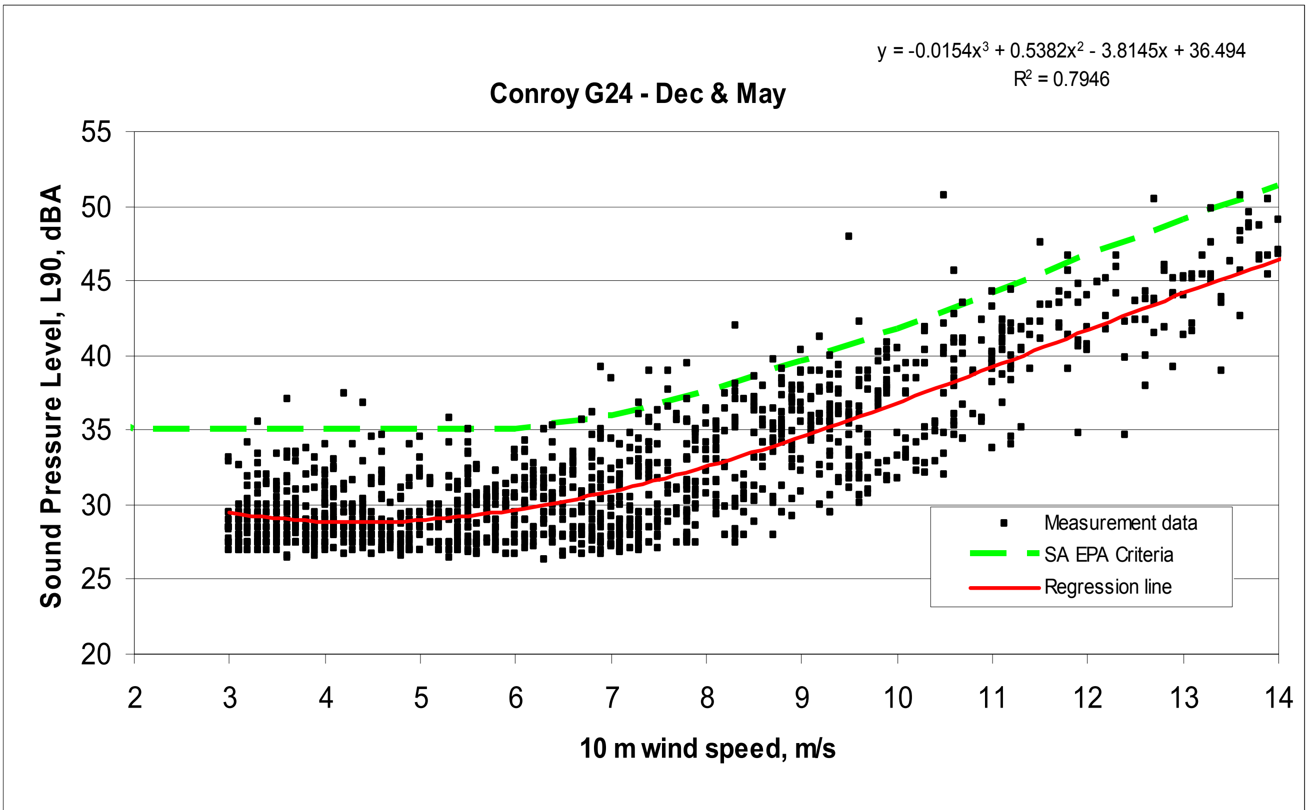
Figure 16 Measurement Location Yowerweena

The results of the background noise monitoring during the December 2005 and May 2006 campaigns, showing the combined data points, line of best fit and the Noise Criteria Curve are shown in **Figure 17.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix C6.**

The 'average' background level was 35.2 dBA.

Figure 17 Background Noise Measurements and Noise Criteria Curve - Yowerweena



6.9 Location G01 - Sutton Grange

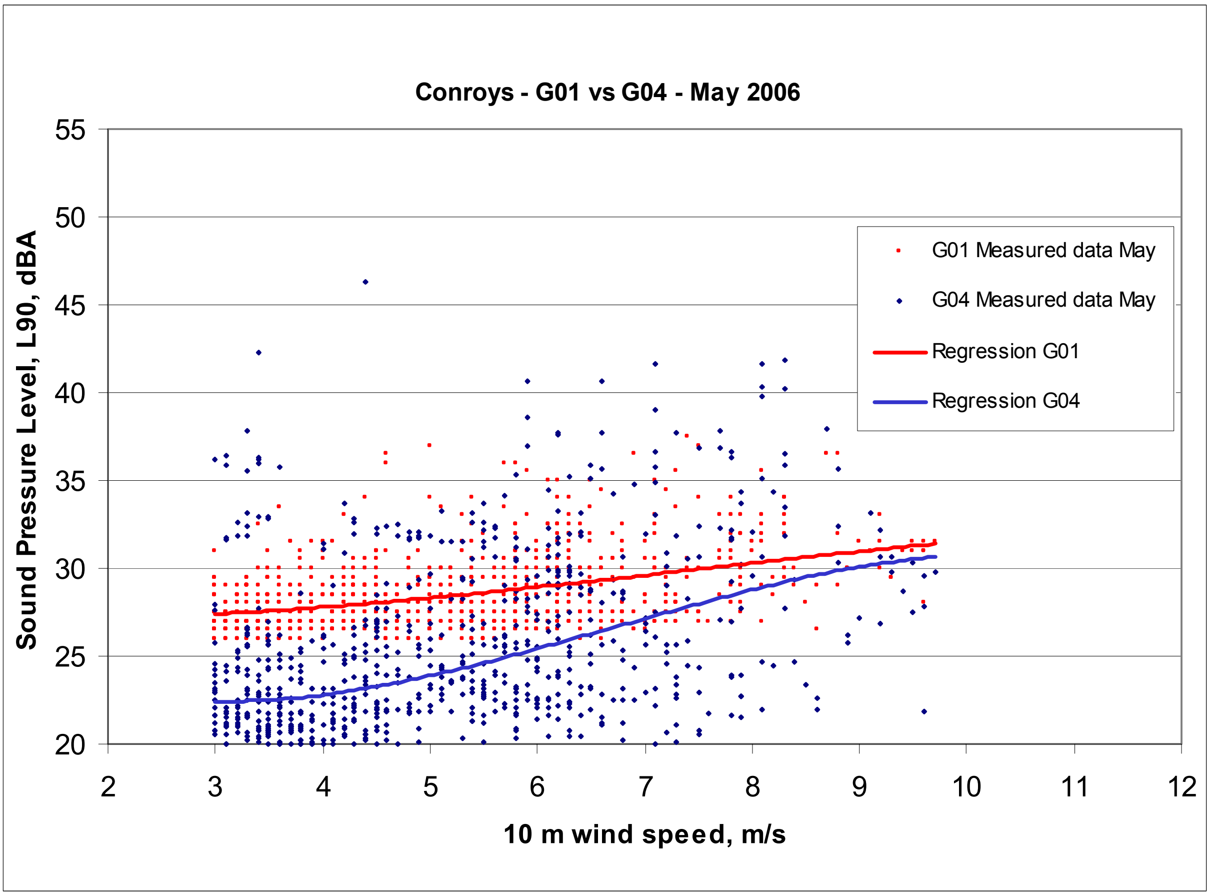
The Sutton Grange homestead is located directly to the South of the main range of the proposed wind farm and due West of the southern most cluster of WTG's. The house has a westerly aspect. The measurement location is shown in **Figure 18.**

Figure 18 Measurement location Sutton Grange

Noise monitoring at this location confirmed that the previous assumption of location G04's baseline at this location was valid, as dicussed previously, G04 was generally more conservative.

The results of the background noise monitoring during the May 2006 campaigns, showing the combined data points for locations G01 and G04 and their respective lines of best fit are shown in **Figure 19.**

Figure 19 Background Noise Measurement Comparison- Sutton Grange vs Ferndale - May



7 ACOUSTIC ASSESSMENT OF PROPOSED WIND FARM

7.1 Predicted Noise Levels

An assessment of the acceptability of wind farm noise levels at all assessment receivers located within a distance of 5 km of the proposed wind farm was made in accordance with SA EPA Guideline criteria and the pre-existing background noise level regression analysis detailed in **Section 6**. The assessment figures are contained in **Appendix A1, Appendix A2** and **Appendix A3**

7.1.1 Layout A - 15 Repower MM82 WTG's

Appendix A1 contains the predicted WTG noise level curves for Layout A, superimposed over SA EPA Guideline Criteria and World Health Organisation based limits. The predicted curves show that all locations comply to their respective criteria.

7.1.2 Layout B - 15 Vestas V90 (1.8 MW) WTG's

Appendix A2 contains the predicted WTG noise level curves for Layout B, superimposed over SA EPA Guideline Criteria and World Health Organisation based limits. The predicted curves show that all locations comply to their respective criteria.

7.1.3 Layout C - 14 Suzlon S88 WTG's

Appendix A3 contains the predicted WTG noise level curves for Layout C, superimposed over SA EPA Guideline Criteria and World Health Organisation based limits. The predicted curves show that most locations comply to their respective criteria.

Layout C, which includes 14 Suzlon S88 WTG's, was predicted to comply to WHO limits, and generally meet the SA EPA Guideline criteria at most locations.

Location G42, (Riverview), is predicted to exceed the SA EPA Guideline criteria by up to approximately 2.2 dBA in the wind speed range 3-6 m/s. Location G01, (Sutton Grange), is predicted to marginally exceed the SA EPA Guideline criteria by up to approximately 1 dBA in the wind speed range 3-6 m/s.

It is worth noting that the criteria for both Location G42 (Riverview) and Location G01 (Sutton Grange), is based on monitoring conducted at Location G04. Whilst geographically similar these locations would in practice have differing background noise level characteristics, where monitoring would be required to confirm the actual background at G42 and G01.

7.2 Assessment of Tonality and Infrasound

WTG manufacturers are obliged to conduct independent tests in accordance with IEC 61400-11. A part of this assessment is to conduct a tonal audibility test. The tonal audibility ∆Lta is typically assessed using the methodology outlined in '*Joint Nordic Method Version 2 – Objective Method for Assessing the Audibility of Tones in Noise'*.

For the proposed WTG's the following ∆Lta values were determined.

Table 13 Audible Tonality Assessment to IEC 61400-11

	Manufacturer / WTG - ∆Lta Value - Audible Tonality	
Wind Speed	**Repower MM82**	**Vestas V90 (1.8 MW)**
6	-14.4	-5.26
7	-13.3	-8.36
8	-14	-6.79
9	-14.4	-5.70
10	-14.4	-7.32

* Detailed WTG measurements are currently being conducted for the Suzlon S88 WTG, expected to be completed in late 2006

For the wind speed range analysed (6 – 10 m/s) tonality was not deemed to be audible (∆Lta <-3) and hence no penalty has been applied.

Infrasound is not tested as an obligatory part of IEC 61400-11. It is noted that in general modern WTG's do not exhibit significant infrasound emissions.

7.3 Temperature Inversions

The SA EPA Guideline does not require or suggest temperature inversions be included during wind farm noise assessments. The NSW Industrial Noise Policy states that temperature inversions be included in an assessment if they are deemed to be a prevalent feature of the environment, which generally requires they occur for greater than 30% of the total night-time during winter (Approximately 2 nights per week between hours of 6 pm to 7am). Currently there is insufficient data available to accurately determine the prevalence of temperature inversions, however, subjective comments received from local residents indicated that it was an effect that they had experienced and had some degree of familiarity with.

Temperature inversion is an atmospheric condition in which temperature increases with height above ground. Such conditions may increase noise levels by focussing sound wave propagation paths at a single point. Typically temperature inversions occurring within the lowest 50 m to 100 m of atmosphere can affect noise levels measured on the ground. Temperature inversions are most commonly caused by radiative cooling of the ground at night leading to cooling of the air in contact with the ground. Such conditions are especially prevalent on cloudless nights with little wind.

Conventional approaches to assessing noise propagation under temperature inversion conditions require knowledge of the temperature gradient and assume that the noise source is located below the temperature inversion, typically near to the ground. The effect of temperature inversions on noise propagation from WTG's is therefore not typical of other sources.

WTG's for the Conroy Gap Project are located on top of the Range, the hub height (assumed acoustic centre of the WTG) is located between 160 m - 200 m higher than receiver locations on the surrounding area. It is therefore unlikely that conventional temperature inversion conditions, in the lower 100 m of the atmosphere, would affect noise propagation from such an elevated source.

A further consideration must be that temperature inversions require little to no wind in order to minimise atmospheric mixing and hence develop. During calm conditions the WTG's are unlikely to operate, as cut-in speed is 3 m/s.

Notwithstanding the above, an adaptive management approach could be implemented if undue noise impacts are identified during WTG operation that are related to temperature inversion effects.

7.4 Atmospheric Stability and Wind Profile

The wind velocity at a location can be represented by a vertical profile (gradient) that generally is at a minimum at ground level and increases with altitude. The wind velocity profile is primarily determined by physical factors such as surface roughness and topographic (relief) effects which are reasonably constant over time, however can also be affected by more variable local atmospheric conditions including atmospheric stability and turbulence.

Atmospheric stability is determined by the total heat flux to the ground, primarily being the sum of incoming solar and outgoing thermal radiation and heat exchanged with the air. During clear summer days (incoming radiation dominates) air is heated from below and rises, causing significant thermal mixing, vertical air movements and turbulence. This process limits large variations in the vertical wind velocity profile.

During clear nights (outgoing radiation dominates) air is cooled from below, air density is greatest closer to the ground and minimal thermal mixing occurs. This leads to a stable atmosphere where horizontal layers of air are largely decoupled and allows for a higher wind velocity gradient.

The noise assessment methodology outlined in the SA EPA Guidelines, as do many other similar wind farm noise assessment methodologies, by necessity rely on the independently verified reference sound power data available for specific wind turbines measured at a manufacturer's test site. The measurement procedure has been standardised to require sound power data to be measured coincidentally with reference wind speed measurements at an altitude of 10 metres. This is then applied at a specific site (e.g. at Conroys Gap) by using a reference wind speed altitude of 10 metres (as measured at the monitoring tower positioned on top of the range) to relate background noise levels to wind conditions present at the same time. The turbine noise power can then be applied and compared with background data at those same conditions of wind speed at 10m above ground level with good accuracy.

The assessment procedure inherently assumes a fixed relationship between the 10 metre reference altitude and that at which the WTG operates, and that the relationship is the same during IEC 61400-11 test conditions. In practice, as discussed above, the wind velocity profile will vary as a result of ground roughness and atmospheric (stability) effects. The varying profile will likely result in variation in WTG noise emission levels, however, the extent to which levels will vary is difficult to quantify, as the IEC 61400-11 wind profile test conditions are not made available to allow comparison with the subject site.

Accordingly, while the proposed layouts meet the requirements of the SA EPA Guidelines, some uncertainty remains as to the likely noise conditions that will result under specific atmospheric conditions over time. The SA EPA Guidelines noise limits are generally set within the requirements of the WHO Guidelines which relate to health impacts, and it is highly unlikely that the remaining uncertainty could lead to health impacts. However, it is possible that under certain conditions the amenity of existing dwellings could be reduced notwithstanding compliance with SA EPA Guidelines. These conditions are likely to be variable and intermittent, and not result in a long-term loss in amenity.

Notwithstanding the above, an adaptive management approach could be implemented if undue noise impacts are identified during WTG operation that are related to elevated WTG noise levels during stable atmosphere conditions.

7.5 Project involved residences

The proponent Taurus Energy intends to enter into noise agreements with project involved residences of Springvale, Sunnyside, Linbrook and Ferndale prior to construction. Under the SA EPA Guidelines these residences are not required to comply to the 35 dBA or background + 5 dBA limits. However, it is necessary to ensure that the project does not result in an 'unreasonable interference' with the amenity of these areas or cause any adverse health affects.

The World Health Organisation (WHO) publication '*Guidelines for Community Noise'* identifies the main health risks associated with noise and derives acceptable environmental noise limits for various activities and environments.

For the assessment of project involved residences the adopted external criteria of 45 dBA or the level given by the SA EPA Guideline criteria, where higher, will be adopted. Effectively this becomes 45 dBA or background + 5 dBA, whichever is the higher.

The predicted noise levels depicted in **Appendix A1, A2** and **A3** are predicted free field noise levels. The noise level at the bedroom façade of a particular location is likely to be less than the predicted free field value as the orientation the building will offer some shielding from some turbine sources.

Therefore, the WHO guideline noise goals, shown in **Table 1,** are predicted to be met for all project involved receivers and layouts.

8 ASSESSMENT OF CONSTRUCTION NOISE LEVELS

The NSW EPA construction noise guidelines recommend noise level goals and hours for work.

The hours of work for construction sites is limited from 7:00 am to 6:00 pm weekdays and 7:00 am to 1:00 pm on Saturdays, with no construction taking place on Sundays or Public Holidays.

For construction programmes that are shorter in duration (less than 4 weeks) it is considered acceptable for construction noise levels to exceed background noise levels by up to 20 dBA. For construction periods of less than 26 weeks (6 months) it is considered acceptable for construction noise levels to be up to 10 dBA above background noise levels.

8.1 Construction Noise

Construction activities include;

- construction of access roads,
- establishment of turbine tower foundations and electrical substation,
- digging of trenches to accommodate underground power cables,
- erection of turbine towers and assembly of WTG's.

The equipment required to complete the above tasks will typically include;

- excavator/grader, bulldozer, dump trucks, roller
- bucket loader, rock breaker, drill rig, excavator/grader, bulldozer, trucks (dump, flat beds, concrete)
- excavator, flat bed trucks
- cranes, fork lift, and various 4WD and service vehicles.

The anticipated construction period is anticipated to be less than 6 months, with civil works expected to span approximately 3 months, however, due to the large area of the wind farm site, intensive works will be located within a distance of potential impact for each surrounding residential receiver for only very short and intermittent periods of time. It is therefore considered appropriate that construction noise levels up to 20 dBA above background noise levels would be considered acceptable for short term intensive civil works that are anticipated to produce high noise levels.

Computer noise models of typical construction scenarios were developed which included all anticipated mobile equipment for the activity operating simultaneously at full load. A de-rating factor of 5 dBA was selected to convert modelled full load simultaneous operation to typical operations of multiple mobile construction vehicles.

Two 'worst case' area of works were chosen;

- for the northern area of the site
- for the central area of the site, near Black Range Road

The resulting predicted construction noise level for the relevant 'worst case' scenario is detailed in **Table 14** together with typical background noise levels obtained during the background noise monitoring campaign.

Table 14 ‘Worst case’ Construction L_{Aeq} Noise Levels (dBA)

			Construction in 'Worst Case' Northern Area of Wind Farm				Construction in 'Worst Case' Central Area of Wind Farm			
	Typical Background LA90	Short Term (<4weeks) Construction Noise Limit	Trench excavation	Access road construction	Turbine foundation establishment	WTG erection	Trench excavation	Access road construction	Turbine foundation establishment	WTG erection
01 Sutton Grange	32.7	52.7	-	12	19.1	4.2	16.2	40.6	28.2	14.1
G02 Grenville	40.1	60.1	-	9.7	15	0.6	19	41.8	23.9	16.4
G02a Grenville 2	32.7	52.7	6.1	15	21.4	6	19	33.4	22.4	16.9
G03 Bogo	32.7	52.7	4	13.7	18.8	3.8	14.7	35	22.5	12.4
G04 Ferndale	32.7	52.7	8.3	17.6	24.7	9.9	20.6	40.3	48.1	22
G04a Kaveney	32.7	52.7	4.1	22.1	30	15.3	3.3	22.7	36.2	20.7
G04b Proposed	32.7	52.7	8.8	19.6	26.6	11.8	24.4	32.3	54.2	27.3
G05 Wattle Valle	34.2	54.2	5.7	15.5	33.9	19.1	12.2	19.8	39.5	13.5
G06 Riverlea	34.2	54.2	-	13.6	21.5	6.6	2	15.7	24.6	9.3
G07 Bernado	34.2	54.2	4.1	21.6	29.8	15	4.3	20.8	33.5	18
G08 Springvale	34.2	54.2	3.3	21.9	29.9	15.2	3.8	21.8	34.8	19.3
G09 Sunnyside	34.2	54.2	4.1	30.5	38.6	23.8	12.1	19.7	31.3	15.8
G10 Linbrook	35.3	55.3	1.9	17.5	18.4	3.6	7	12.5	38.2	23.4
G11 Tannochbrae	35.2	55.2	5.7	17.9	37	21.9	1.3	8.7	18.7	3.6
G12 House	35.2	55.2	7.5	15.8	23.5	8.3	-	6.6	16.2	1.2
G13 Woodleigh	35.2	55.2	4.7	12	19.4	4.2	-	4.5	13.6	-
G13 Woodleigh	35.2	55.2	4.7	12	19.4	4.2	-	4.5	13.6	-
G14 Bellevue Hil	35.2	55.2	5.7	12.9	20.2	5	-	5	14.1	-
G15 Marilba	35.2	55.2	6.5	13.9	17.8	3	0.3	6.9	15.6	0.7
G16 Malcom van	35.2	55.2	10.5	18.1	23.2	7.8	4.7	11.2	30.6	15.8
G17 Ian & Una	34.2	54.2	4.8	20.3	39	24.2	11.8	21	33	17.5
G18 Elvington	35.2	55.2	2.9	10.4	28.9	13.8	-	4	13.1	-
G19 Rose Hill	35.2	55.2	2.9	10.5	29	14	-	4.3	13.4	-
G20 Sreath Dubh	35.2	55.2	-	18.4	27.2	12.2	4.3	11.3	21.7	6.5
G23 Jilla Colo	35.2	55.2	-	19	27.8	12.9	-	14.3	25.1	9.9
G24 Yowerweena	35.2	55.2	4	32.9	41.7	26.9	9.5	17.2	39.9	24.5
G26 Cooinda	32.7	52.7	4.5	13.6	19.7	4.8	13	33.3	25.2	11.3
G27 Fairview	32.7	52.7	-	7.8	14.4	-	6.6	17.3	20.1	15.9
G28 Lynn Lee	32.7	52.7	-	3.9	10.6	-	0.7	21.3	14.8	-
G29 Bogo Cottage	35.3	55.3	5.4	12.5	13.9	-	11.3	18.3	25.5	21.5
G32 House	35.2	55.2	18.1	25.4	20.9	5.8	-	7.1	16	1
G33 House	35.2	55.2	5.6	23.6	19.3	4.2	-	5.9	25.3	10.3
G38 Waterview	35.2	55.2	5.2	23.5	31.6	16.5	-	6.1	15.5	0.4
G41 Proposed house	35.2	55.2	7.2	25.7	34	18.9	-	-	-	-
42 Riverview	32.7	52.7	-	7.8	14.8	-	4.2	25.4	18.2	3.2
G43 Ildemere	32.7	52.7	-	5.9	12.8	-	0.4	21	14.5	-
G44 House	32.7	52.7	3.4	-	-	-	-	9.8	14.1	-
G45 Bertangles	32.7	52.7								
G46 House	32.7	52.7	-	5.3	12.6	-	2.3	12.3	16.2	1.4
G47 House	32.7	52.7	-	3.7	12.1	-	2.5	12.2	16.7	1.8
G48 House	32.7	52.7	-	3	12.1	-	2.3	12.1	16.1	1.1
G49 House	32.7	52.7	-	4.6	11.9	-	2.4	12.1	16.4	1.5
G50 House	32.7	52.7	-	4.7	12.1	-	-	4.9	1.1	-

The predicted ‘worst case’ construction noise impacts are for most receiver locations below the existing typical daytime background noise level.

Some nearby receivers are anticipated to receive elevated construction noise levels when turbine foundation civil works are located nearby, however, due to the anticipated short period of localised works would likely be considered satisfactory.

In consideration that the predicted levels represent ‘worst case’ construction scenarios and are within limits which would be considered acceptable, it is unlikely that construction noise will cause any unnecessary impact.

8.2 Blasting

8.2.1 Applicable Criteria

The ground vibration and airblast levels which cause concern or discomfort to residents are generally lower than the relevant building damage limits.

The NSW EPA advocates the use of the ANZECC guidelines for assessing potential residential disturbance arising from blast emissions. 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 during the hours of 9:00 am to 5:00 pm 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 15**.

Table 15 Blast Emission Building Damage Assessment Criteria (AS 2187)

Building Type	Vibration Level	Airblast Level (dB re 20 µPa)
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

8.2.2 Blasting Assessment

As part of the civil works it is expected that infrequent blasting will be required to clear obstacles and prepare WTG foundations. It is anticipated that a single blast every 2-3 days may be required for a period of approximately 2 weeks.

Blasting may be required in some areas to clear large rock outcrops to prepare turbine foundations.

The proposed wind farm site is a green field site where no previous blasting or blast monitoring has been conducted and therefore no specific site laws exist. We have therefore adopted a site law derived from measurement data at a different site to give an indicative result.

The 5% site laws for ground vibration and airblast are:

Ground Vibration $PVS\ (5\%) = 16202\ (SD_1)^{-2.03}$

Airblast $SPL(5\%) = 189.3 - 31.8 \log (SD_2)$

where PVS (5%) and SPL (5%) are the levels of ground vibration (Peak Vector Sum - mm/s) and airblast (dB Linear) respectively, above which 5% of the total population (of data points) will lie, assuming that the population has the same statistical distribution as the underlying measured sample.

SD_1 and SD_2 are the ground vibration and airblast scaled distances, where:

$$SD_1 = \frac{\text{Distance}}{\sqrt{MIC}} \quad (m.kg^{-0.5})$$

and,

$$SD_2 = \frac{\text{Distance}}{\sqrt[3]{MIC}} \quad (m.kg^{-0.33})$$

Based on the blast emissions site laws, calculations were also conducted to indicate the allowable MIC's for compliance with the general EPA Human Comfort criteria of 115 dB Linear (airblast) and 5 mm/s (ground vibration).

The closest anticipated distance between blasting and residences would be approximately 640 metres (location G04b, proposed house and WTG V10). At this distance the predicted maximum MIC of up to 26 kg is likely to produce an airblast overpressure below the acceptable level of 115 dB Linear. At the distance to the nearest existing residence a predicted maximum MIC of up to is 50 kg is likely to produce an airblast overpressure below the acceptable level of 115 dB Linear.

It is evident that the anticipated blasting is likely to meet all human comfort limits and building damage assessment criteria are easily met.

9 CONCLUSION

WTG noise has been predicted and assessed against relevant criteria prescribed by the SA EPA Guideline and World Health Organisation goals where appropriate.

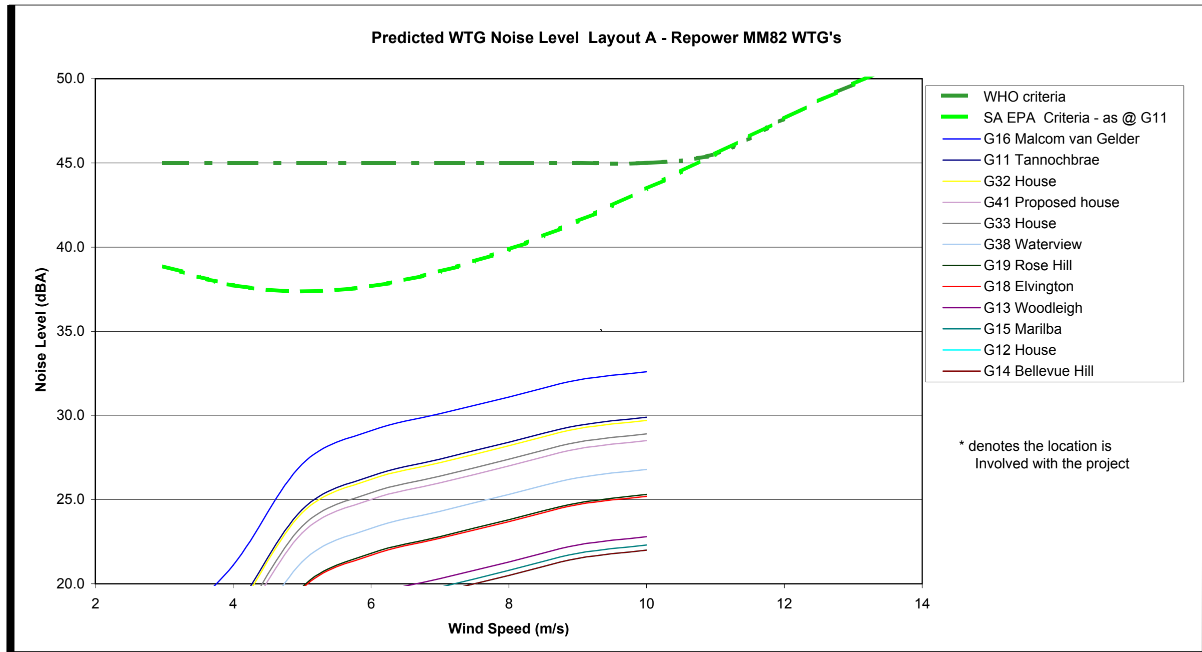
Layout A which includes 15 Repower MM82 WTG's was predicted to comply to all relevant noise criteria, SA EPA Guideline and WHO limits, at all respective receivers.

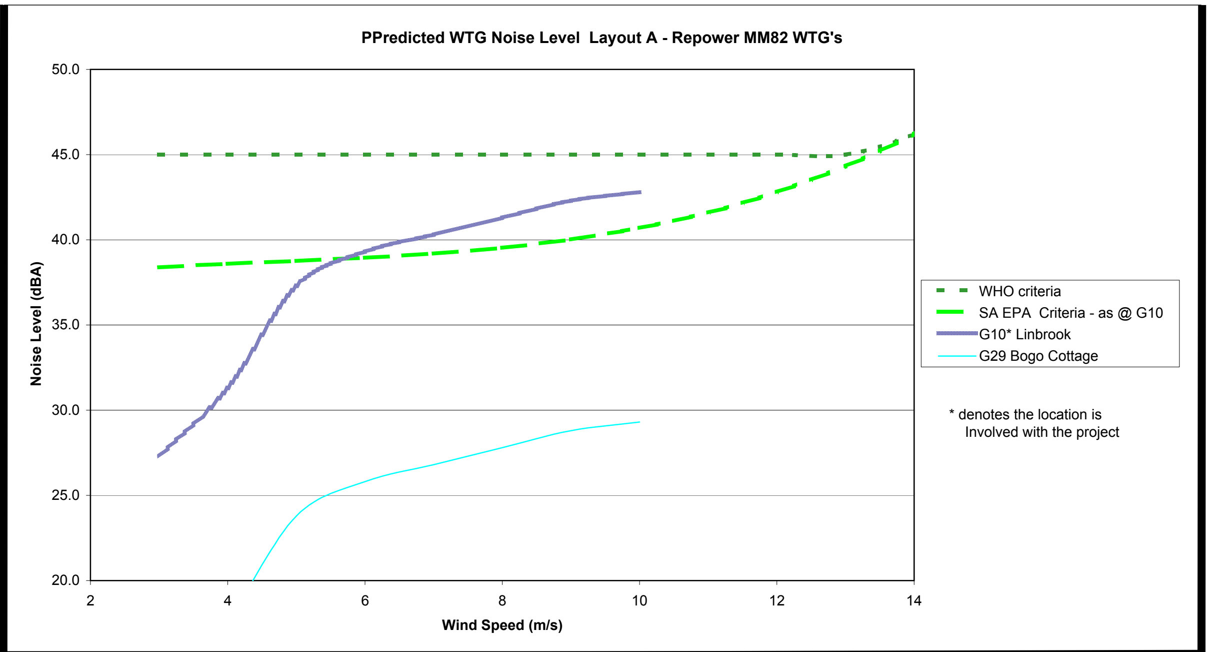
Layout B which includes 15 Vestas V90 WTG's was predicted to comply to all relevant noise criteria, SA EPA Guideline and WHO limits, at all respective receivers.

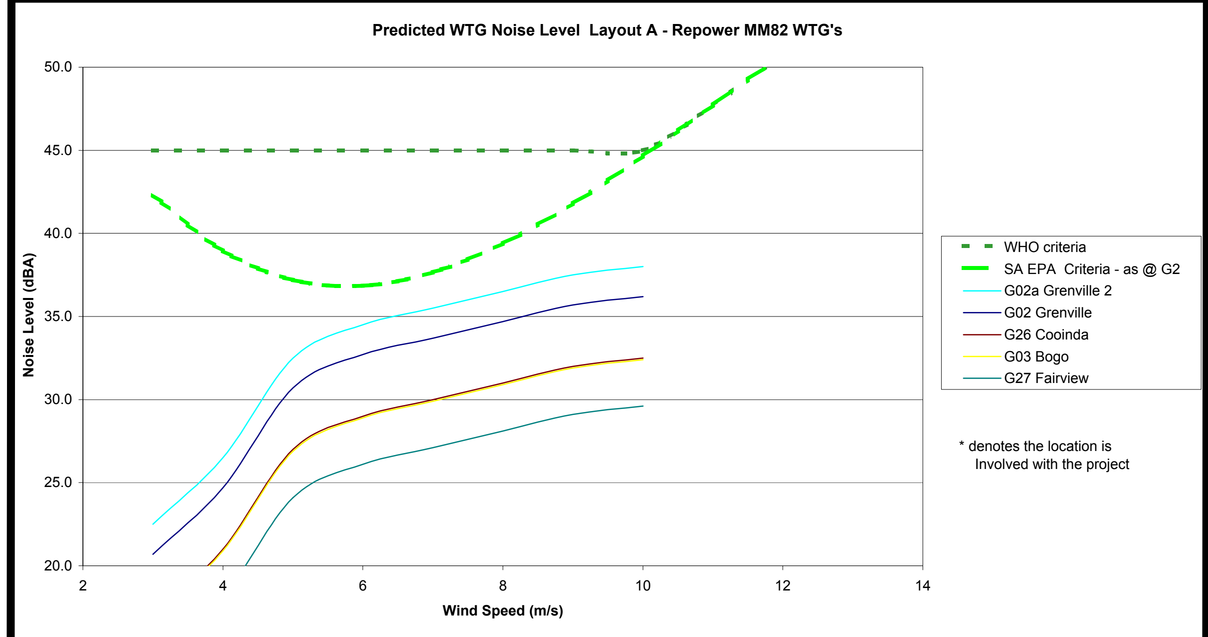
Layout C, which includes 14 Suzlon S88 WTG's, was predicted to comply to WHO limits, and generally meet the SA EPA Guideline criteria at most locations. Location G42, (Riverview), is predicted to exceed the SA EPA Guideline criteria by up to approximately 2.6 dBA in the wind speed range 3-6 m/s. Location G01, (Sutton Grange), is predicted to marginally exceed the SA EPA Guideline criteria by up to approximately 1.4 dBA in the wind speed range 3-6 m/s. These would be considered a marginal exceedance and noise monitoring at these locations would be required at this location to comprehensively confirm the ambient baseline noise conditions at this location.

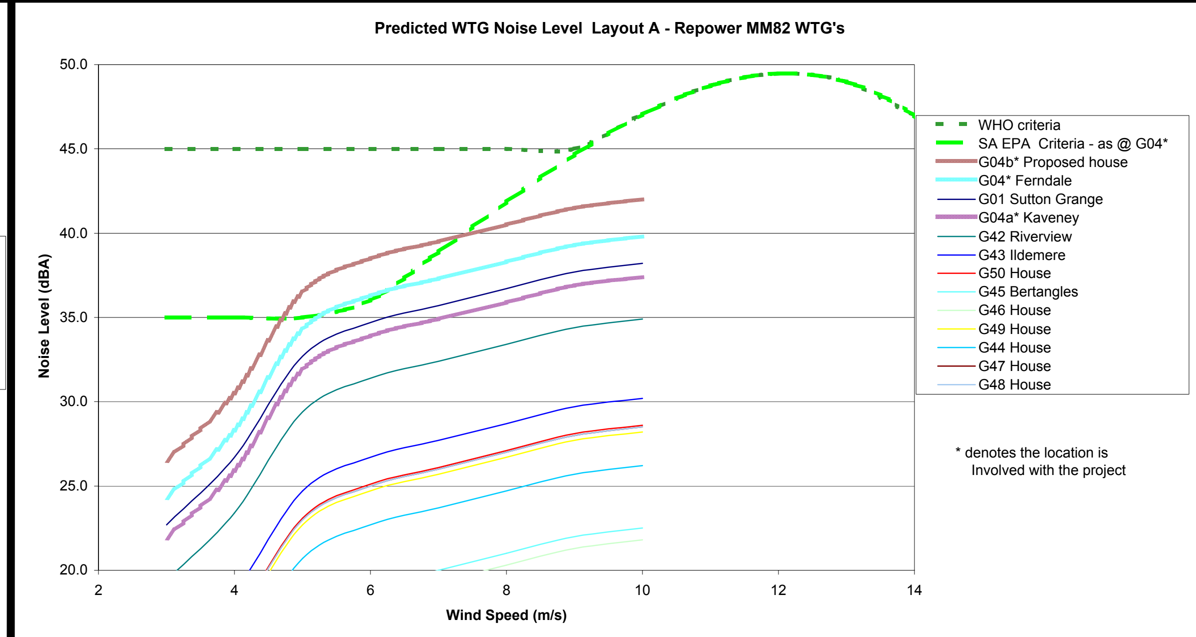
Construction noise impact has been assessed and the 'worst case' scenario's modelled were found to be acceptable.

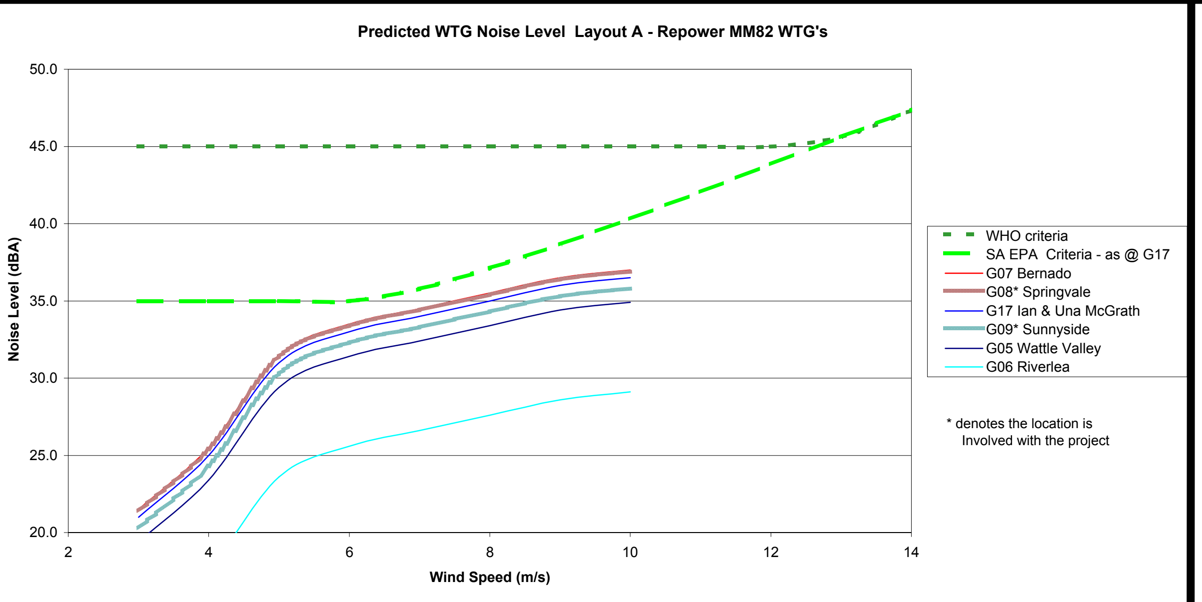
Blasting impact has been assessed and found to be acceptable. With a maximum MIC of up to 50 kg, the airblast overpressure is anticipated to be below the acceptable level of 115 dB Linear for all existing residences.

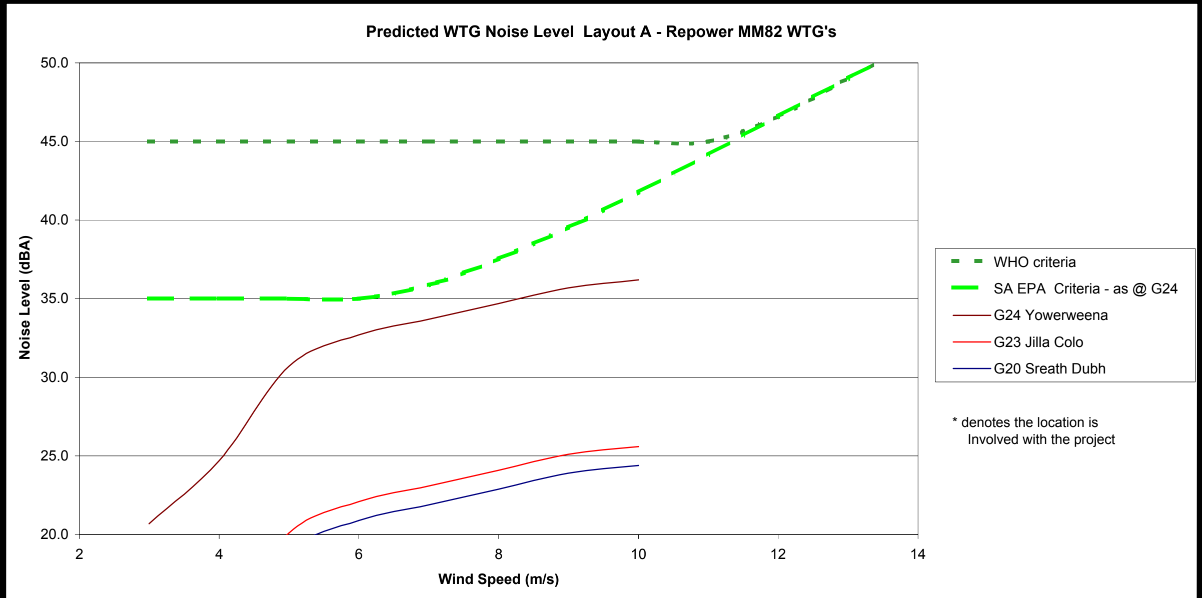

Predicted WTG Noise Level Layout A - Repower MM82 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G11
G16 Malcom van Gelder
G11 Tannochbrae
G32 House
G41 Proposed house
G33 House
G38 Waterview
G19 Rose Hill
G18 Elvington
G13 Woodleigh
G15 Mariiba
G12 House
G14 Bellevue Hill
* denotes the location is Involved with the project

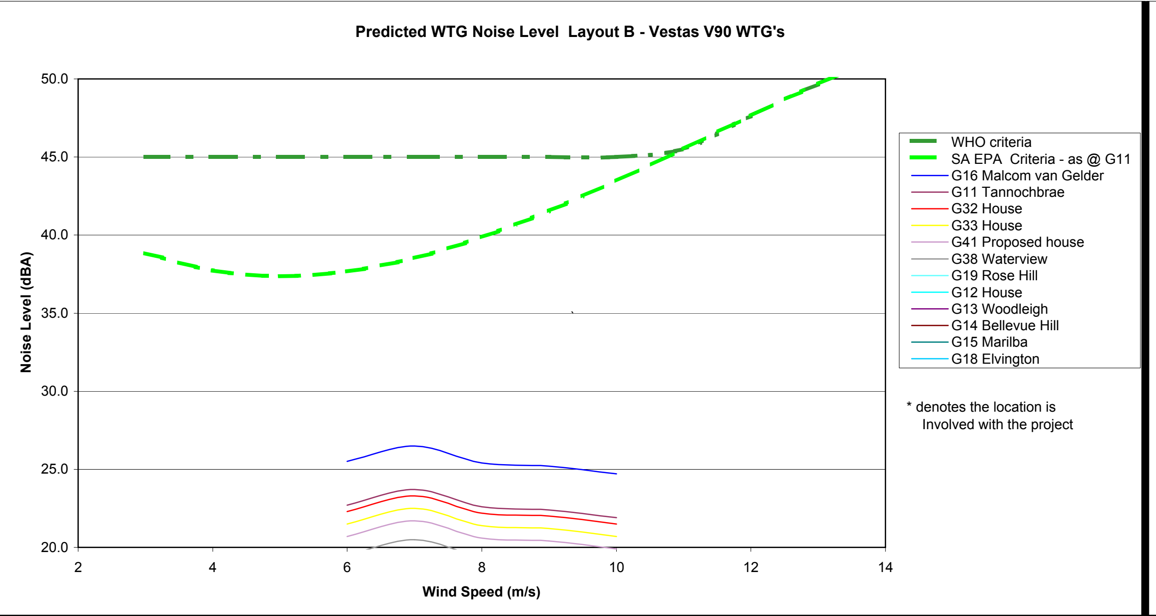

PPredicted WTG Noise Level Layout A - Repower MM82 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G10
G10* Linbrook
G29 Bogo Cottage
* denotes the location is Involved with the project


Predicted WTG Noise Level Layout A - Repower MM82 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G2
G02a Grenville 2
G02 Grenville
G26 Cooinda
G03 Bogo
G27 Fairview
* denotes the location is Involved with the project

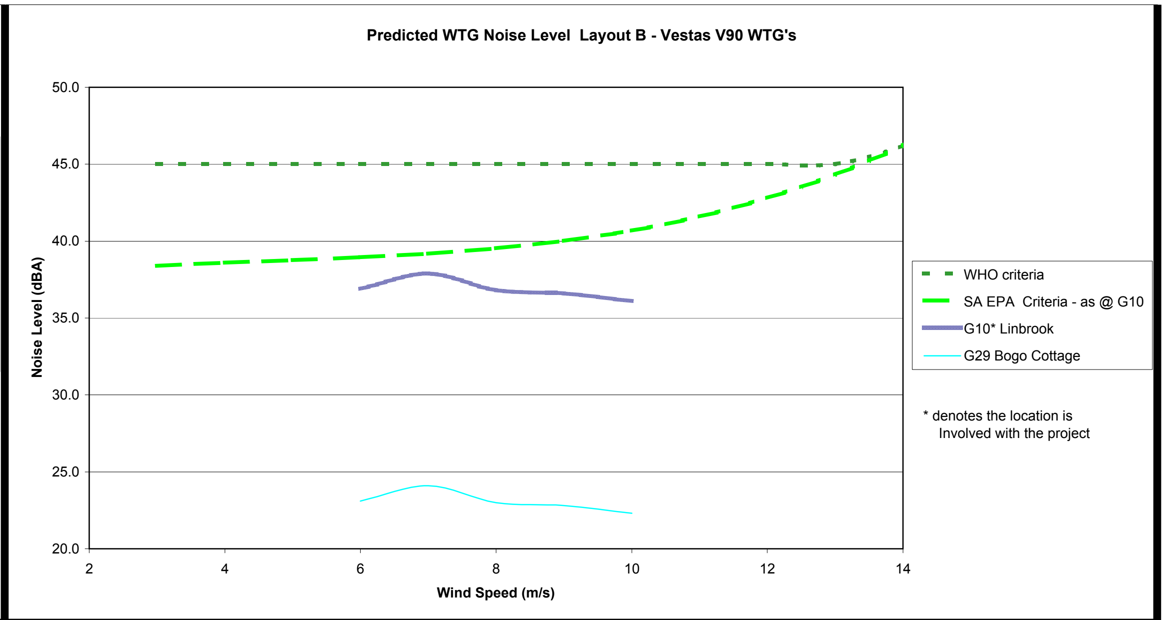

Predicted WTG Noise Level Layout A - Repower MM82 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G04*
G04b* Proposed house
G04* Ferndale
G01 Sutton Grange
G04a* Kaveney
G42 Riverview
G43 Ildemere
G50 House
G45 Bertangles
G46 House
G49 House
G44 House
G47 House
G48 House
* denotes the location is Involved with the project


Predicted WTG Noise Level Layout A - Repower MM82 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G17
G07 Bernado
G08* Springvale
G17 Ian & Una McGrath
G09* Sunnyside
G05 Wattle Valley
G06 Riverlea
* denotes the location is Involved with the project

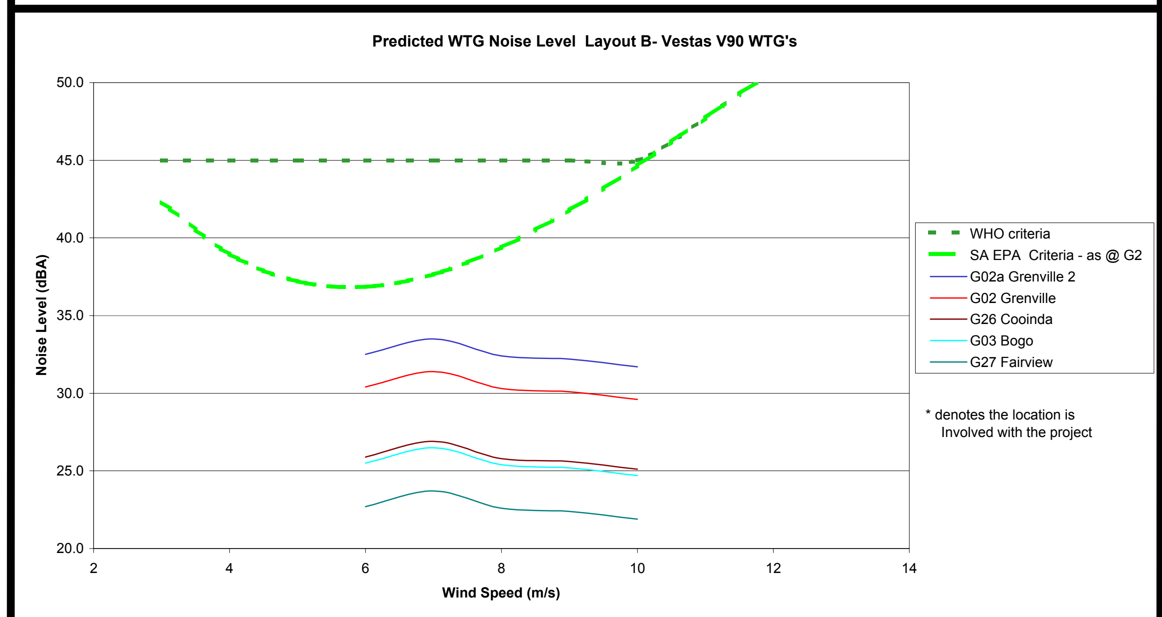

Predicted WTG Noise Level Layout A - Repower MM82 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G24
G24 Yowerweena
G23 Jilla Colo
G20 Sreath Dubh
* denotes the location is Involved with the project



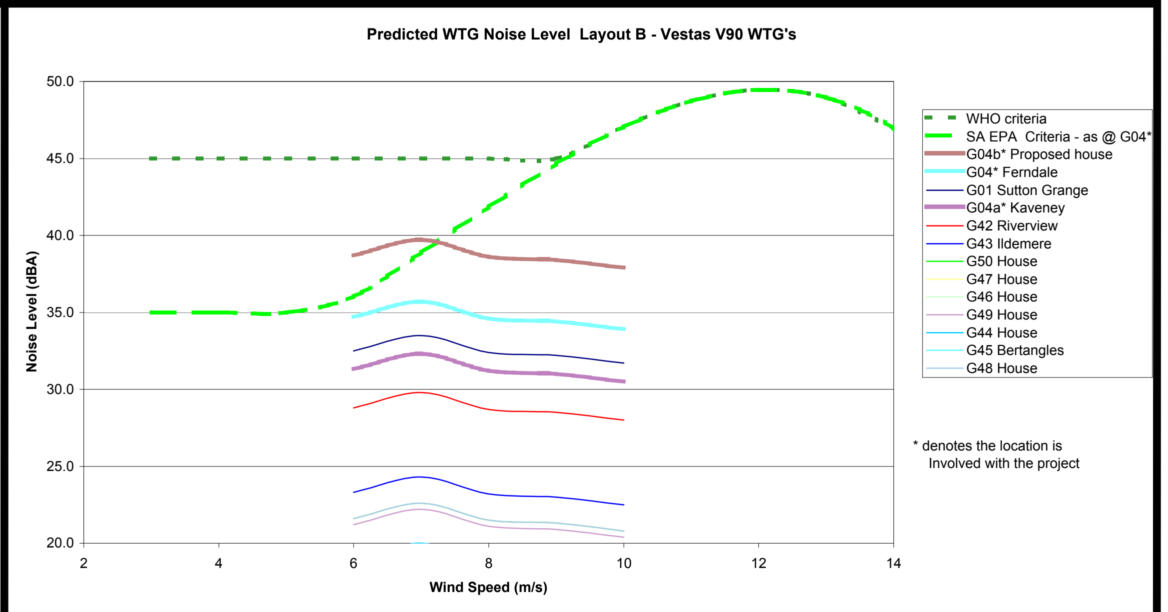
Predicted WTG Noise Level Layout B - Vestas V90 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G11
G16 Malcom van Gelder
G11 Tannochbrae
G32 House
G33 House
G41 Proposed house
G38 Waterview
G19 Rose Hill
G12 House
G13 Woodleigh
G14 Bellevue Hill
G15 Marilba
G18 Elvington
* denotes the location is Involved with the project



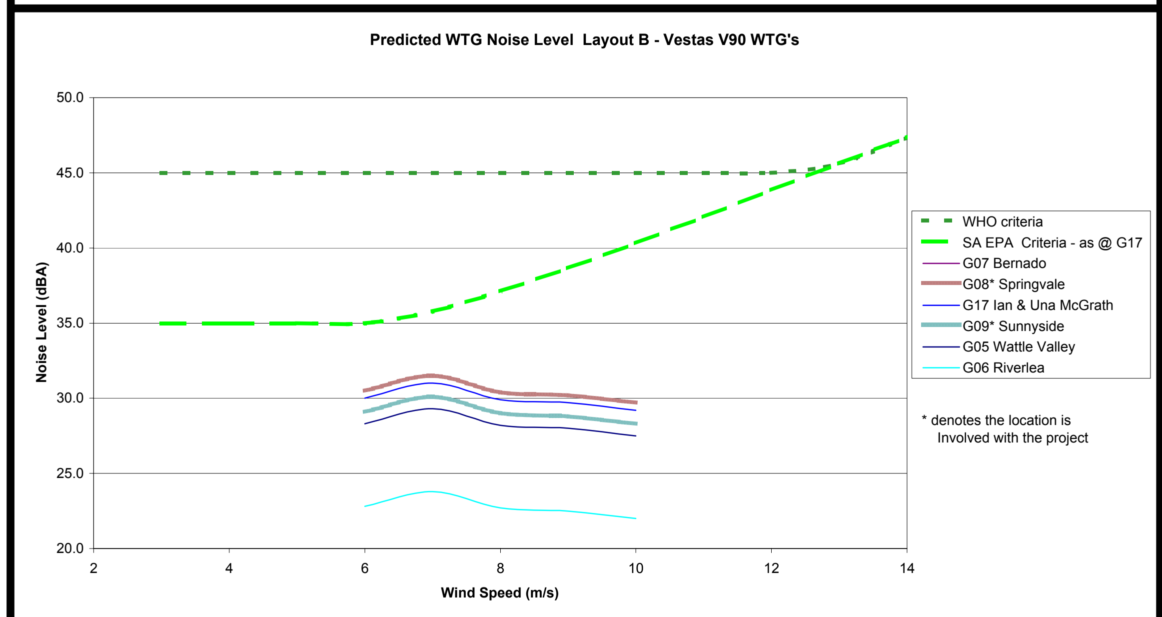
Predicted WTG Noise Level Layout B - Vestas V90 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G10
G10* Linbrook
G29 Bogo Cottage
* denotes the location is Involved with the project



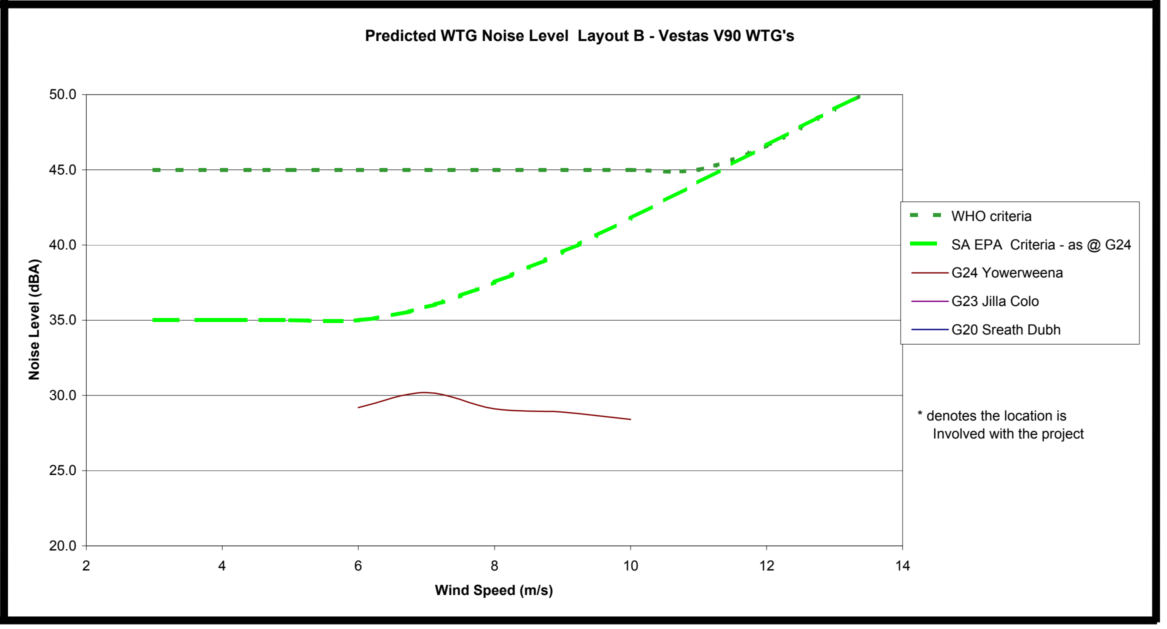
Predicted WTG Noise Level Layout B- Vestas V90 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G2
G02a Grenville 2
G02 Grenville
G26 Cooinda
G03 Bogo
G27 Fairview
* denotes the location is Involved with the project



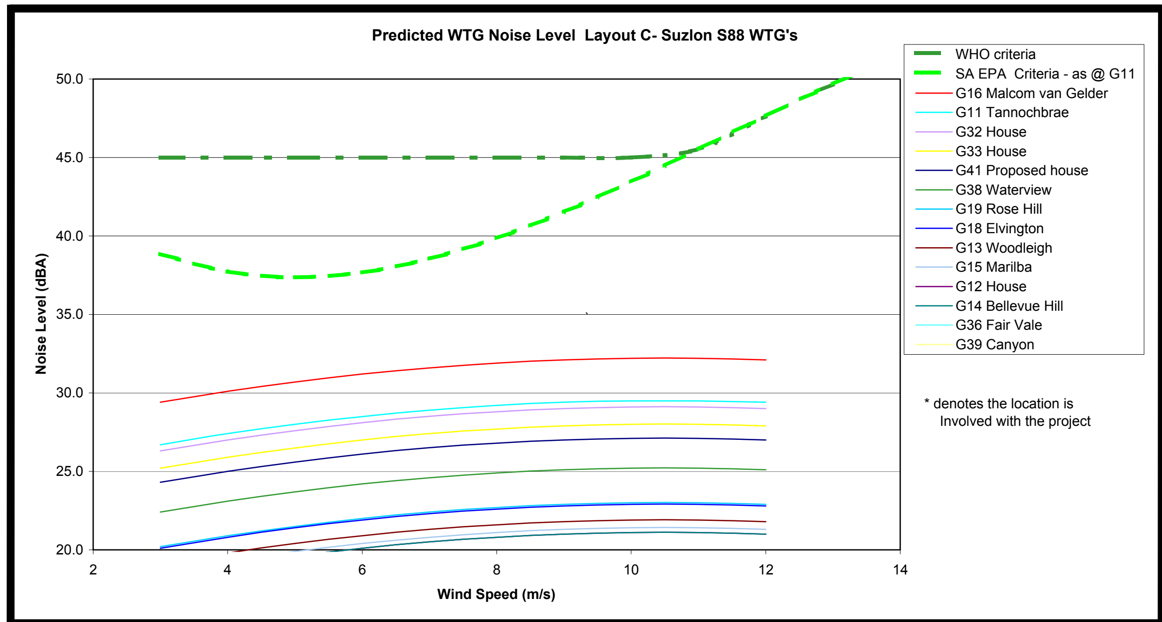
Predicted WTG Noise Level Layout B - Vestas V90 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G04*
G04b* Proposed house
G04* Ferndale
G01 Sutton Grange
G04a* Kaveney
G42 Riverview
G43 Ildemere
G50 House
G47 House
G46 House
G49 House
G44 House
G45 Bertangles
G48 House
* denotes the location is Involved with the project

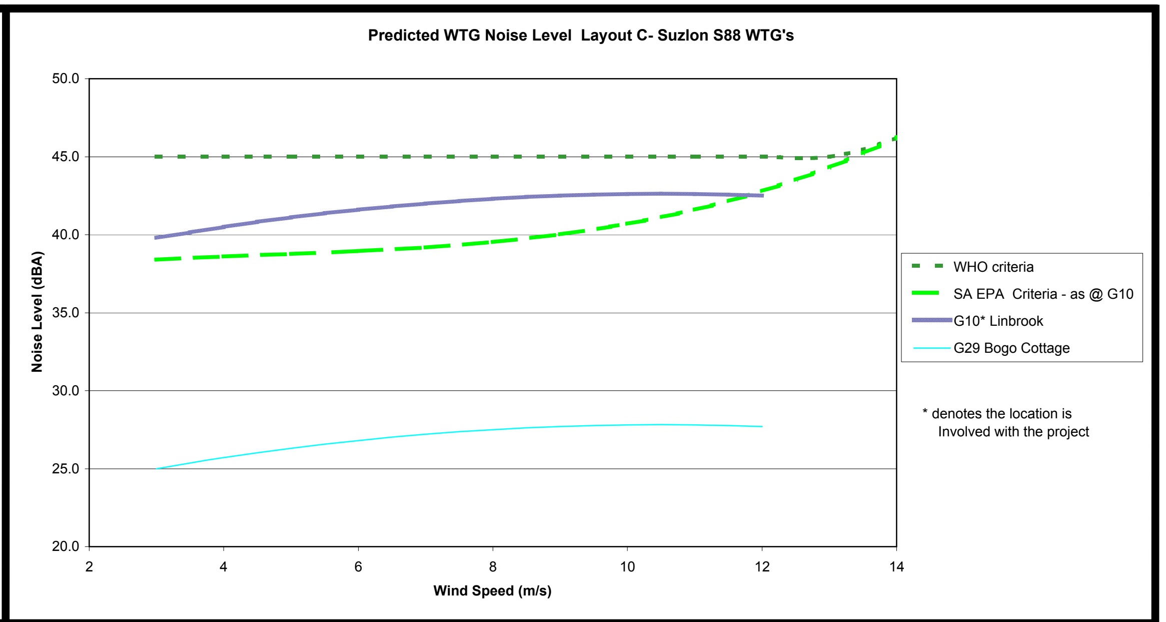


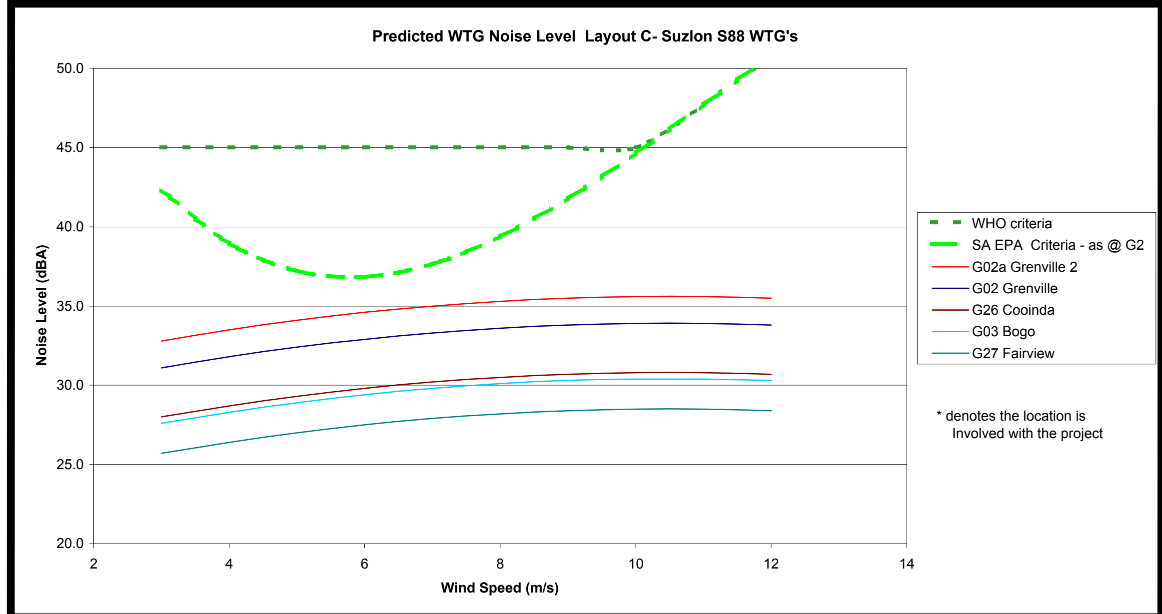
Predicted WTG Noise Level Layout B - Vestas V90 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G17
G07 Bernado
G08* Springvale
G17 Ian & Una McGrath
G09* Sunnyside
G05 Wattle Valley
G06 Riverlea
* denotes the location is Involved with the project

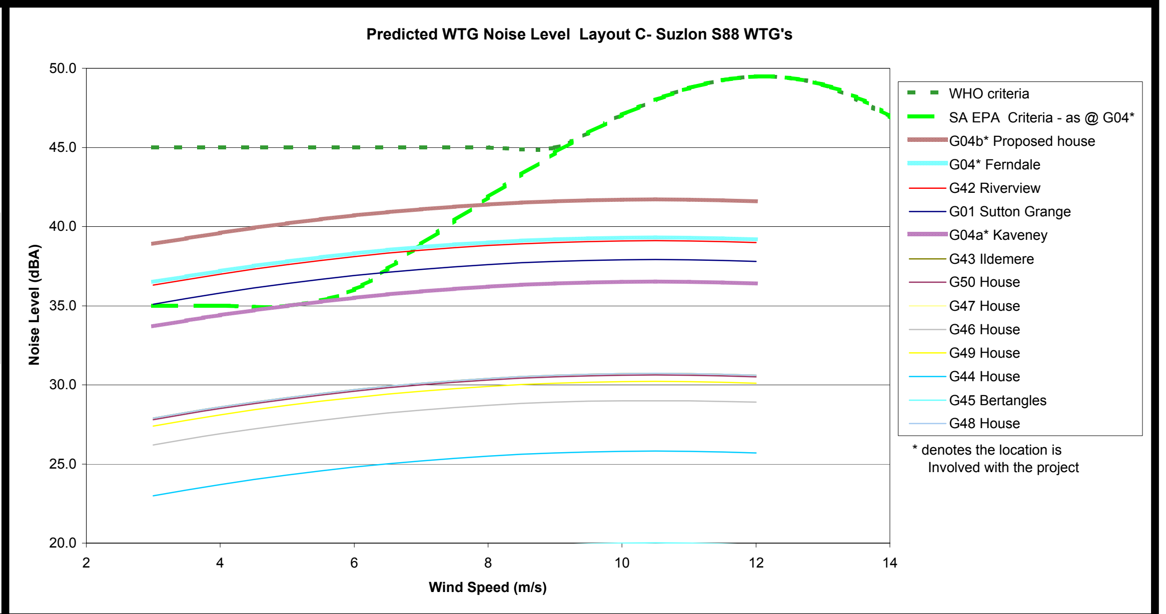


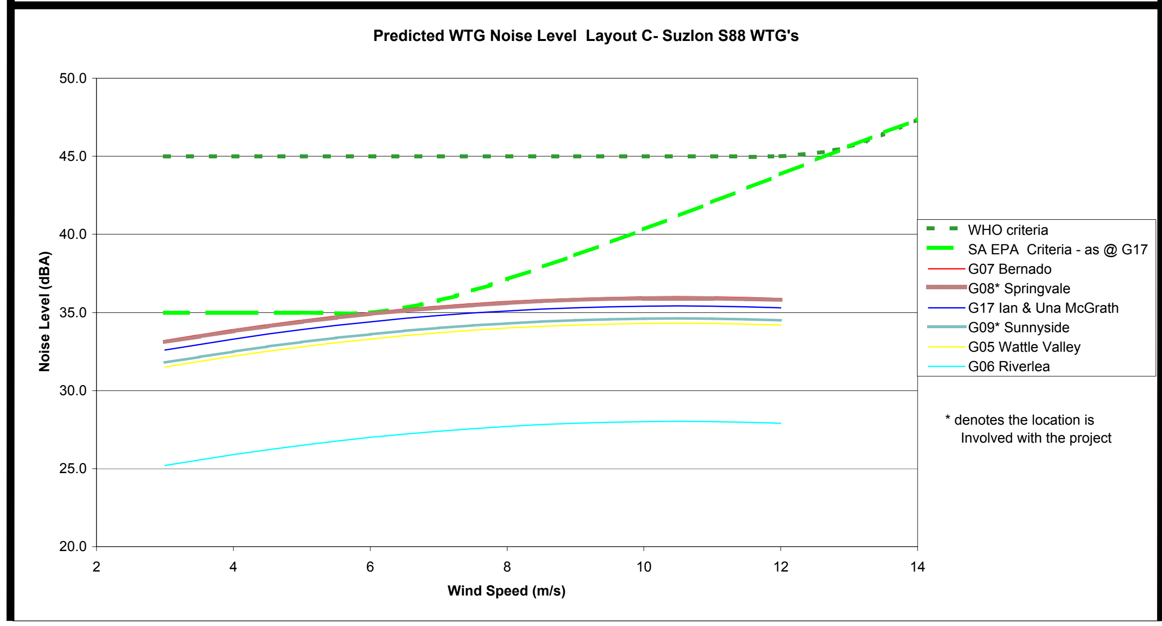
Predicted WTG Noise Level Layout B - Vestas V90 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G24
G24 Yowerweena
G23 Jilla Colo
G20 Sreath Dubh
* denotes the location is Involved with the project

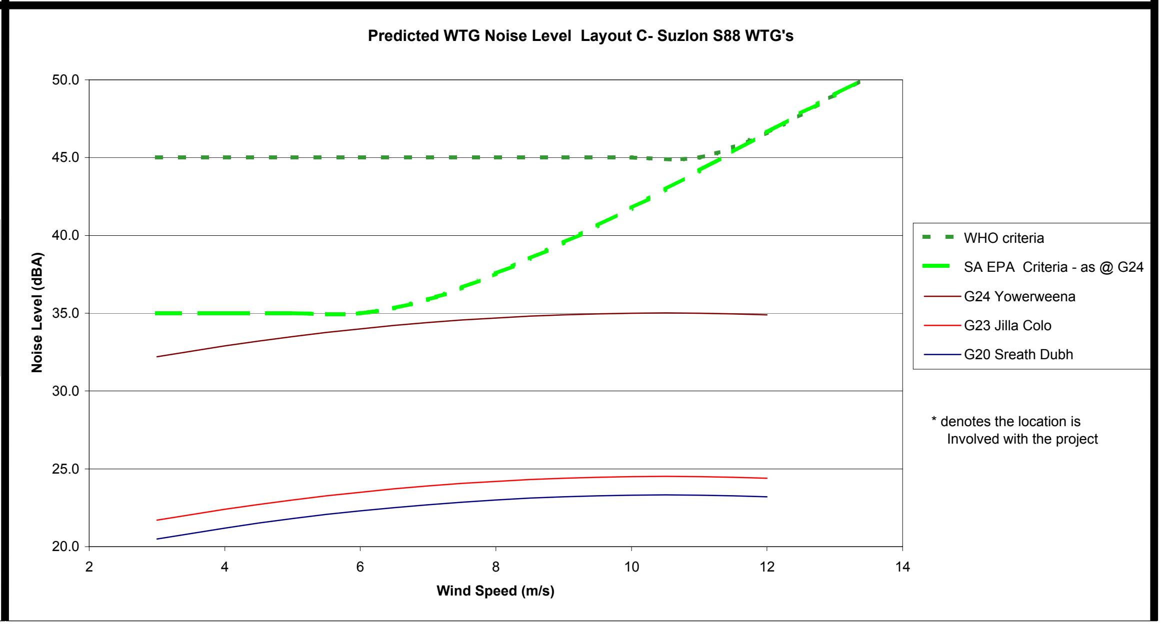

Predicted WTG Noise Level Layout C- Suzlon S88 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G11
G16 Malcom van Gelder
G11 Tannochbrae
G32 House
G33 House
G41 Proposed house
G38 Waterview
G19 Rose Hill
G18 Elvington
G13 Woodleigh
G15 Marilba
G12 House
G14 Bellevue Hill
G36 Fair Vale
G39 Canyon
* denotes the location is Involved with the project


Predicted WTG Noise Level Layout C- Suzlon S88 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G10
G10* Linbrook
G29 Bogo Cottage
* denotes the location is Involved with the project


Predicted WTG Noise Level Layout C- Suzlon S88 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G2
G02a Grenville 2
G02 Grenville
G26 Cooinda
G03 Bogo
G27 Fairview
* denotes the location is Involved with the project


Predicted WTG Noise Level Layout C- Suzlon S88 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G04*
G04b* Proposed house
G04* Ferndale
G42 Riverview
G01 Sutton Grange
G04a* Kaveney
G43 Ildemere
G50 House
G47 House
G46 House
G49 House
G44 House
G45 Bertangles
G48 House
* denotes the location is Involved with the project


Predicted WTG Noise Level Layout C- Suzlon S88 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G17
G07 Bernado
G08* Springvale
G17 Ian & Una McGrath
G09* Sunnyside
G05 Wattle Valley
G06 Riverlea
* denotes the location is Involved with the project


Predicted WTG Noise Level Layout C- Suzlon S88 WTG's
Noise Level (dBA)
Wind Speed (m/s)
WHO criteria
SA EPA Criteria - as @ G24
G24 Yowerweena
G23 Jilla Colo
G20 Sreath Dubh
* denotes the location is Involved with the project

Wind Turbine Generator

Sound Power Level Measurement Reports - IEC 61400-11

Sound power level REpower MM82 LM Rotor Blade

Hub height 59.0m

V_{10}[1] [m/s]	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0
L_{WA}[2] [dB(A)]	89,2	93,2	99,6	101,7	102,6	103,8	104,8	105,5

Hub height 69.0m

V_{10} [m/s]	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0
L_{WA} [dB(A)]	89,4	93,4	99,8	101,8	102,8	103,9	104,9	105,5

Hub height 80m

V_{10} [m/s]	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0
L_{WA} [dB(A)]	90,0	94,0	100,0	102,0	103,0	104,0	105,0	105,5

Hub height 100m

V_{10} [m/s]	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0
L_{WA} [dB(A)]	90,6	94,6	100,2	102,2	103,1	104,1	105,1	105,5

All sound power levels are based on wind speeds of v10 at 10 m height. The data of the noise level are based on the requirements of the IEC 61400-11: Wind turbine generator systems – part 11, as well as the Technical Guideline Fördergesellschaft Windenergie e.V. (FGW).

1 Wind speed at 10 meters height

2 sound power level of the turbine in hub height

WINDTEST
Kaiser-Wilhelm-Koog GmbH

Summary of results of the noise emission measurement, in accordance with IEC 61400-11, of a WTGS of the type

REpower MM82

		Site:	Reußenköge 80027
Customer:	REpower Systems AG Hollesenstraße 15 24768 Rendsburg Germany	**Contractor:**	WINDTEST Kaiser-Wilhelm-Koog GmbH Sommerdeich 14b 25709 Kaiser-Wilhelm-Koog Germany
Date of Order:	2004-02-02	**Order No:.**	6020 04 02391 06

Wind Turbine Technical Data:

Type: .... REpower MM82
Manufacturer: .... REpower Systems AG
Turbine serial number: 80027
Rated power: .... 2000 kW
Power control: .... pitch
Tower type: .... tapered conical tube

Rotor manufacturer: .... A&R
Rotor blade type: PP82-20-A
Rotor blade serial number: 020/017/018
Rotor diameter: .... 82 m
Rotor blade pitch angle: ...... variabel (0..91 Grad) degrees
Number of rotor blades: 3
Rotor speed(s) (or range): .... 8,5-17,1 min^{-1}

Gearbox manufacturer: .... Eickhoff
Gearbox type: CPNHZ-217
Gearbox serial number: 20623

Generator manufacturer: .... VEM
Generator type: .... DASAA 5025-4 U
Generator serial number: 2346624/2003
Generator speed(s) (or range): .... 900-1800 min^{-1}
Generator rated power: .... 2040 kW

These data do not replace the corresponding manufacturer's certificate.

Measurement geometry:

Hub height above ground: .... 59 m
Measurement distance R_0: .... 100 m
Height of microphone h_A: .... -1,5 m
Distance rotor centre to tower axis d: .... 3,2 m

Measurement conditions:

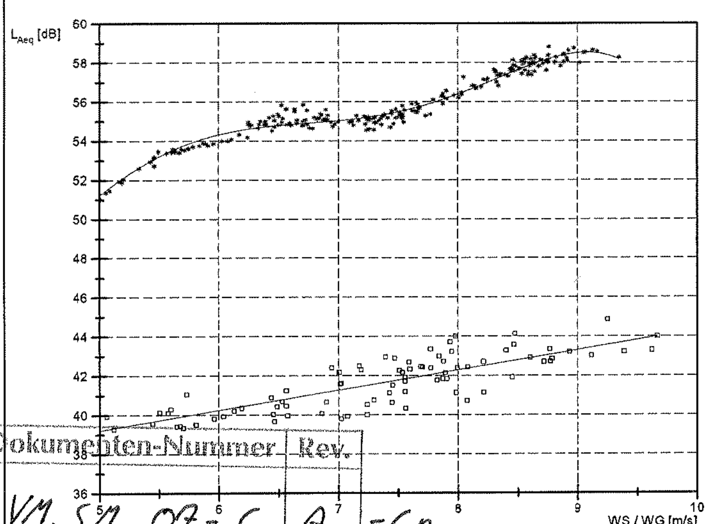
Measurement date: .... 2004-02-05 / 2004-03-17
Range of wind speed at 10m height, 1-min average WS_{10m}: .... 3,1 - 9,7 m/s
Wind direction: .... W / SW
Range of power, 1-min-average $P_{w\,el}$: .... 105 - 1913 kW
Air pressure p_{Luft}: .... 1010 hPa / 1020 hPa
Air temperature T_{Luft}: .... 8 °C / 12 °C
Turbulence intensity: .... 13,3 %

Power curve:

From report: WT 2986/03
Testing Authority: WINDTEST Kaiser-Wilhelm-Koog GmbH
Measurement Period: 2003-09-24 - 2003-11-20

WS (m/s)	Power (kW)	WS (m/s)	Power (kW)	WS (m/s)	Power (kW)
3,43	6,0	9,00	983,7	14,50	2048,6
3,99	47,4	9,54	1119,4	14,93	2051,5
4,46	89,3	10,01	1230,1	15,52	2050,0
5,04	148,3	10,51	1390,6	16,10	2056,6
5,50	207,8	10,99	1529,9	16,43	2057,5
6,03	286,6	11,52	1685,8	16,98	2058,1
6,46	360,9	12,00	1800,2	17,45	2057,9
7,04	496,1	12,46	1891,7	17,95	2059,5
7,50	595,3	13,02	1974,8	18,41	2060,1
8,02	738,0	13,53	2015,0	18,96	2058,6
8,50	852,1	13,99	2039,3	19,51	2060,1

Determination of the sound power level:



WS_{10m} [m/s]	6	7	8	9	9,38[1]
$P_{W\,el}$ [kW]	739,0	1084,0	1456,0	1822,0	1900,0
L_{Aeq} [dB]	54,3	55,0	56,4	58,5	58,1
L_n [dB]	40,2	41,3	42,3	43,3	43,7
$L_{Aeq,c}$ [dB]	54,1	54,8	56,2	58,4	57,9
L_{WA} [dB]	100,7	101,4	102,8	104,9	104,5
U_C [dB]	0,7	0,8	0,7	0,7	0,7

[1] There were no values of κ-corrected measured wind speed above 9,38 m/s where the corresponding power output was more than 95% of rated power.

REpower Dokumenten-Nummer	Rev.	
D-2.2-VM.S11.07-C	A	-GB
Freigabe	**Datum**	
TR	06.04.2004	

Summary of results of the noise emission measurement, in accordance with IEC 61400-11, of a WTGS of the type **REpower MM82**

WINDTEST
Kaiser-Wilhelm-Koog GmbH

Recalculation of $L_{WA,P}$ for different hub heights in dB(A) (WS at a height of 10 m) **:

Hub height [m]	$L_{WA,P}$ (6 m/s)	$L_{WA,P}$ (7 m/s)	$L_{WA,P}$ (8 m/s)	$L_{WA,P}$ (9 m/s)	$L_{WA,P}$ (9,38 m/s)
69	100,8	101,4	103,1	104,8	104,4
80	100,9	101,5	103,5	104,4	104,4
90	101,0	101,6	103,9	104,4	104,4
100	101,0	101,8	104,1	104,4	104,4

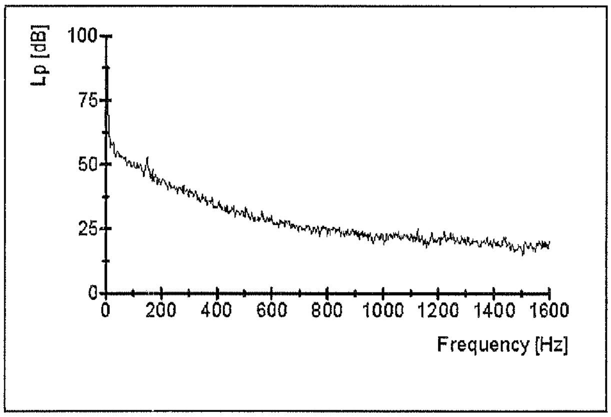
** A direct recalculation of the tonality is not possible, as other acoustic effects may arise due to the changed geometry of the tower.

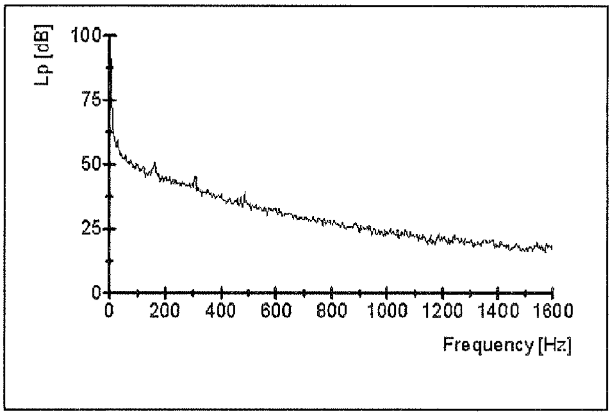
Third octave sound pressure spectra in dB(A) for the wind speed in 10 m height corresponding to the maximum sound power level given on page 1:

1/3 octave freq. [Hz]	50	63	80	100	125	160	200	250	315	400	500	630
L_{pA} (9 m/s)	77,5	81,7	85,8	89,4	92,3	93,8	95,9	95,8	95,3	95,2	93,4	92,4
1/3 octave freq. [Hz]	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**	**10000**
L_{pA} (9 m/s)	91,6	90,8	90,5	91,0	89,4	87,2	84,2	81,9	77,2	73,0	66,1	59,4

Tonality according to IEC 61400-11/Ed.2:

Representative FFT - Spectra (left 8 m/s and right 9,38 m/s at a height of 10 m):





WS in 10 m Höhe [m/s]	6,0	7,0	8,0	9,0	10,0
Freq. of tone, f [Hz]	-	-	-	-	-
Tonality, ΔL_k [dB]	-17,0	-15,4	-16,3	-17,0	-17,1
Audibility, $\Delta L_{a,k}$ [dB]	-14,4	-13,3	-14,0	-14,4	-14,4

REpower Dokumenten-Nummer	Rev.
D-2.2-VM.SM.07-C	A -GB
Freigabe	Datum
TR	06.04.2004

Engineer:

Dipl.-Ing. J. Dedert

Checked:

Dipl.-Ing. A. Trautsch

By DAP (Deutsches Akkreditierungssystem Prüfwesen) accredited laboratory according to DIN EN ISO/IEC 17025. The accreditation is valid for the scope mentioned in the certificate.

Deutscher Akkreditierungs Rat
DAP-PL-1556.00

Kaiser-Wilhelm-Koog, 2004-03-29

WINDTEST
Kaiser-Wilhelm-Koog GmbH

Report of acoustical emissions of a wind turbine generator system of the type Vestas V90-1.8 MW, Mode 0 near Schönhagen (Stadt Pritzwalk), Brandenburg, Germany

Report WT 4282/05

Site or measuring place:	Schönhagen (Stadt Pritzwalk), Brandenburg, Germany

Customer:	Vestas Wind Systems A/S Alsvej 21 8900 Randers Denmark

Contractor:	WINDTEST Kaiser-Wilhelm-Koog GmbH Sommerdeich 14 b 25709 Kaiser-Wilhelm-Koog, Germany

Date of order:	2005-05-04	Order No.:	4025 05 02967 64

Engineer:	Checked:

Dipl.-Ing. A. Trautsch

Dipl.-Ing. J. Neubert
Leiter Gruppe Akustik

Kaiser-Wilhelm-Koog, 2005-06-16

Table of contents

1 Scope

The order from Vestas Wind Systems A/S dated 2005-05-04 required WINDTEST Kaiser-Wilhelm-Koog GmbH (WINDTEST) to carry out acoustic noise measurements on the wind turbine generator system (WTGS or 'turbine') Vestas V90-1.8 MW, Mode 0 of hub height 105 m near Schönhagen (Stadt Pritzwalk), Brandenburg, Germany. From this, the sound power level, relevant for noise propagation calculations, of the noise emitted from the turbine at different wind speeds, and frequency spectra of the same, was also to be determined.

The results given in this report relate only to this WTGS.

2 Method

2.1 Measurement procedures

All measurements and analysis described in this report were done in accordance with the IEC 61400-11: Wind turbine generator systems – Part 11: Acoustic noise measurement techniques, Ed. 2 [IEC 61400-11] using Method 1 as outlined in 7.3.1.1 "Method 1: determination of the wind speed from the electric output and the power curve". In this report the sound power level and the tonality are given in the range of wind speeds from 6 to 10 $^{m}/_{s}$ at a height of 10 m.

Note: A measured power curve for the turbine was provided by the customer for purposes of converting the measured turbine power output into the standardised wind speed. This power curve is given in the Annex.

2.2 Measurement object

Table 1 shows the characteristics of the measured WTGS. The remaining characteristics can be found in the manufacturer's certificate included in the Annex.

Table 1: Characteristics of the measured WTGS

parameter	Value
manufacturer	Vestas Wind Systems A/S
type	Vestas V90-1.8 MW, VCS
WTGS No.	V18864
site	Schönhagen, Brandenburg, Germany
hub-height above ground	105 m
rotor diameter	90 m
distance middle of tower to middle of blade flange	4,44 m
power control (pitch/stall)	pitch

2.3 Course of the measurements

The total measurement period lasted from 2005-05-31 08^{30} h until 2005-05-31 16^{00} h. During this time the measured wind speed ranged from 3,0 to 9,0 m/s at a height of 10 m. The real electrical power output of the turbine ranged between 781 and 1808 kW. The turbine was running continuously during the operating noise measurements.

The sound pressure level was recorded with a microphone on an acoustically hard board. The real electrical power output and the wind speed at a height of 10 m, taken upwind of the turbine in clear air, were also recorded. Time periods, where there were intermittent background noise of a significant nature, e.g. passing cars, planes flying over, rain etc., were marked accordingly during the measurements, and were omitted in the later evaluation. If there were random and reoccurring disturbances, which could not be marked during the measurement, a later state correction by means of a comparison with the DAT-recording was done.

The wind turbine generator system is sited in farmland. The surface roughness length for this measurement is assumed to be 0.05 m. The microphone position was chosen to minimise the effect of buildings, trees or bushes in the surrounding area of the wind turbine generator system, which might have had an influence on the measurement results. The conditions comply with free field behaviour over a reflecting plane.

During the noise measurements the meteorological conditions given in Table 2 were prevailing.

Table 2: Prevailing meteorological conditions during the measurements

barometric pressure at 2 m height above ground [hPa]	*1007*
air temperature at 2 m height above ground [°C]	*9-20*
prevailing wind direction	*W*
range of wind direction	*264 -310*
weather conditions	*cloudy and showers*
Turbulence intensity at 10 m height above ground [%]	*20,8*

2.4 Measuring equipment

The measuring equipment used is listed in the Annex. This equipment is tested regularly according to [IEC 61400-11] to ensure a high degree of measurement accuracy as well as security of data. The complete acoustic measurement system was checked before and after the measurements using an acoustic calibrator (B&K 4231).

2.5 Position of microphone

The microphone was placed according to [IEC 61400-11]. The distance from the turbine to the reference measuring point, R_0 = 120 m, was chosen taking local circumstances into account. The height of the microphone with respect to the bottom of the turbine foundation was 0 m.

3 Measurement results

3.1 Determination of directivity

As no significant directivity was ascertained the reference measurement position was chosen to be directly downwind of the turbine. This ensured worst case sound propagation conditions were taken into account.

3.2 Sound pressure level

The microphone converts the sound pressure into a continuous analogue signal which is then fed to a sound level meter. The resulting dB value, L_{Aeq}, together with the status, the wind speed at a height of 10 m, WS, and the real power output of the turbine, P_w, all recorded by the measurement system, is plotted against time in a graph given in the Annex. Here it can be seen at which points in time the turbine is switched on and off and provides an overview of the background noise in relation to the operating noise recorded by the measurement system over the whole period of the measurement. As can be seen, data was captured continuously throughout the whole measurement period. Non-normal background noises occurring in the measurement period, e.g. from aircraft or traffic, were marked during data acquisition to enable their easy omission in the evaluation to follow. The state signal is used to differentiate between periods when the turbine is running and when it is stopped. *State = 1,5* depicts a running turbine, *state = 0.5* depicts a stopped turbine, and *state = 0* marks the data to be omitted in the evaluation.

The noise produced by the turbine alone $L_{Aeq,c}$ at wind speeds of 6, 7, 8, 9 and 10 m/s is then determined by converting the dB levels of background and in-service noise to intensities, performing a subtraction and converting back again to dB. In order to determine this, regression curves of the measured sound pressure level with the turbine both running and stopped, plotted with respect to the standardised wind speed at a height of 10 m are required. The wind speed measured during the background noise measurement is multiplied by the factor κ, which is defined as the following:

$$\kappa = \frac{V_s}{V_z}$$

where,

V_s is the standardised wind speed

V_z is the measured wind speed.

For this measurement, κ = 1,01.

The results of this regression analysis are given in the Annex. All relevant sound pressure level values are given in the annex.

Remark: The data have been analysed using a sixth order regression because this is the best fitting approximation through all the relevant data points. The sound levels resulting from the sixth order regression have been applied in the third octave analysis.

3.3 Sound power level of the turbine

In accordance with [IEC 61400-11] the sound power level $L_{WA,k}$ of the turbine in dB is derived from the corrected sound pressure level $L_{Aeq,c,k}$, at wind speeds between 6 and 10 m/s at a height of 10 m, using the following formula:

$$L_{WA,k} = L_{Aeq,c,k} - 6 + 10 \cdot \lg\left(\frac{4 \cdot \pi \cdot R_1^2}{S_0}\right)$$

where, 6 dB is the correction due to the doubled sound pressure sensed by the microphone caused by coherent interference at the acoustically hard board.

$10 \cdot \lg\left(\frac{4 \cdot \pi \cdot R_1^2}{S_0}\right)$ = the ratio in dB of the surface area of a sphere having the radius R_1 to the reference surface area of S_0

where,

S_0 = 1 m^2

$R_1 = \sqrt{(R_0 + d)^2 + (H - h_A)^2}$

R_0 = distance between tower centre and microphone position

d = distance between tower centre and rotor flange middle point

H = hub-height above ground level

h_A = height of microphone

The following results are given in the Annex:

- A graph showing regressions through all the measured wind turbine sound data L_{Aeq} and background noise data L_n.
- A plot of the background corrected normalised values of L_{WA} against the standardised wind speed.
- A plot of L_{Aeq} and L_n against measured wind speed.
- A plot of L_{Aeq} against power.
- A plot of pitch angle against power.
- A plot of rotor speed against power.
- A time plot of the measurement.

For the Vestas V90-1.8 MW, Mode 0 in the present configuration the real power output and the apparent sound power levels are given in table 4.

3.4 Tonal and frequency analyses

In accordance with the technical guideline [IEC 61400-11] a tonal analysis has to be carried out. The frequency spectrum of the noise, which is measured on the acoustically hard board, is determined on the basis of a narrow band analysis by means of the FFT-analyser B&K 2144. This analysis was performed after the measurements using the audio signal recorded on a DAT-recorder.

The results of the tonal analysis of the Vestas V90-1.8 MW, Mode 0 according to [IEC 61400-11] are given in table 4.

3.5 3rd octave analysis

The A-weighted sound spectra at all the integer wind speeds are given in the Annex.

3.6 Uncertainties

3.6.1 Sound power level

The result of the sound power level measurement is subject to uncertainties which are due to the environment, meteorological conditions and the measurement system. For these measurements all the type B measurement uncertainty components as specified in the technical guideline [IEC 61400-11] are given in Table 3. For all of the type B uncertainties mentioned here, a rectangular distribution of possible values is assumed for simplicity with a range described as "±a". The standard deviation for such a distribution is:

$$U = \frac{a}{\sqrt{3}}$$

Table 3: Type B measurement uncertainty components

Component	**Range [dB]**	**Uncertainty [dB]**
Calibration, U_{B1}	±0,2	0,12
Chain of acoustic measurement instruments, U_{B2}	±0,4	0,23
Acoustically hard board, U_{B3}	±0,5	0,29
Distance measurement, U_{B4}	±0,1	0,06
Acoustic impedance of air, U_{B5}	±0,2	0,12
Meteorological variation (including turbulence), U_{B6}	±0,7	0,40
Wind speed derived from the power curve, U_{B7}	±0,3	0,17
Wind direction, U_{B8}	±0,5	0,29
$\sum_{i=1}^{8} U_{Bi}^{2}$		0,44

The error in the background correction U_{B9} in dB has been calculated for each integer wind speed as follows:

$$U_{B9} = L_{Aeq,c,k} - \left[10 \cdot \log\left(10^{0,1 \cdot L_{Aeq,k}} - 10^{0,1(L_n + U_{HG})}\right)\right]$$

where U_{HG} is the error in the background noise in dB defined as follows:

$$U_{HG} = \sqrt{\frac{(y_n - y_{n,est})^2}{N_n - 2}}$$

where:

y_n = measured sound pressure level of background noise in dB

$y_{n,est}$ = estimated sound pressure level of background noise from the regression analysis in dB

N_n = number of background noise measurement values in the wind speed bin corresponding to the integer wind speed.

The combined measurement uncertainty U_C relating to the sound power level $L_{WA,k}$ is calculated as follows:

$$U_C = \sqrt{U_A{}^2 + U_{B9}{}^2 + \sum_{i=1}^{8} U_{Bi}{}^2}$$

where:

$$U_A = \sqrt{\frac{\sum (y - y_{est})^2}{N - 2}}$$

where:

y = measured sound pressure level of total noise (operating plus background) in dB

y_{est} = estimated sound pressure level of total noise from the regression analysis in dB

N = number of total noise measurement values in the wind speed bin corresponding to the integer wind speed.

All values for U_A, U_{B9} and U_C are given in the annex.

3.6.2 One-third octave band spectra

The uncertainty in the one-third octave band spectra is given in the Annex for all the third octave bands.

3.6.3 Tonality

The uncertainty in the tonality is given in the Annex for all the given tones.

4 Summary

As ordered by Vestas Wind Systems A/S, 8900 Randers, WINDTEST Kaiser-Wilhelm-Koog GmbH took measurements of the acoustic noise emissions on the WTGS Vestas V90-1.8 MW, Mode 0 with a hub height of 105 m.

All measurements and analyses of the sound power level and tonality described in this report were made on the basis of the technical guideline [IEC 61400-11]. The analysis of the sound power level was carried out using the standardised wind speed which was calculated from the certified, measured power curve provided by the customer (see Annex).

The data on the WTGS Vestas V90-1.8 MW, Mode 0 have been evaluated by using a sixth order regression because this is the best fitting approximation over all relevant points.

The results of this measurement are given in table 4.

Table 4: Summary of results

wind speed in 10 m height [m/s]	*6*	*7*	*8*	*9*	*10*
electrical power output calculated from the power curve [kW]	*1.114*	*1.605*	*1.797*	*1.808*	*1.808*
sound power level [dB]	*102,7*	*103,7*	*102,6*	*102,4*	*101,9*
combined uncertainty in the sound power level, U_C [dB]	*0,8*	*0,7*	*0,8*	*1,0*	-
tonality, ΔL_k [dB]	*-7,81*	*-10,93*	*-9,30*	*-8,10*	*-9,71*
tonal audibility, $\Delta L_{a,k}$ [dB]	*-5,26*	*-8,36*	*-6,79*	*-5,70*	*-7,32*
frequency of the most prevalent tone [Hz]	*720*	*734*	*728*	*726*	*726*

Remark: It should be noted that there are only 2 minute values in the 10 m/s bin.

It is assured that this report has been drawn up impartially in accordance with state-of-the-art science and technology and with best knowledge and conscience.

5 List of employed symbols and abbreviations

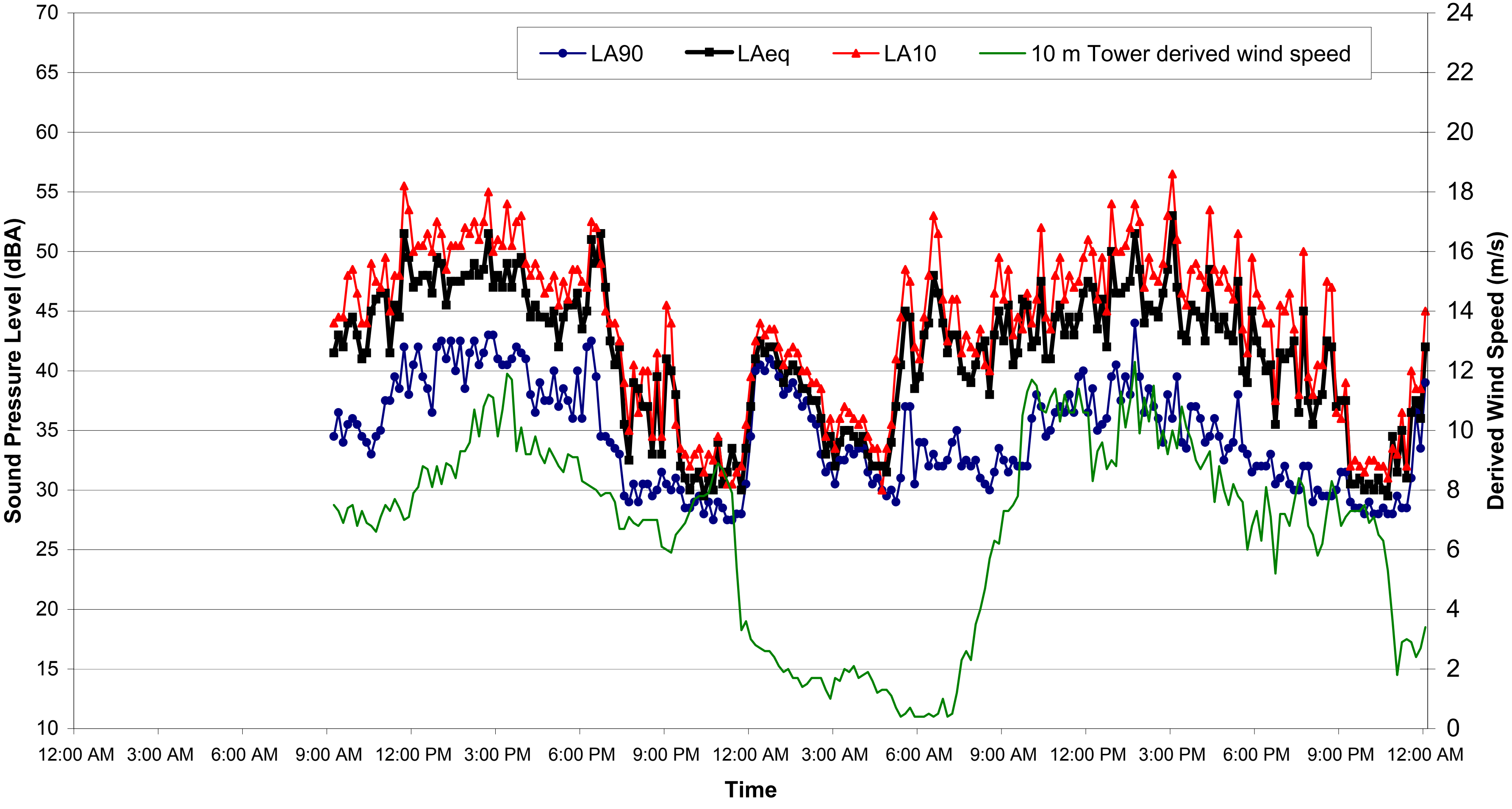
d	-	distance from rotor centre to tower axis	m
D	-	rotor diameter	m
$\Delta L_{tn,j,k}$	-	tonality of the 'j th' spectrum at 'k th' wind speed, where j = 1 to 12 and k = 6, 7, 8, 9, 10	dB
ΔL_{k}	-	energetic average of the 12 $\Delta L_{tn,j,k}$	dB
$\Delta L_{a,k}$	-	tonal audibility	dB
f	-	frequency of the tone	Hz
f_c	-	centre frequency of critical band	Hz
H	-	height of rotor centre (horizontal axis turbine) or height of rotor equatorial plane (vertical axis turbine) above local ground near the wind turbine	m
h_A	-	location point height (in measurement equal to microphone height)	m
κ	-	the ratio between standardised wind speed and measured wind speed	-
L_A or L_C	-	A or C-weighted sound pressure level	dB
$L_{Aeq,k}$	-	equivalent continuous A-weighted sound pressure level, where k = 6, 7, 8, 9, 10	dB
$L_{Aeq,c,k}$	-	equivalent continuous A-weighted sound pressure level corrected for background noise at each integer wind speed and corrected to reference conditions, where k = 6, 7, 8, 9, 10	dB
L_n	-	equivalent continuous sound pressure level level of the background noise	dB
L_p	-	sound pressure level	dB
$L_{pn,j,k}$	-	sound pressure level of masking noise within a critical band in the 'j th' spectrum at the 'k th' wind speed, where j = 1 to 12 and k = 6, 7, 8, 9, 10	dB
$L_{pn,avg,j,k}$	-	average of analysis bandwidth sound pressure levels of masking noise in the 'j th' spectrum at the 'k th' wind speed, where j = 1 to 12 and k = 6, 7, 8, 9, 10	dB
$L_{pt,j,k}$	-	sound pressure level of the tone or tones in the 'j th' spectrum at the 'k th' wind speed, where j = 1 to 12 and k = 6, 7, 8, 9, 10	dB
L_s	-	equivalent continuous sound pressure level of only wind turbine noise	dB
L_{s+n}	-	equivalent continuous sound pressure level of combined wind turbine and background noise	dB
$L_{WA,k}$	-	apparent sound power level, where k = 6, 7, 8, 9, 10	dB
N	-	Number of measured values	-
P_W	-	effective electrical power	kW
R_0	-	reference distance	m
R_i	-	slant distance from rotor centre to actual measurement position	m
S_0	-	reference area, $S_0 = 1\ m^2$	m
U_A, U_B	-	Uncertainty components	dB
U_C	-	Total uncertainty	dB
U_{HG}		Error in the background noise	dB
V_m	-	derived wind speed from power curve	m/s
V_S	-	standardised wind speed	m/s
WTGS	-	wind turbine generator system	-
y	-	measured sound pressure level of operating plus background noise	dB
y_{est}	-	estimated sound pressure level of operating plus background noise from the regression analysis	dB

6 References

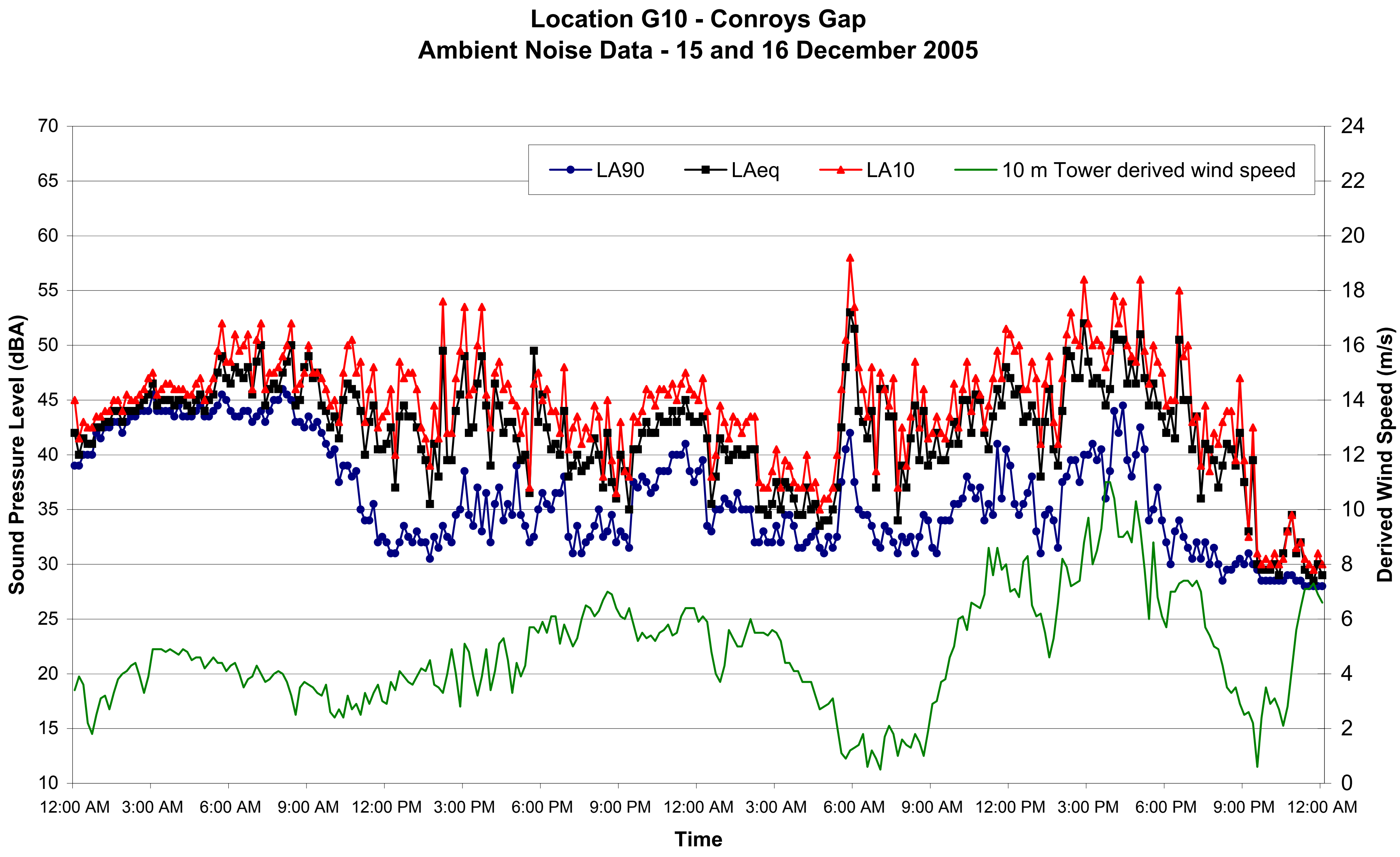
[IEC 61400-11] IEC 61400-11, Wind turbine generator systems - Part 11: Acoustic noise measurement techniques, Ed. 2.

7 Annex

Location G10 - Conroys Gap
Ambient Noise Data - 13 and 14 December 2005



Appendix C1
40-1143
Level Wind vs Time



Appendix C1
40-1143
Level Wind vs Time

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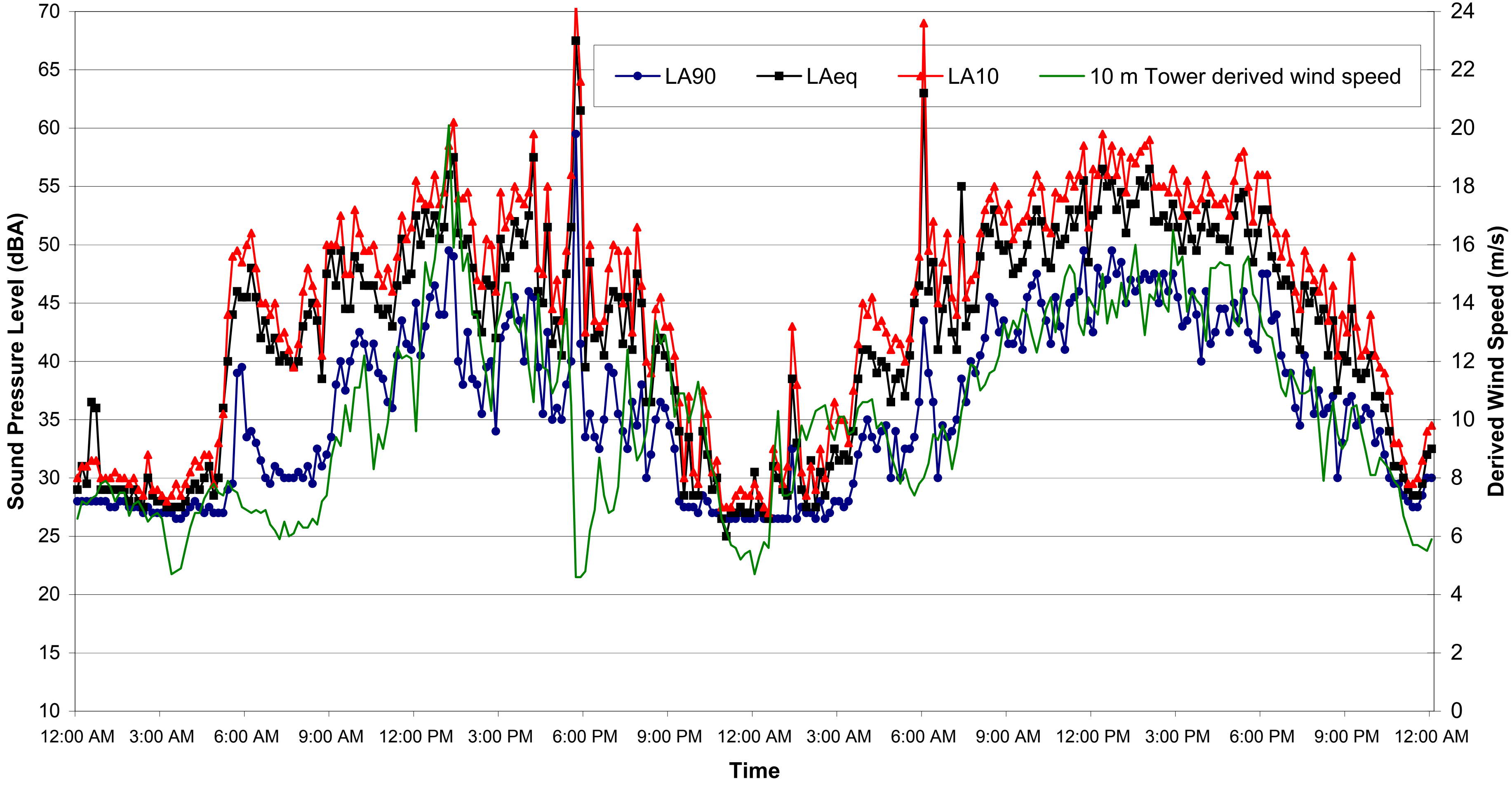
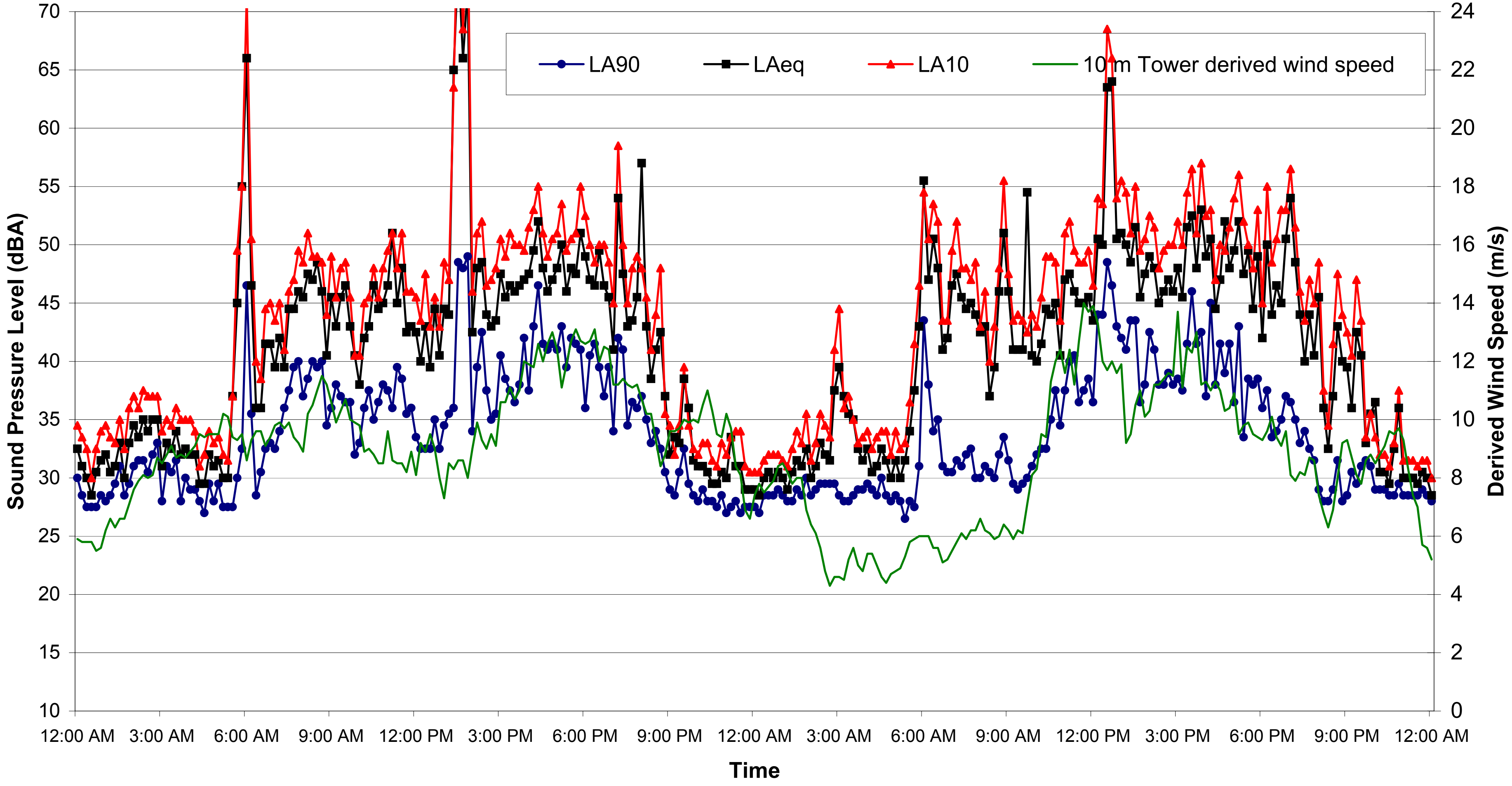
Chart2 Printed 23-03-2006 17:06

Location G10 - Conroys Gap
Ambient Noise Data - 17 and 18 December 2005

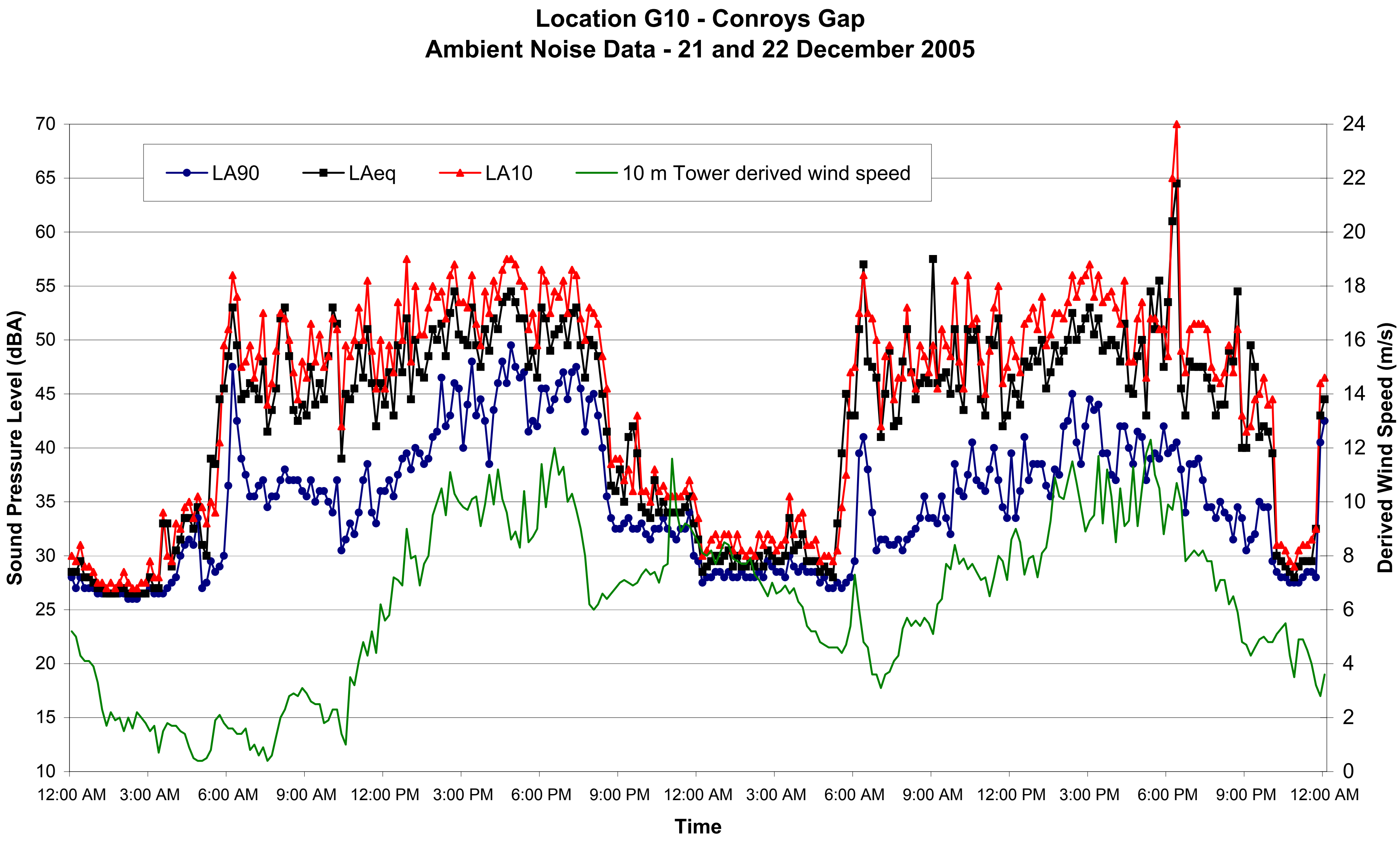


Appendix C1
40-1143
Level Wind vs Time

Location G10 - Conroys Gap
Ambient Noise Data - 19 and 20 December 2005



Appendix C1
40-1143
Level Wind vs Time



Appendix C1
40-1143
Level Wind vs Time

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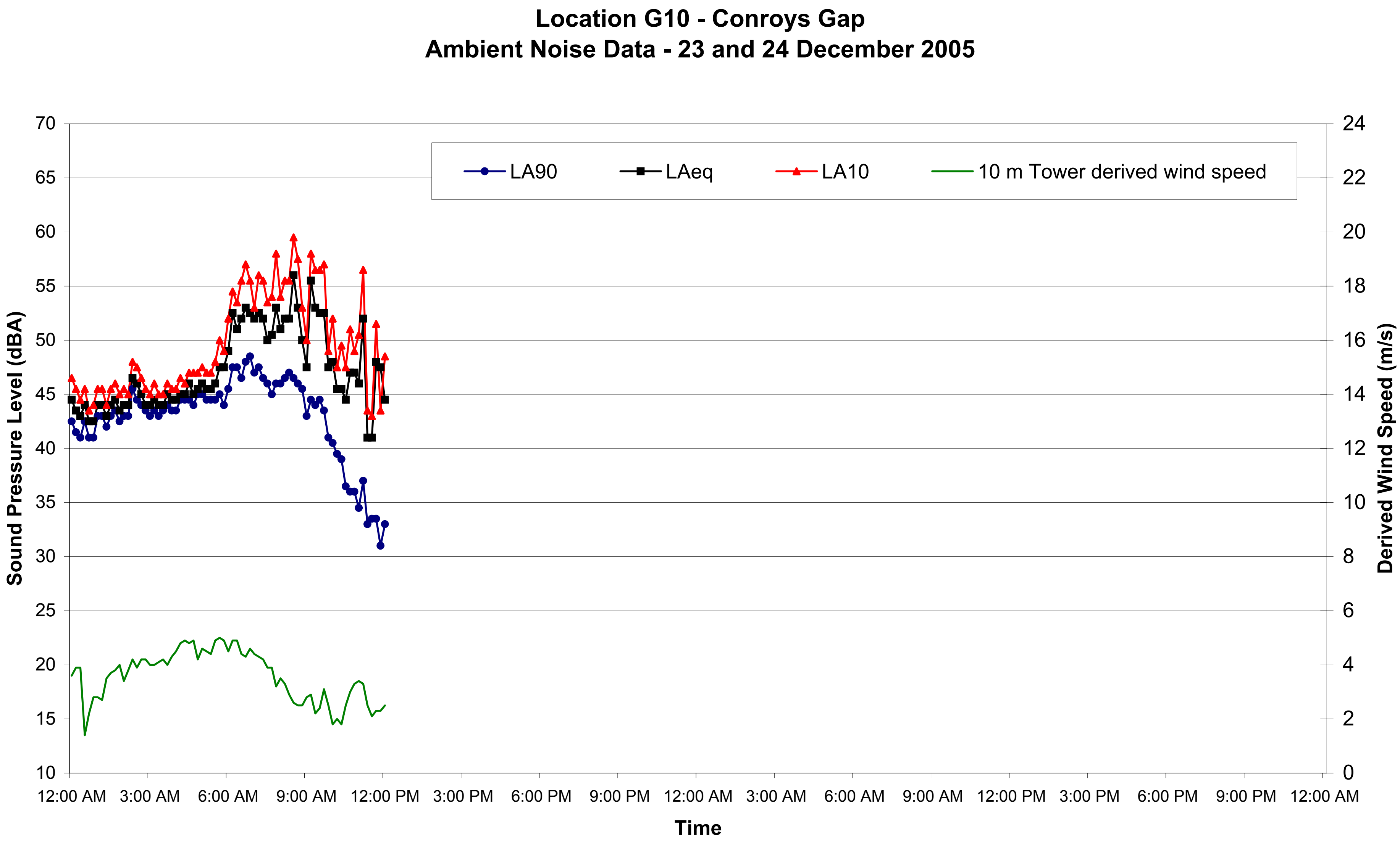
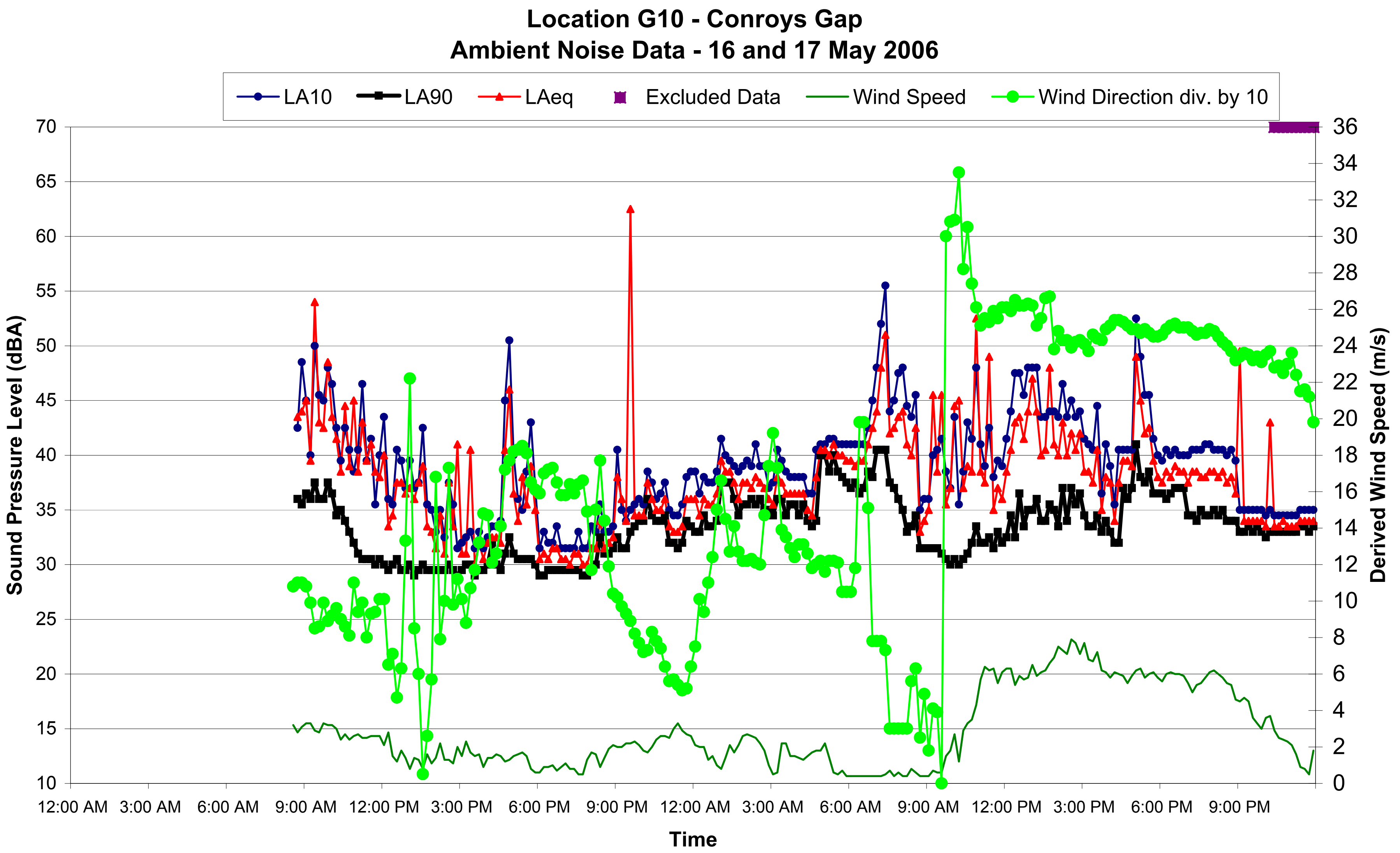


Appendix C1
40-1143
Level Wind vs Time



Appendix C1
40-1143
Level Wind vs Time

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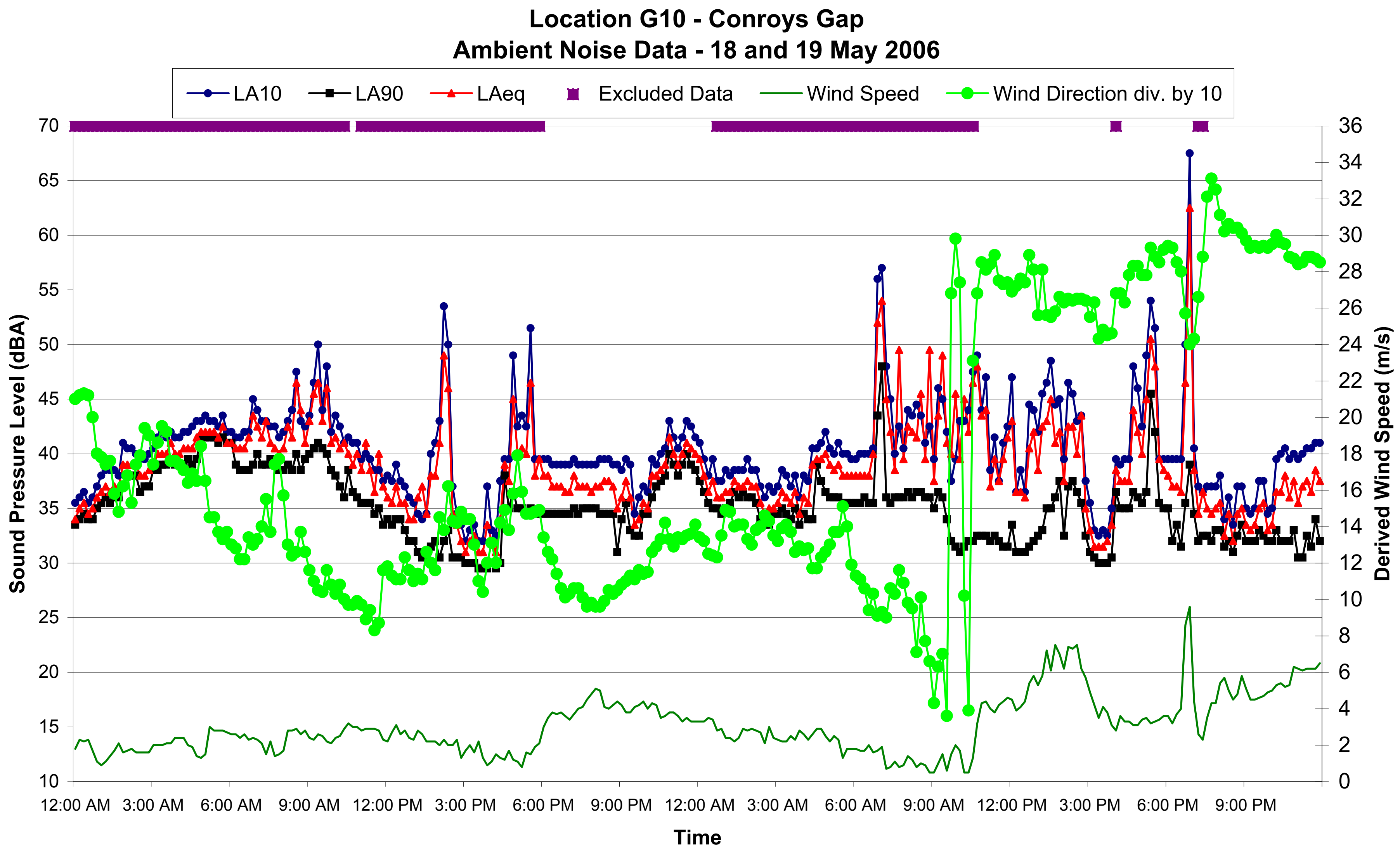
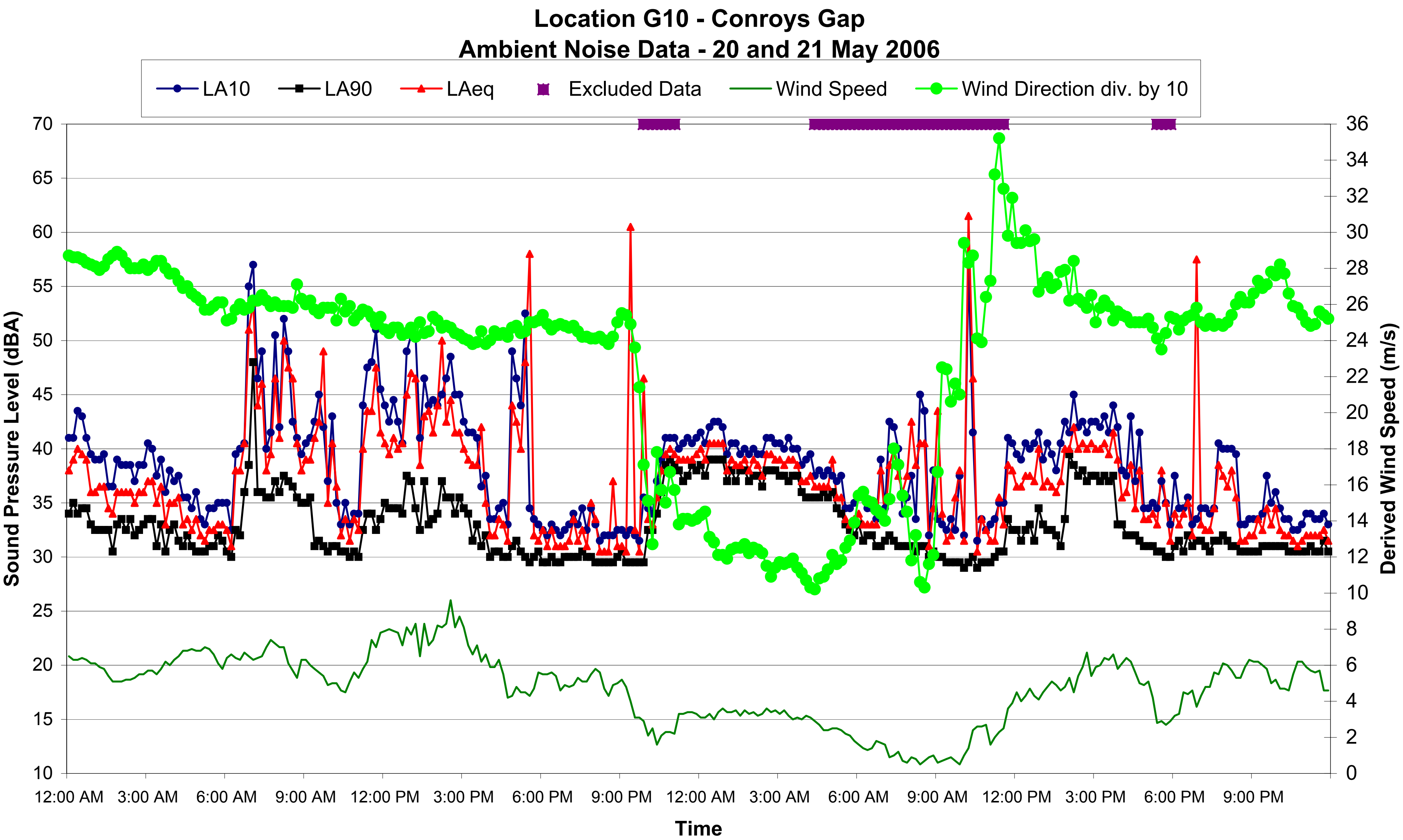
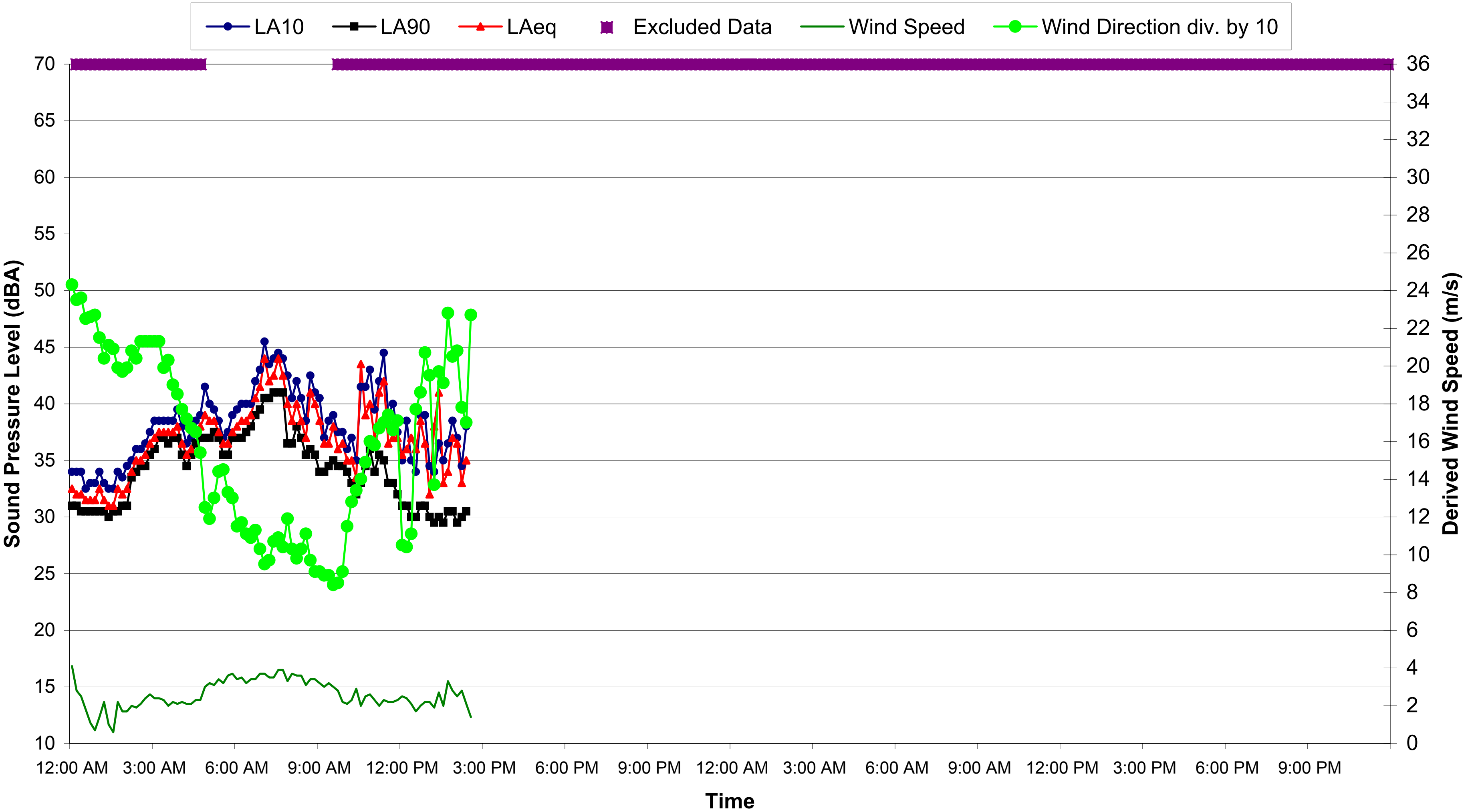


Appendix C1
40-1143
Level Wind vs Time



Appendix C1
40-1143
Level Wind vs Time

Location G10 - Conroys Gap
Ambient Noise Data - 22 and 23 May 2006



Appendix C1
40-1143
Level Wind vs Time

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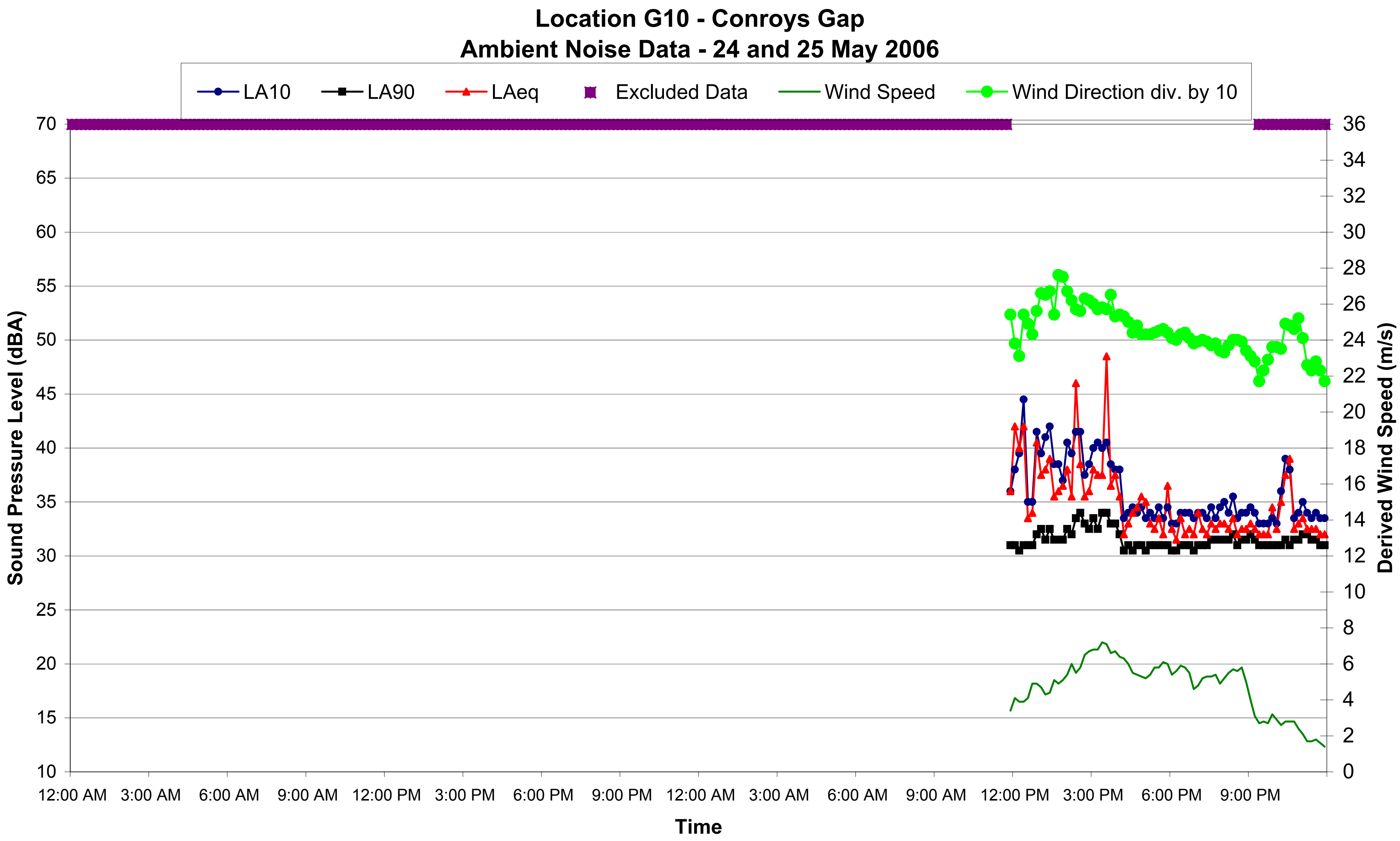
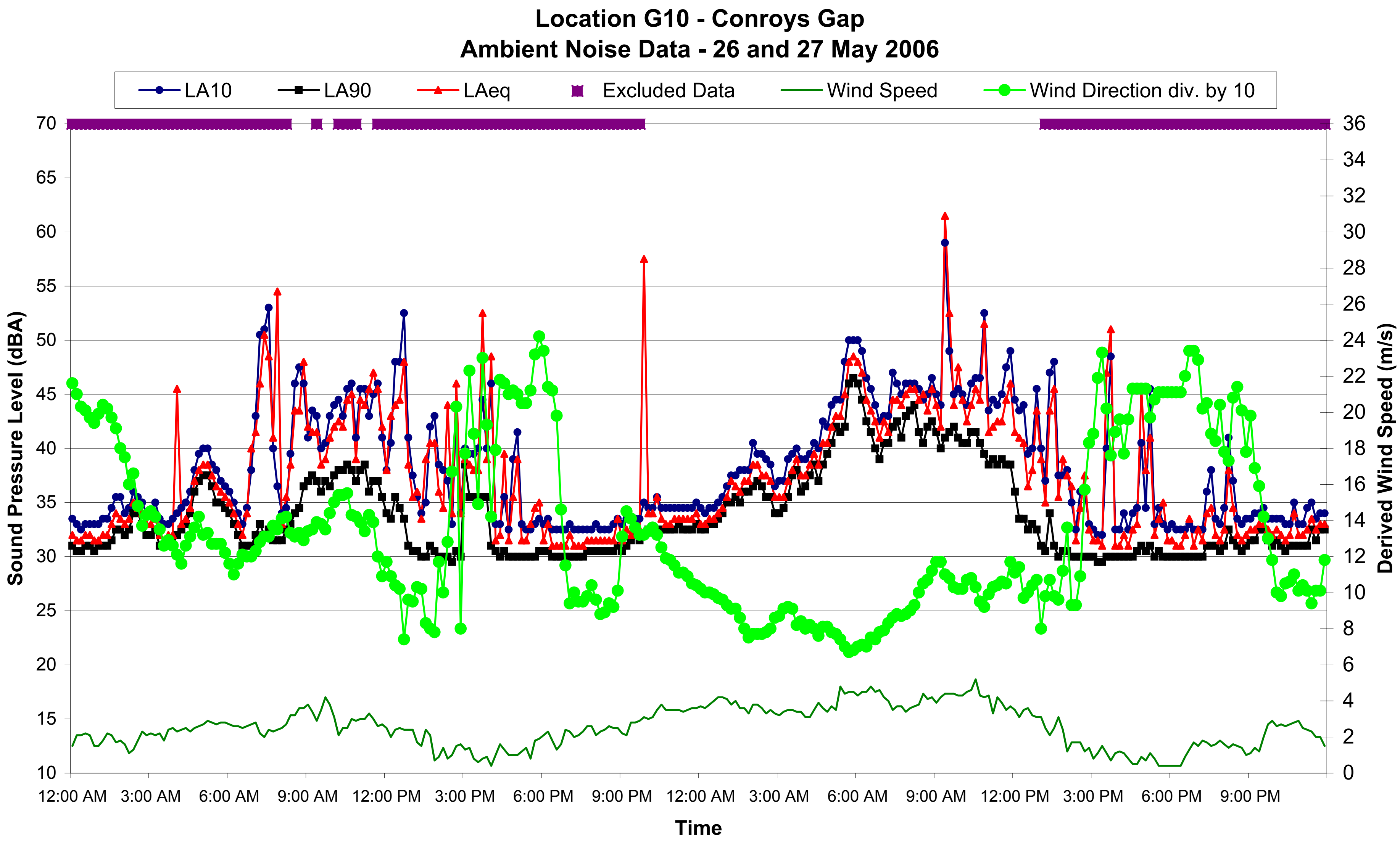


Appendix C1
40-1143
Level Wind vs Time



Appendix C1
40-1143
Level Wind vs Time

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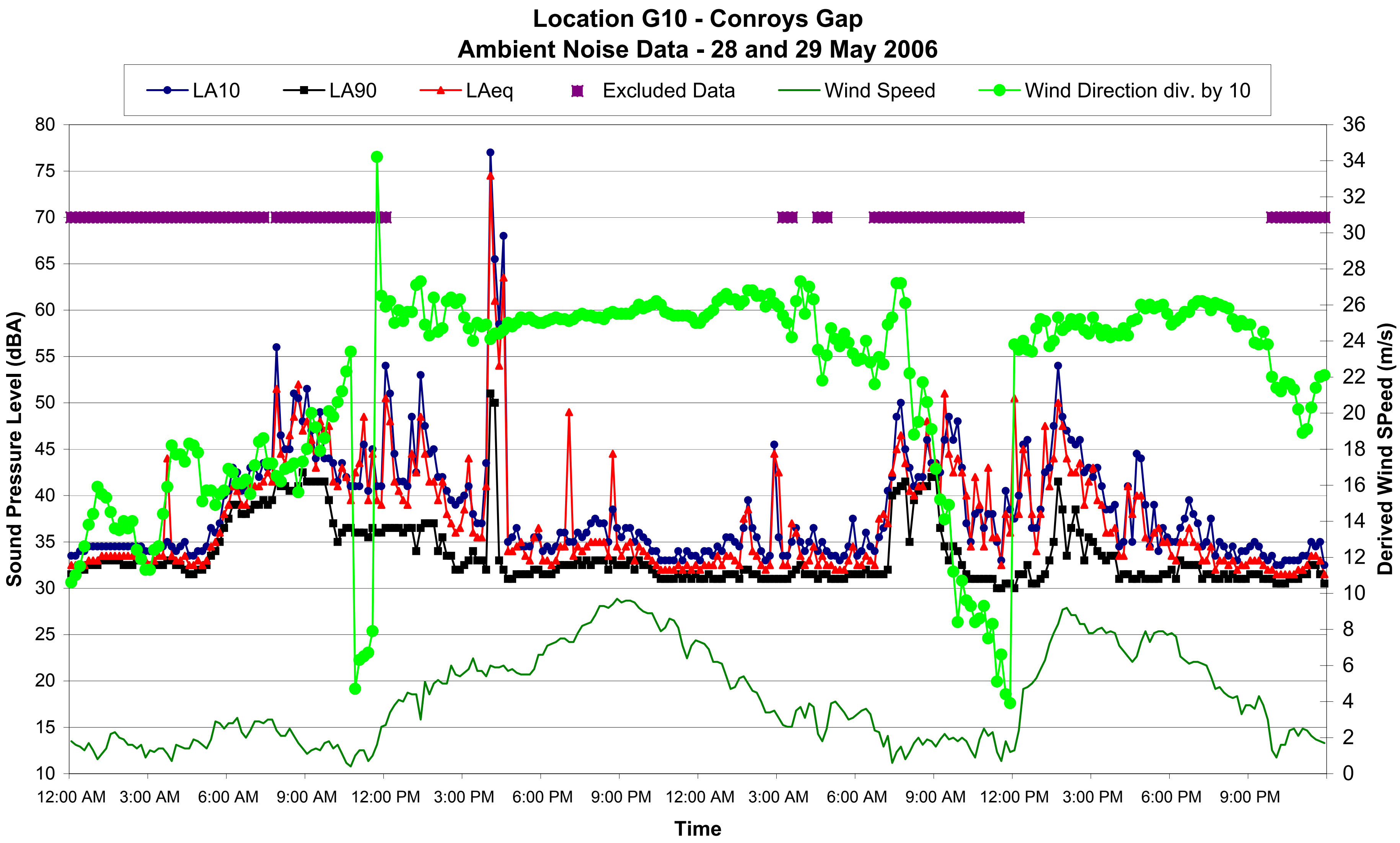

Appendix C1
40-1143
Level Wind vs Time

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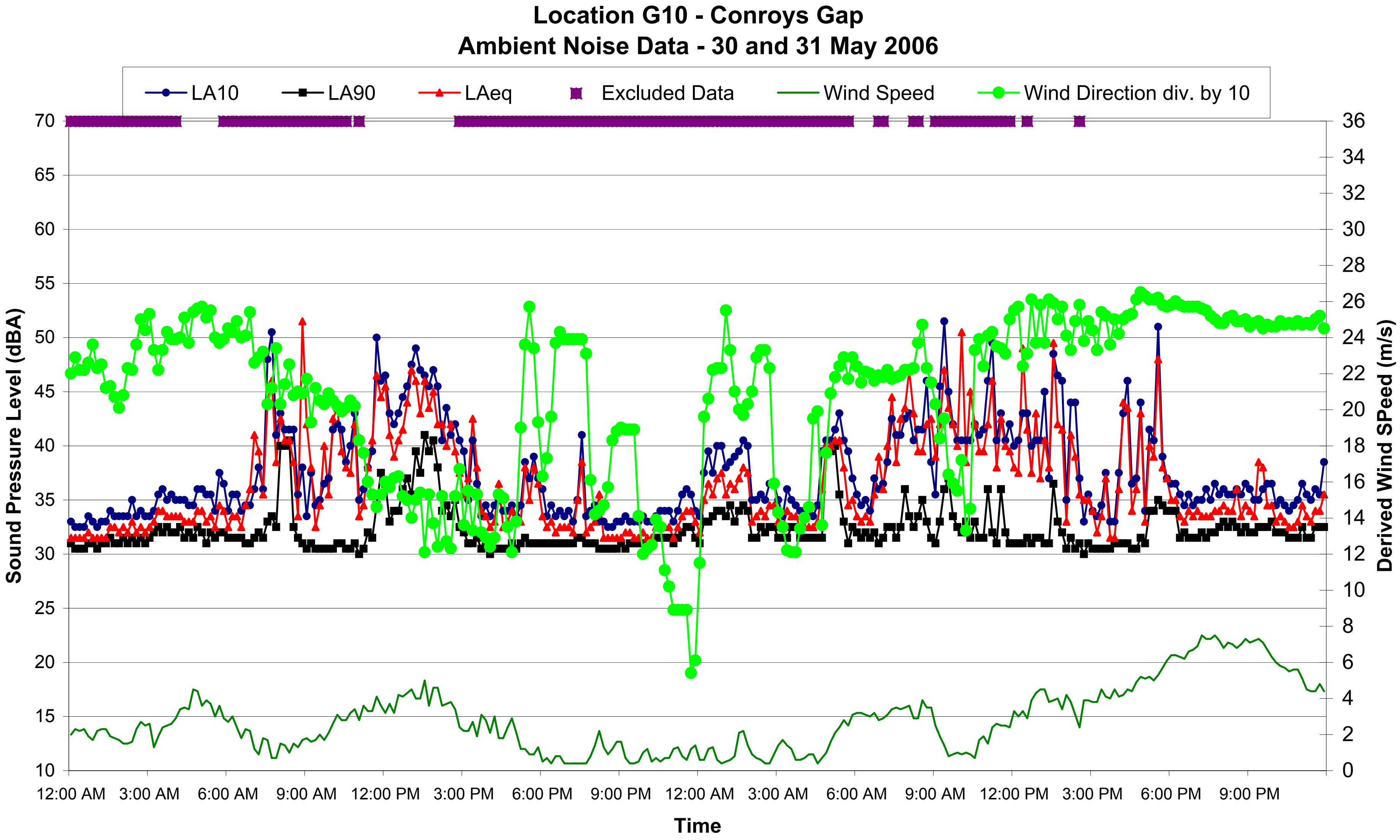

Appendix C1
40-1143
Level Wind vs Time

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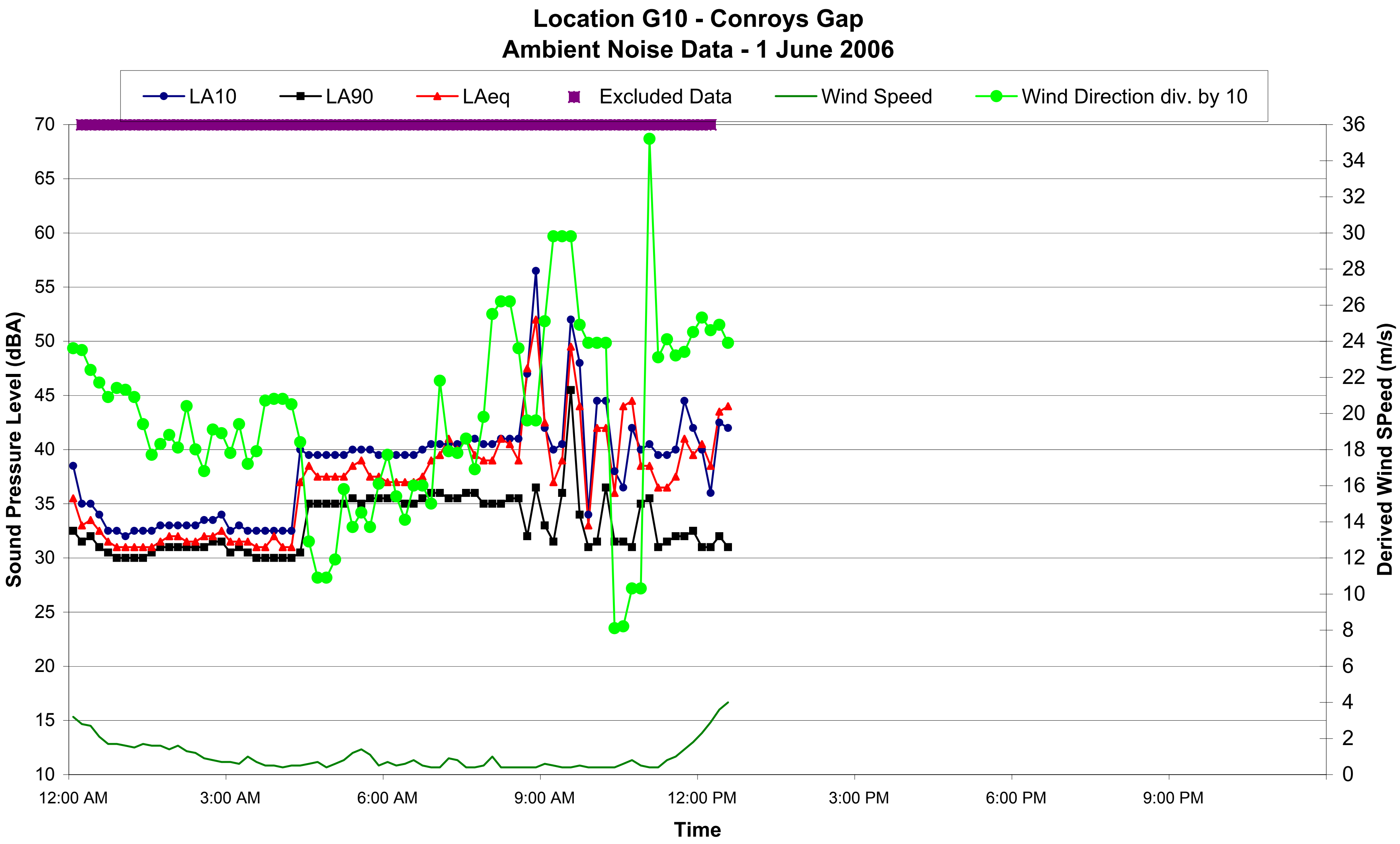
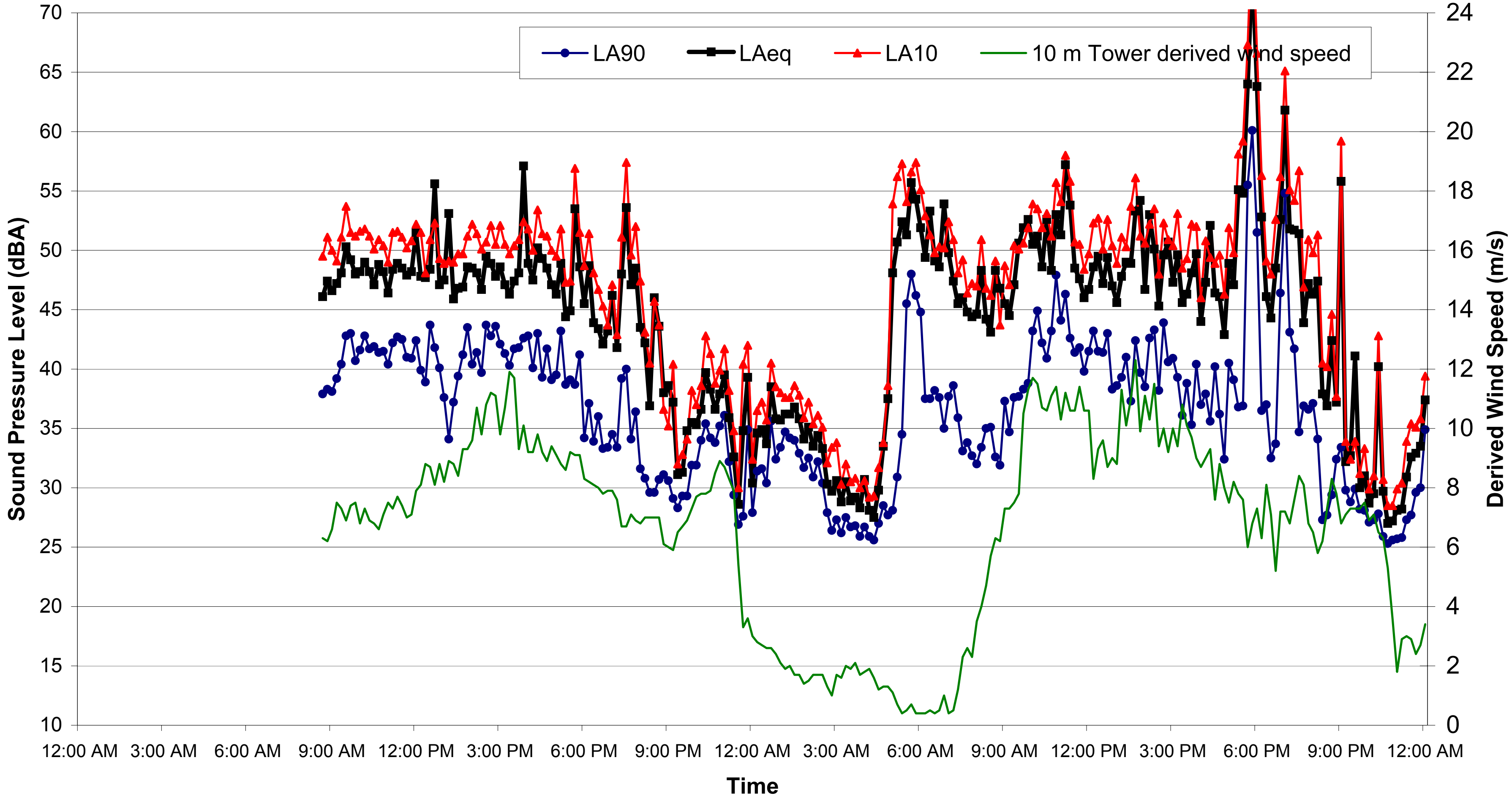


Appendix C1
40-1143
Level Wind vs Time

Location G11 - Conroys Gap
Ambient Noise Data - 13 and 14 December 2005



Appendix C2
40-1143
Level Wind vs Time

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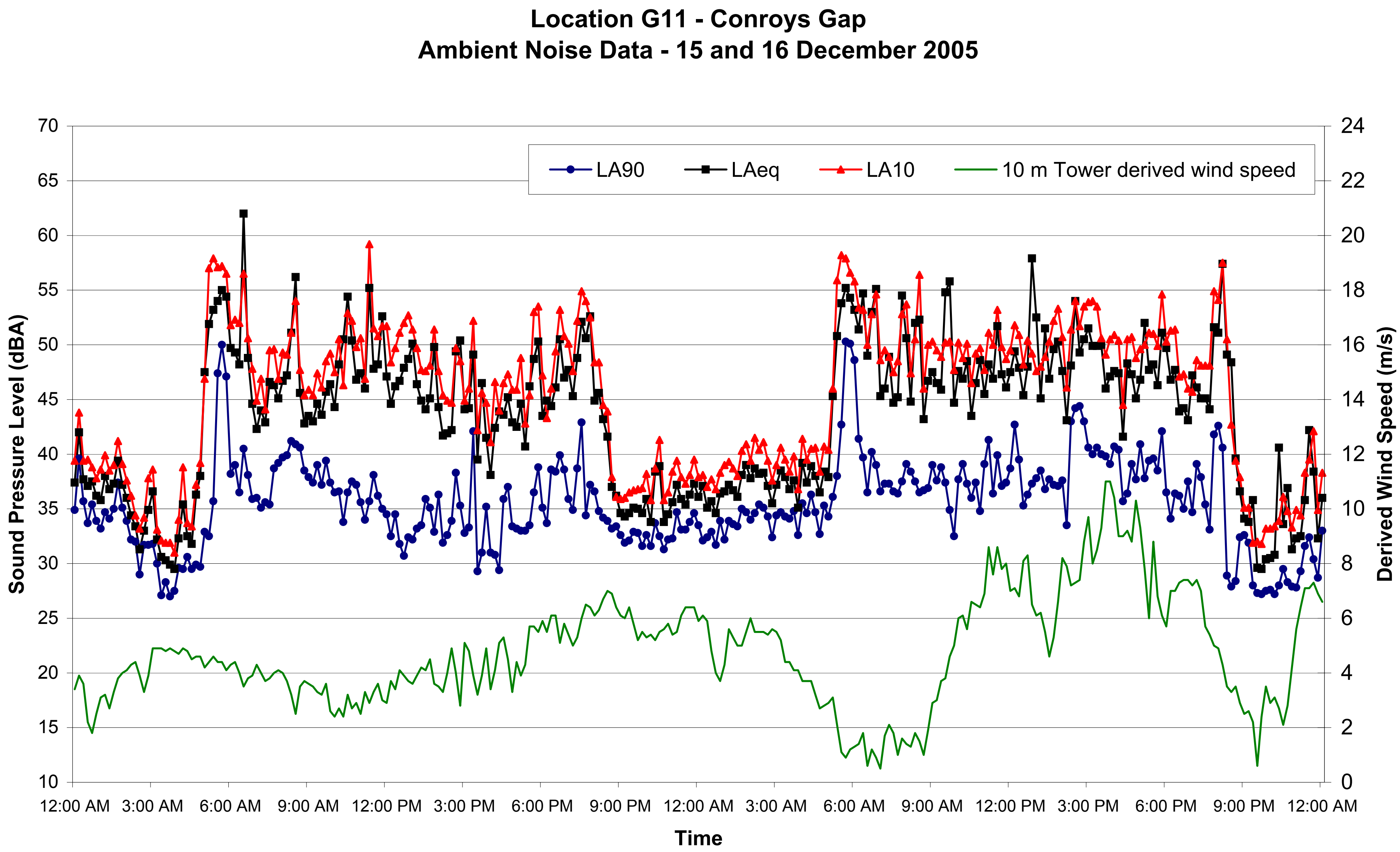

Appendix C2
40-1143
Level Wind vs Time

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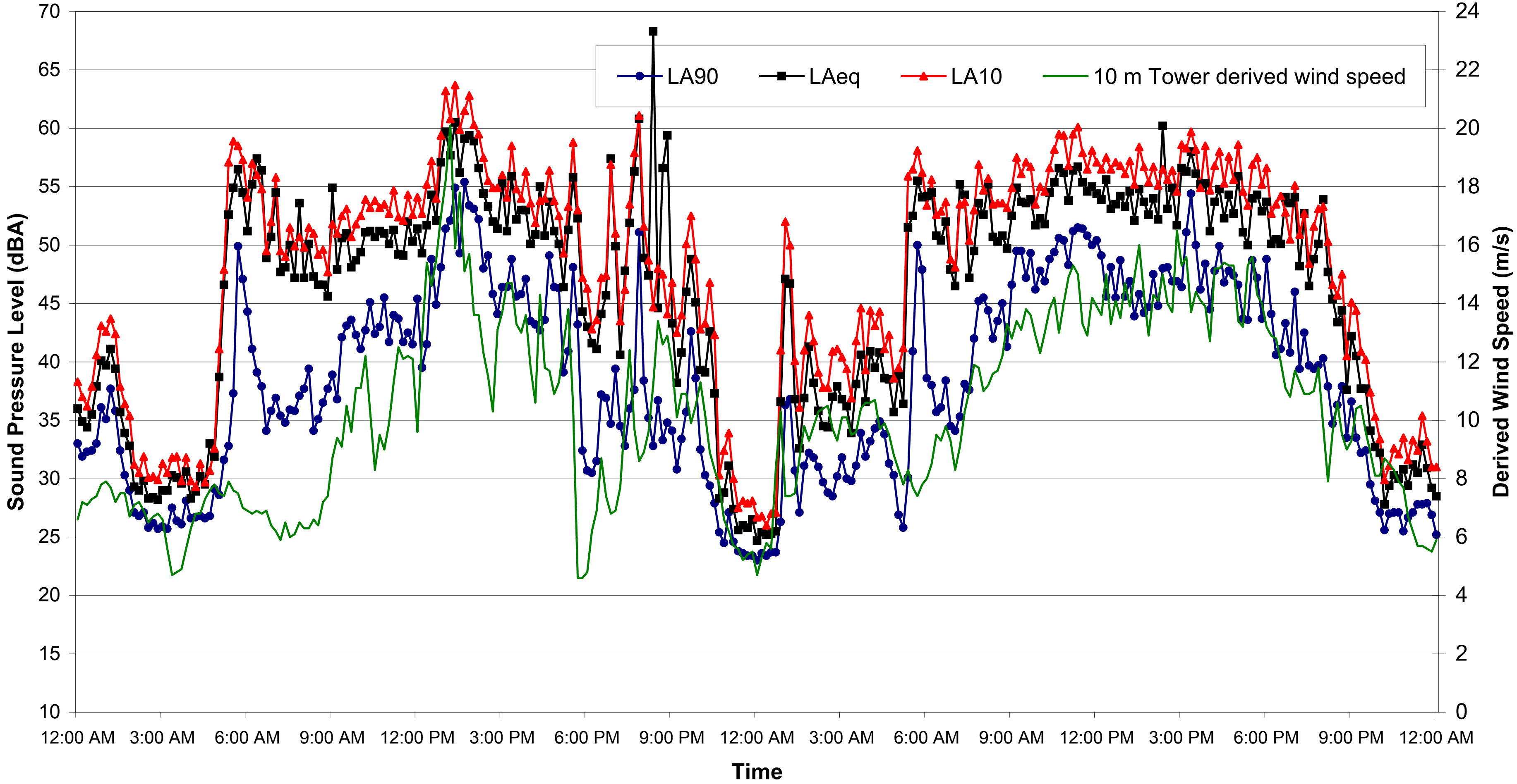
Location G11 - Conroys Gap
Ambient Noise Data - 17 and 18 December 2005



Appendix C2
40-1143
Level Wind vs Time

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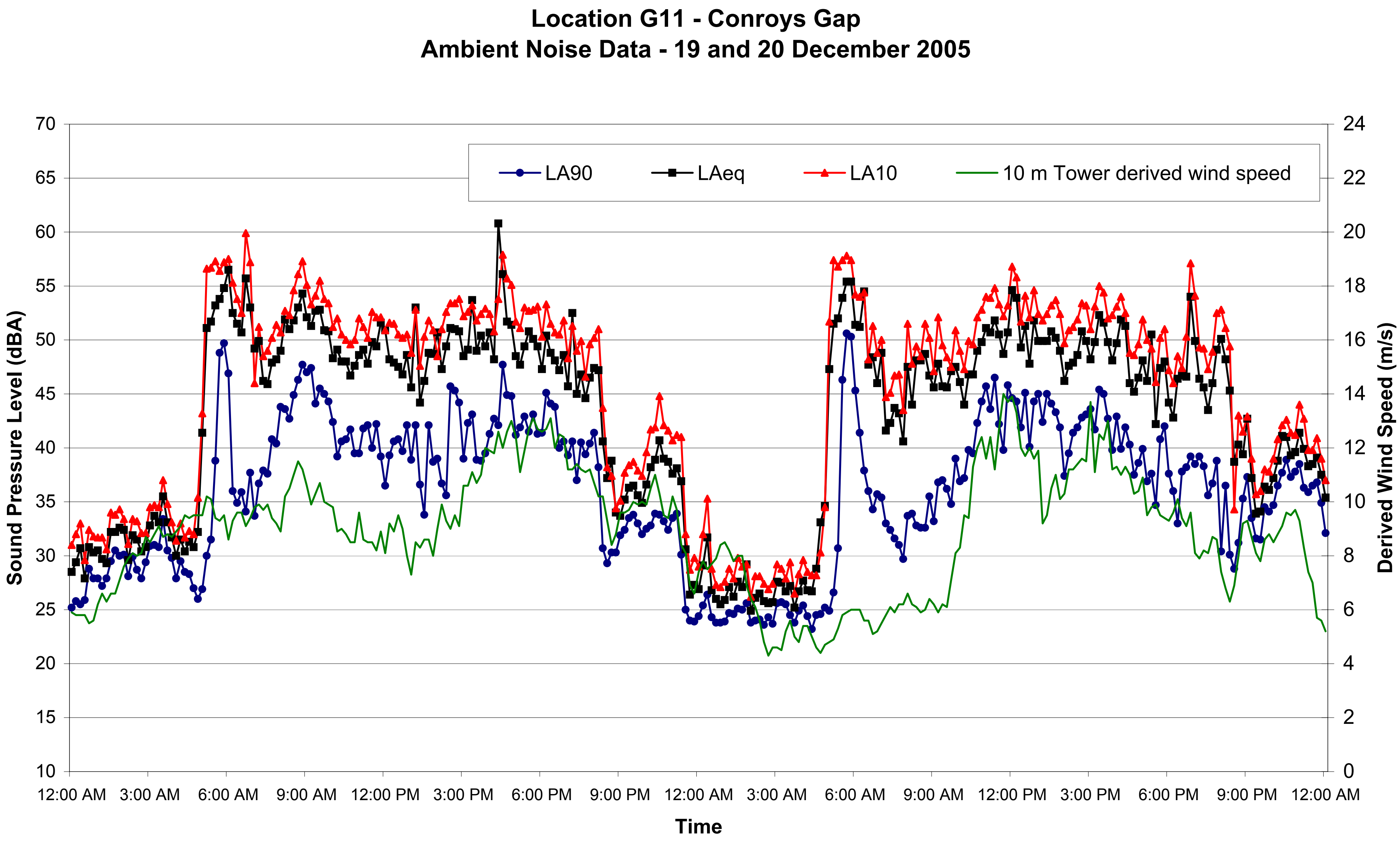

Appendix C2
40-1143
Level Wind vs Time

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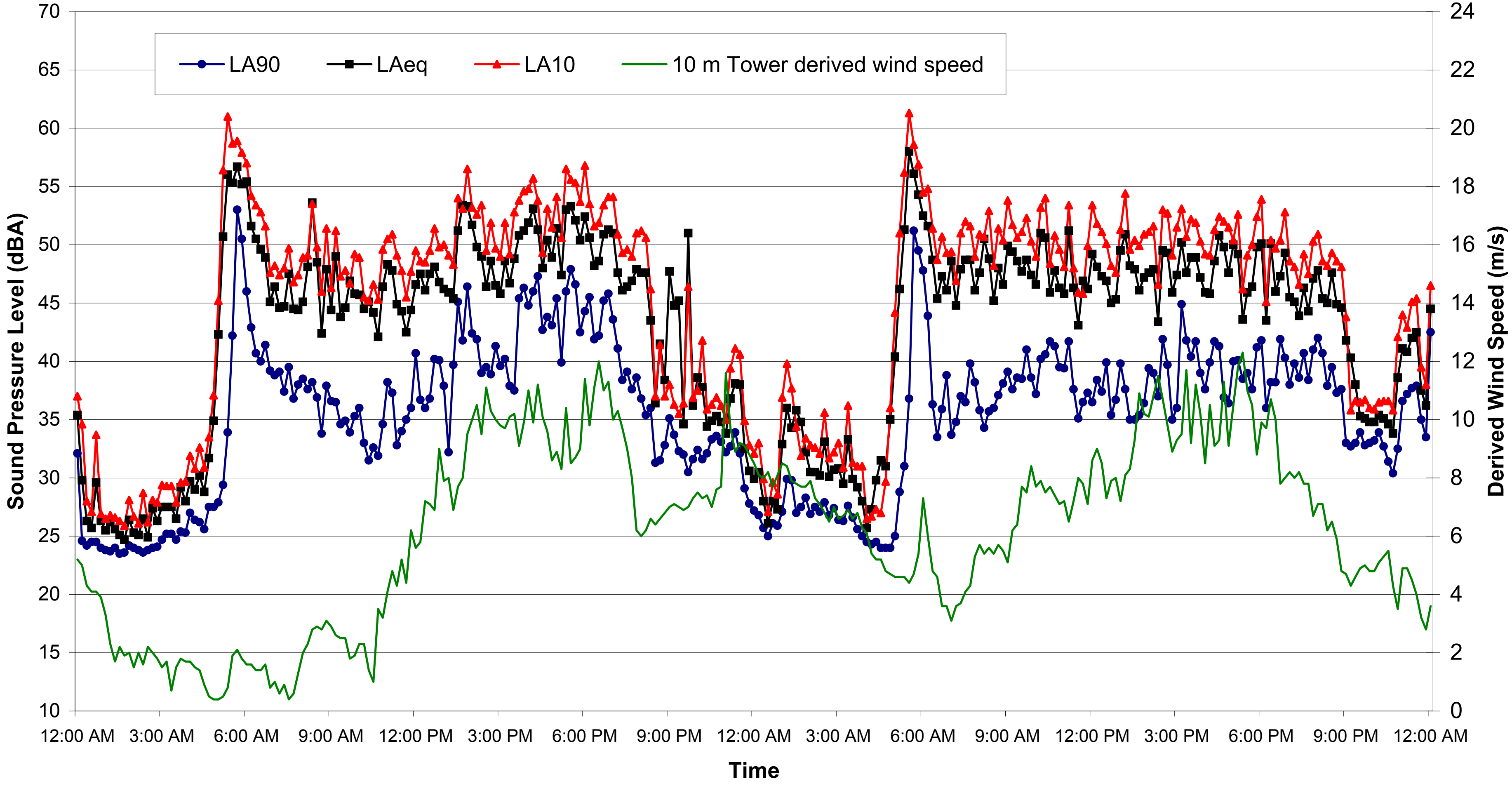
Location G11 - Conroys Gap
Ambient Noise Data - 21 and 22 December 2005



Appendix C2
40-1143
Level Wind vs Time

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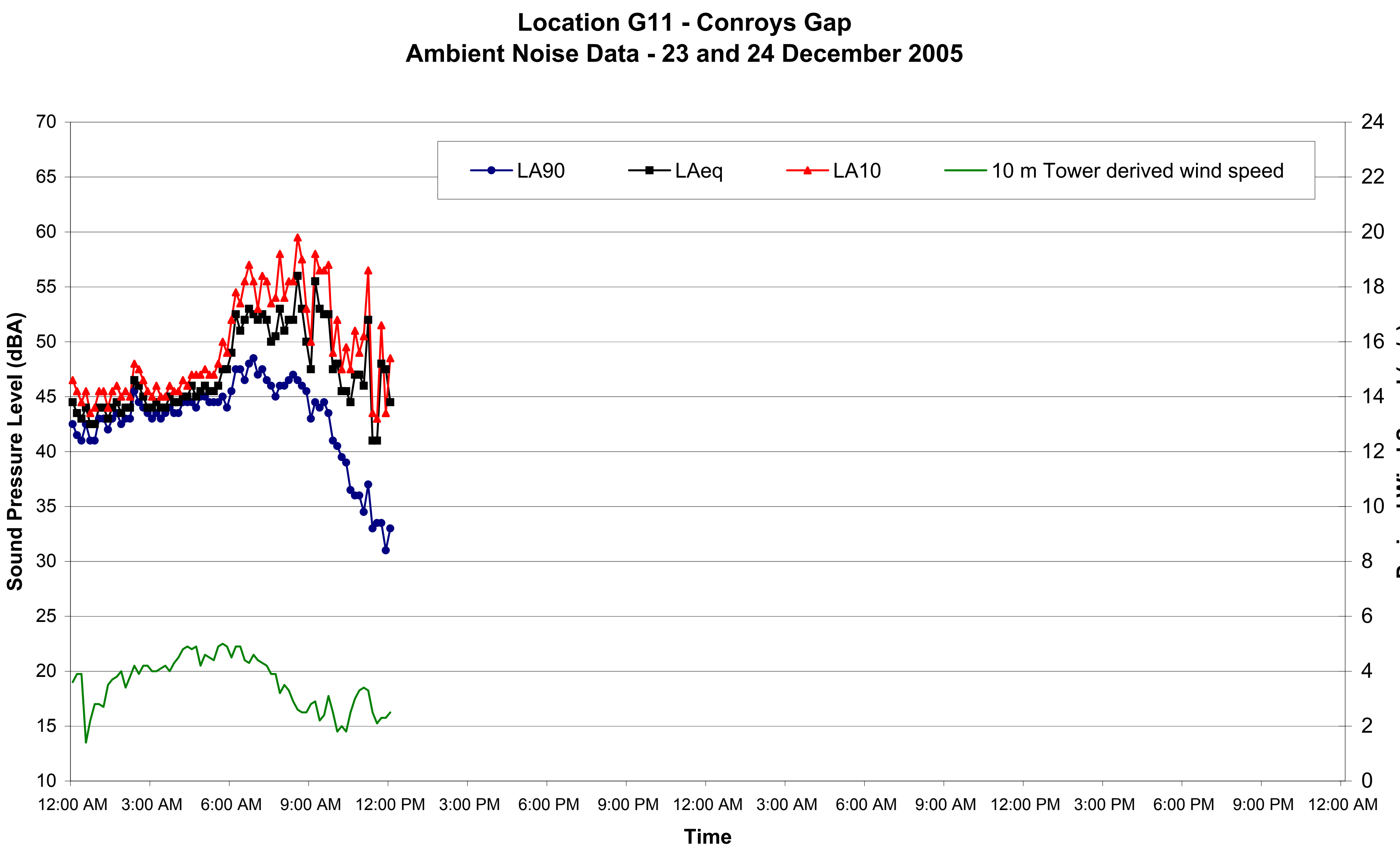

Appendix C2
40-1143
Level Wind vs Time

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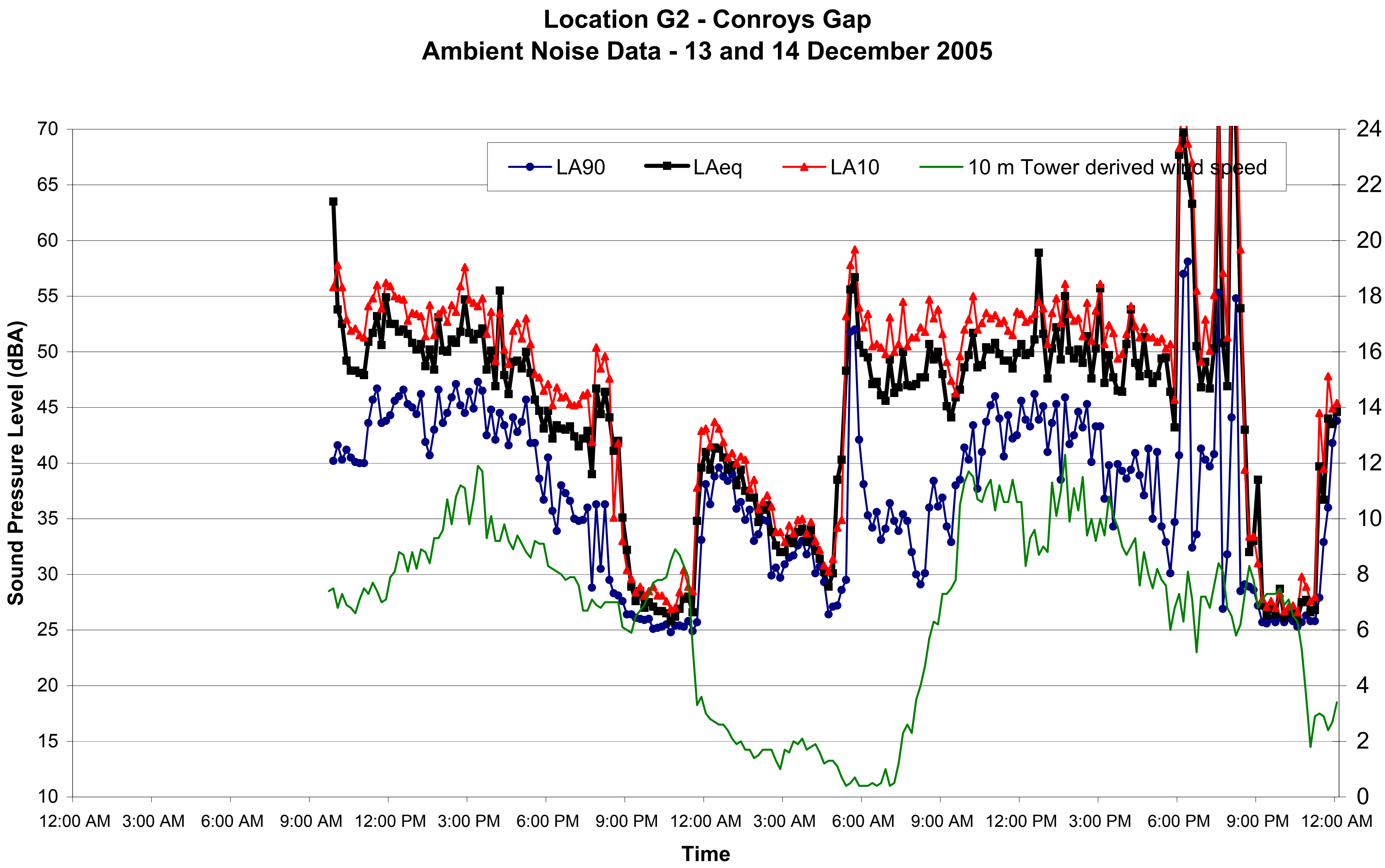

Appendix C3
40-1143
Level Wind vs Time

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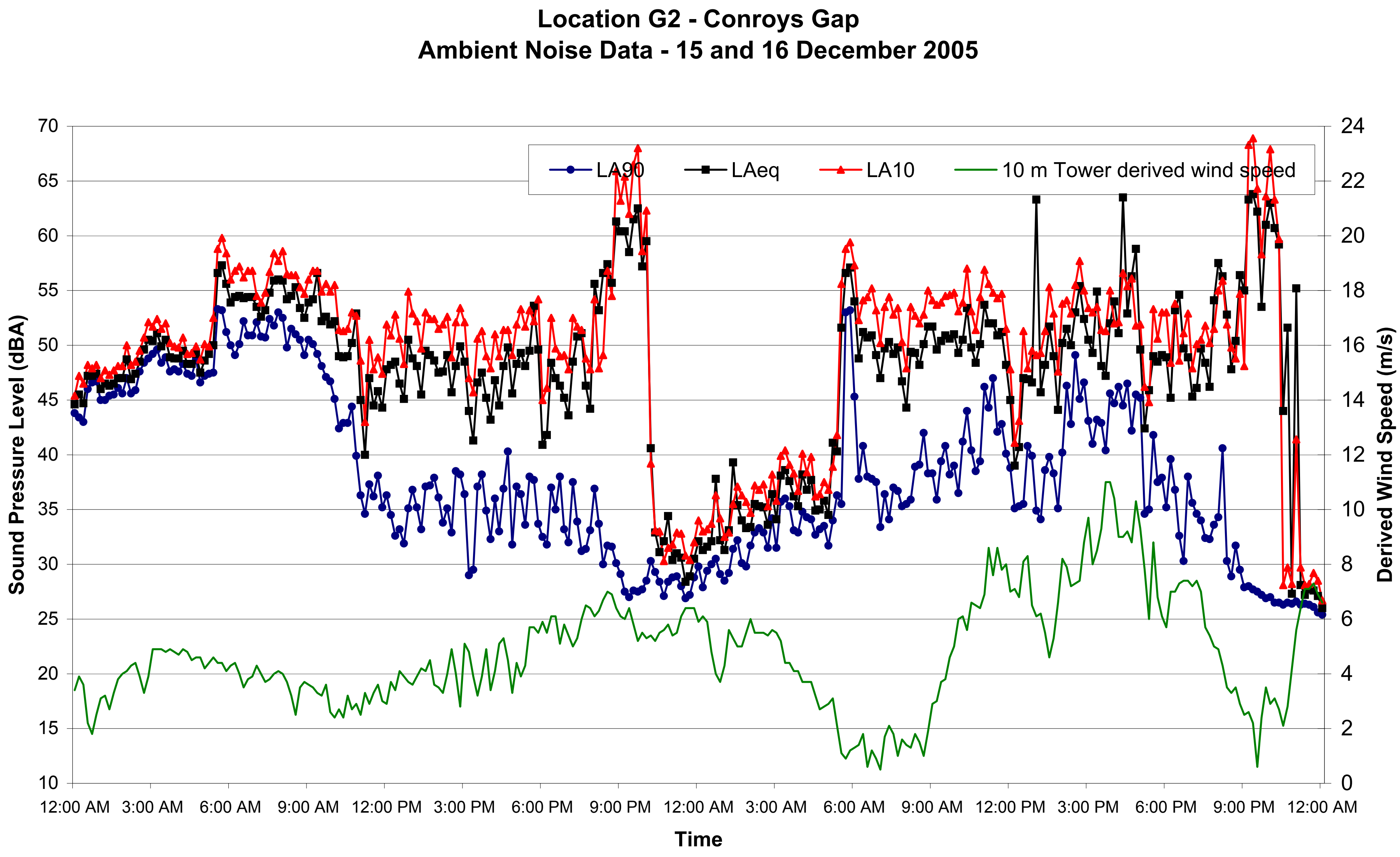
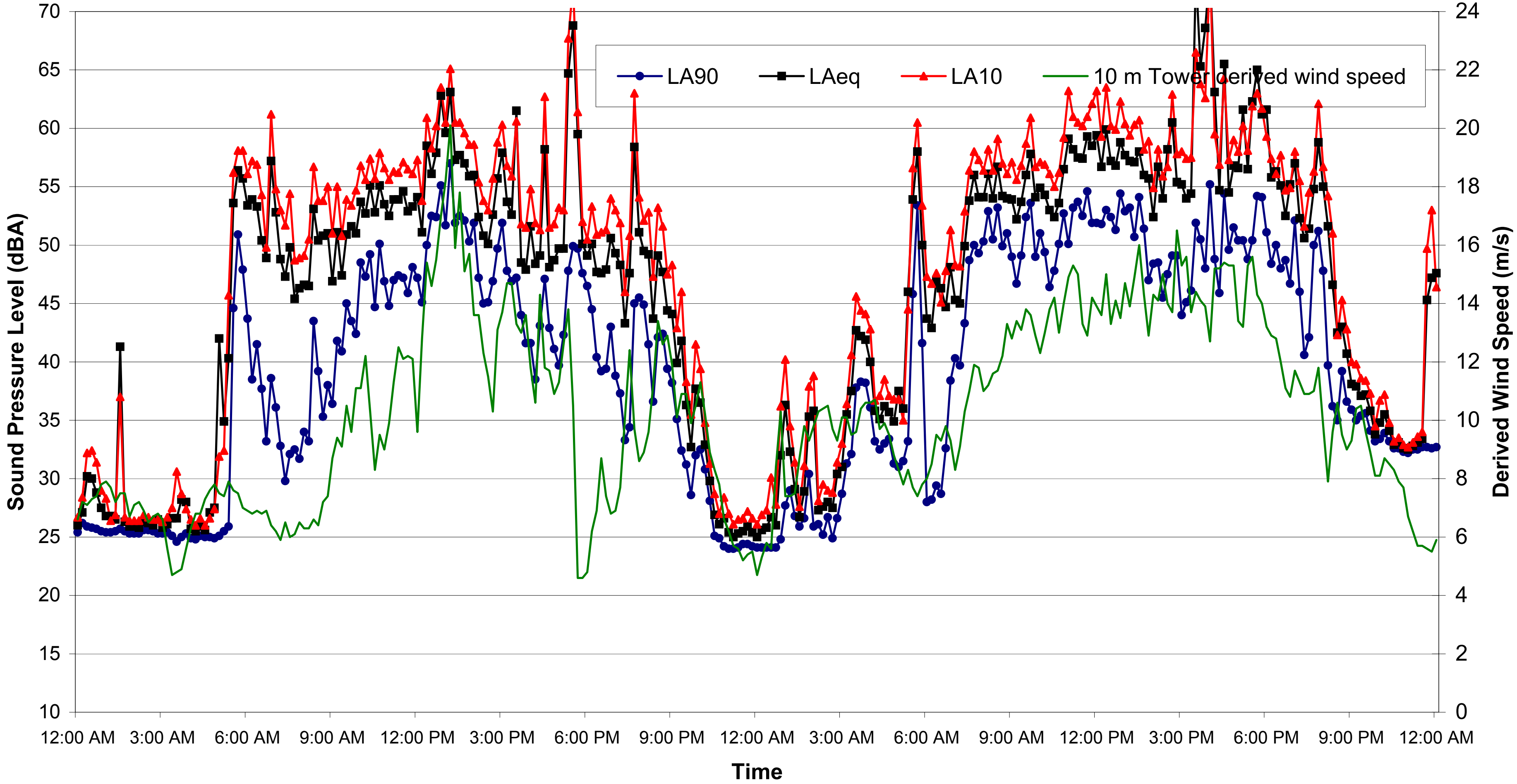


Appendix C3
40-1143
Level Wind vs Time

Location G2 - Conroys Gap
Ambient Noise Data - 17 and 18 December 2005



Appendix C3
40-1143
Level Wind vs Time

Location G2 - Conroys Gap
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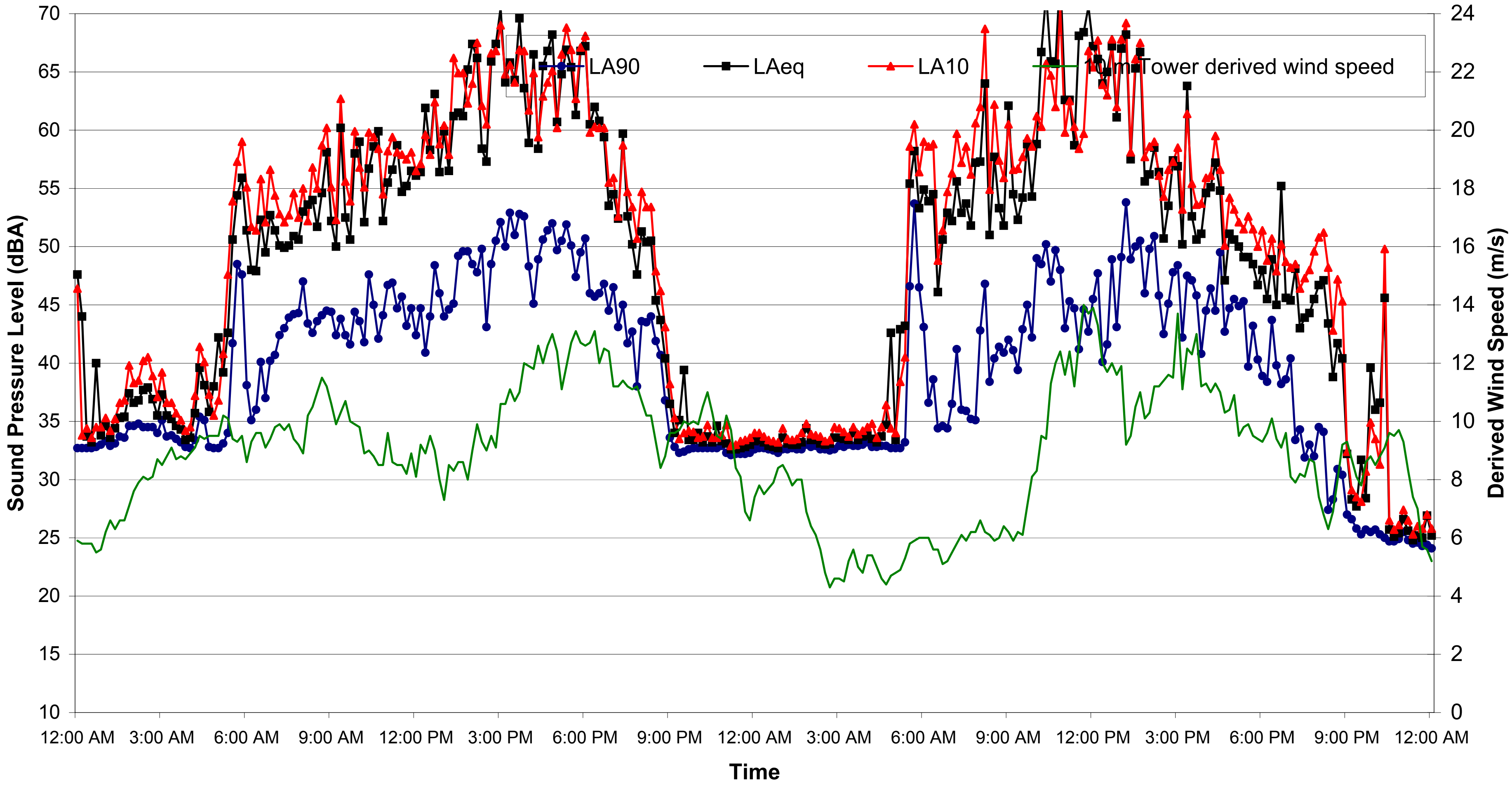

Appendix C3
40-1143
Level Wind vs Time

Location G2 - Conroys Gap
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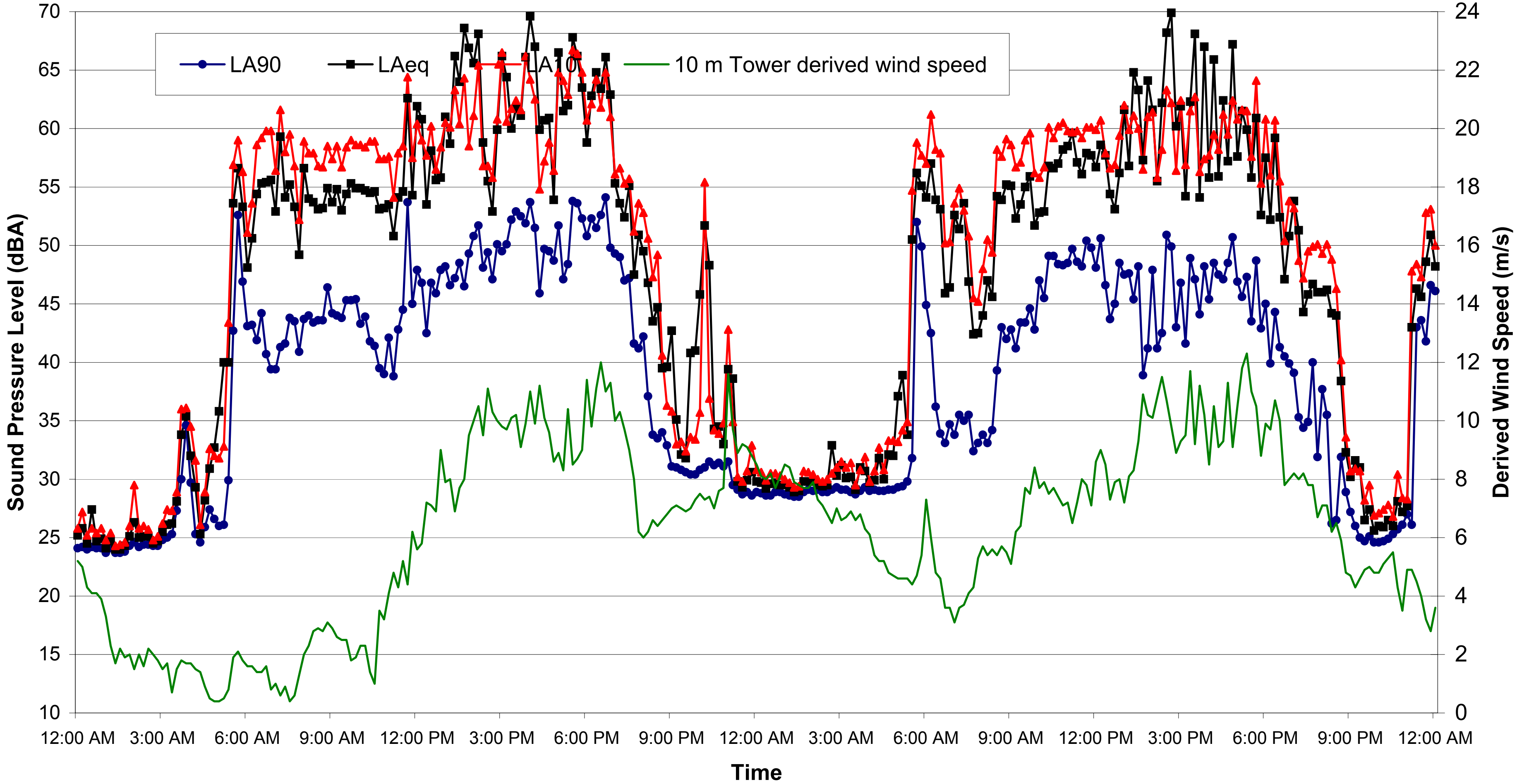
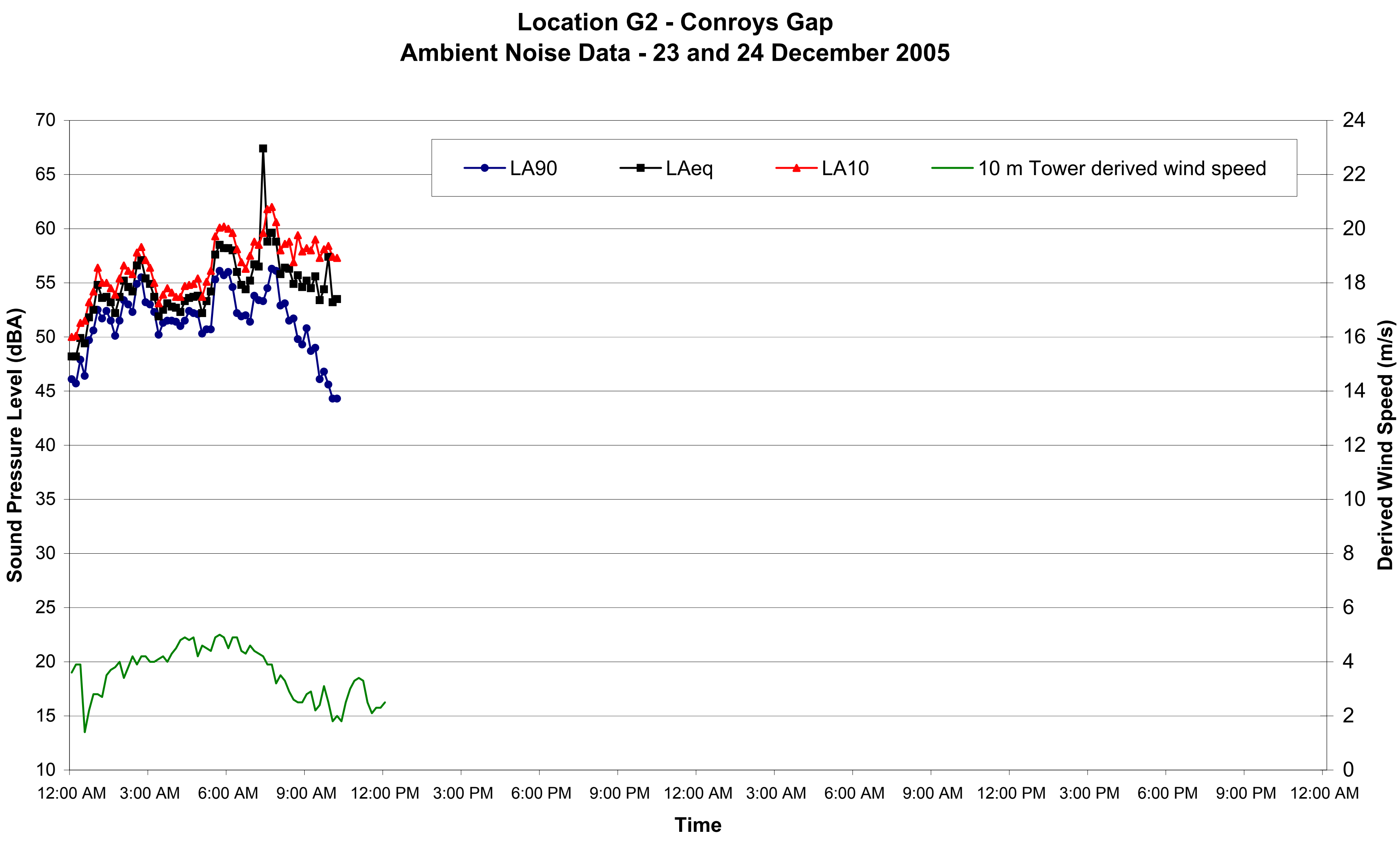
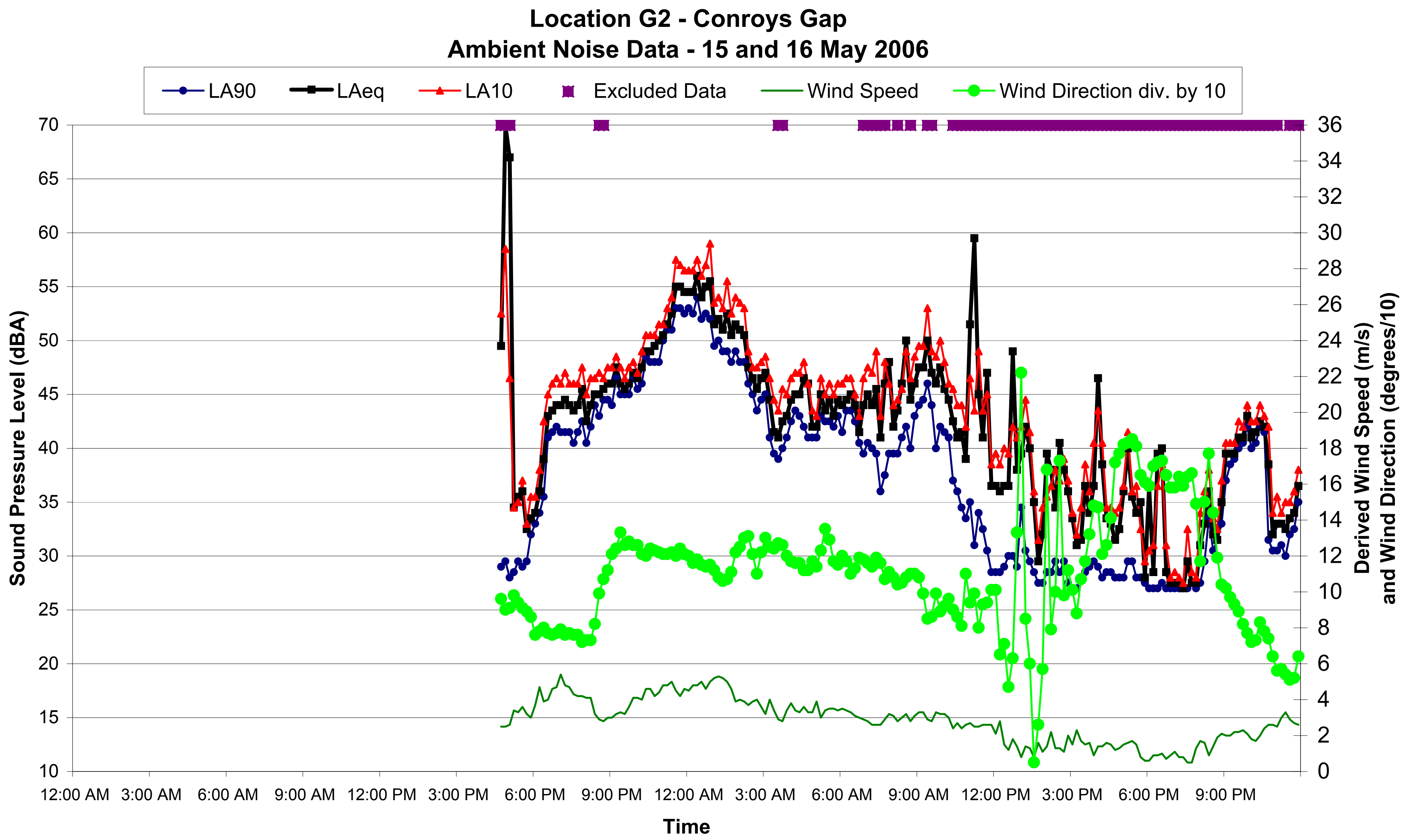


Appendix C3
40-1143
Level Wind vs Time



Appendix C3
40-1143
Level Wind vs Time



Appendix C3
40-1143
Level Wind vs Time

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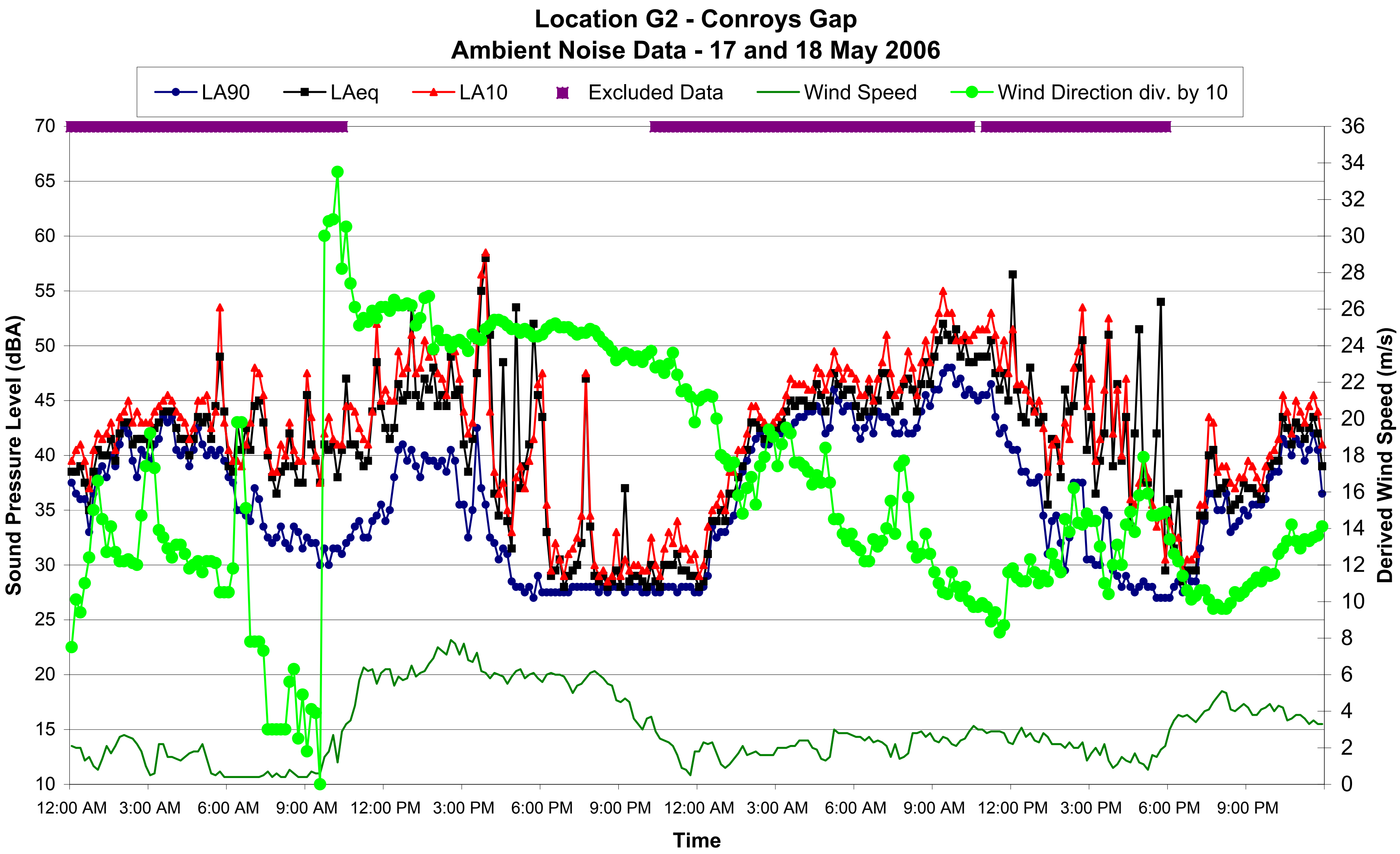

Appendix C3
40-1143
Level Wind vs Time

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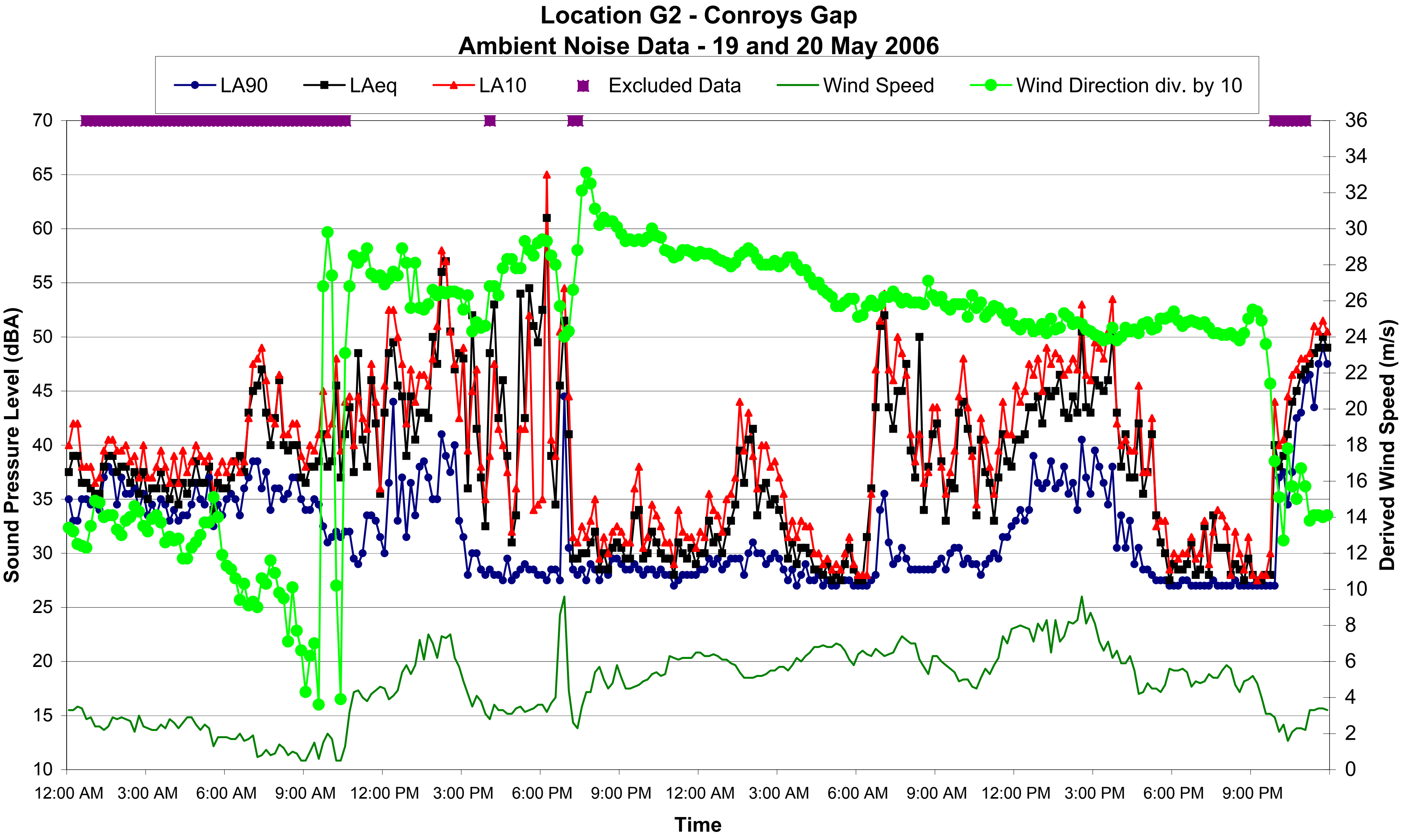
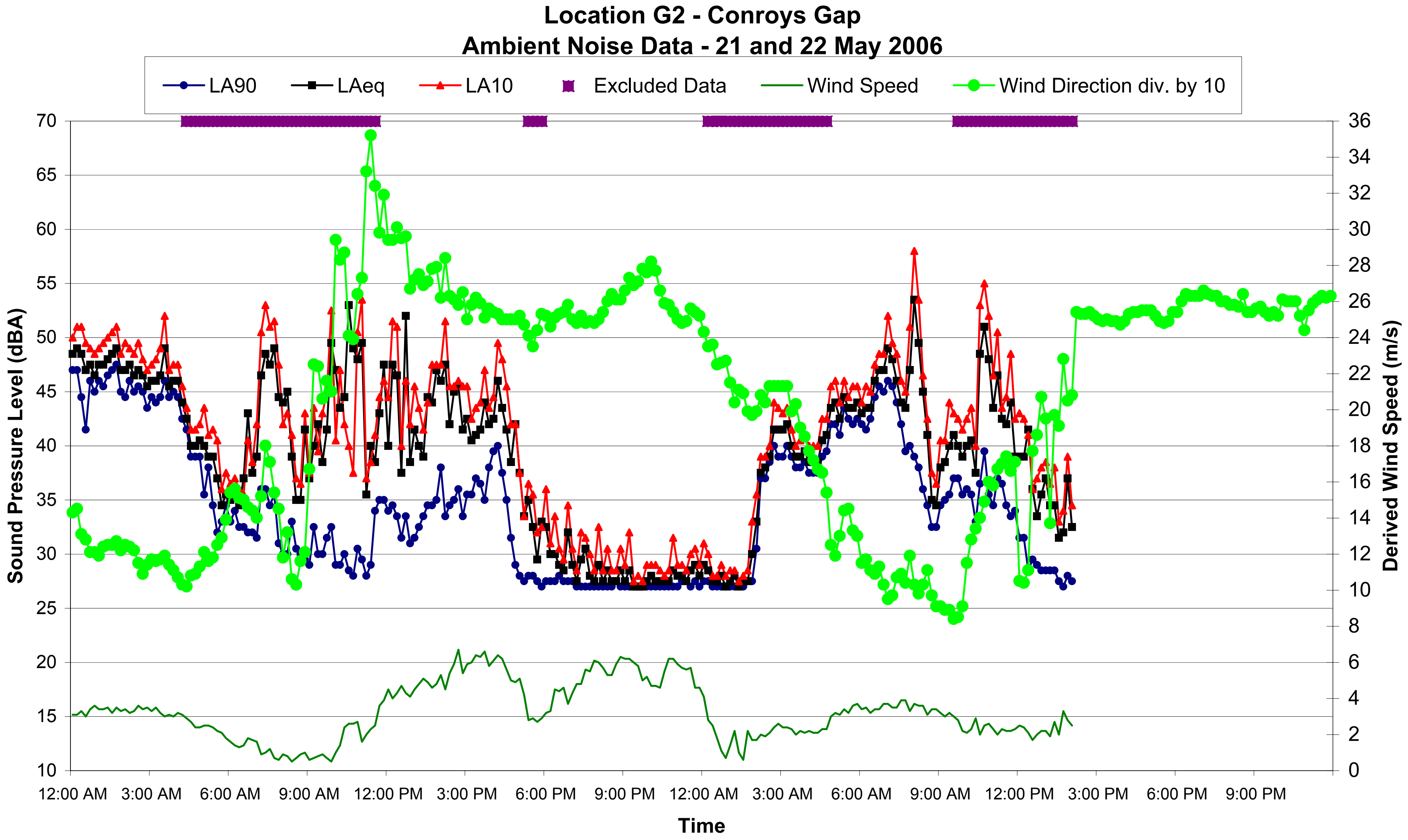
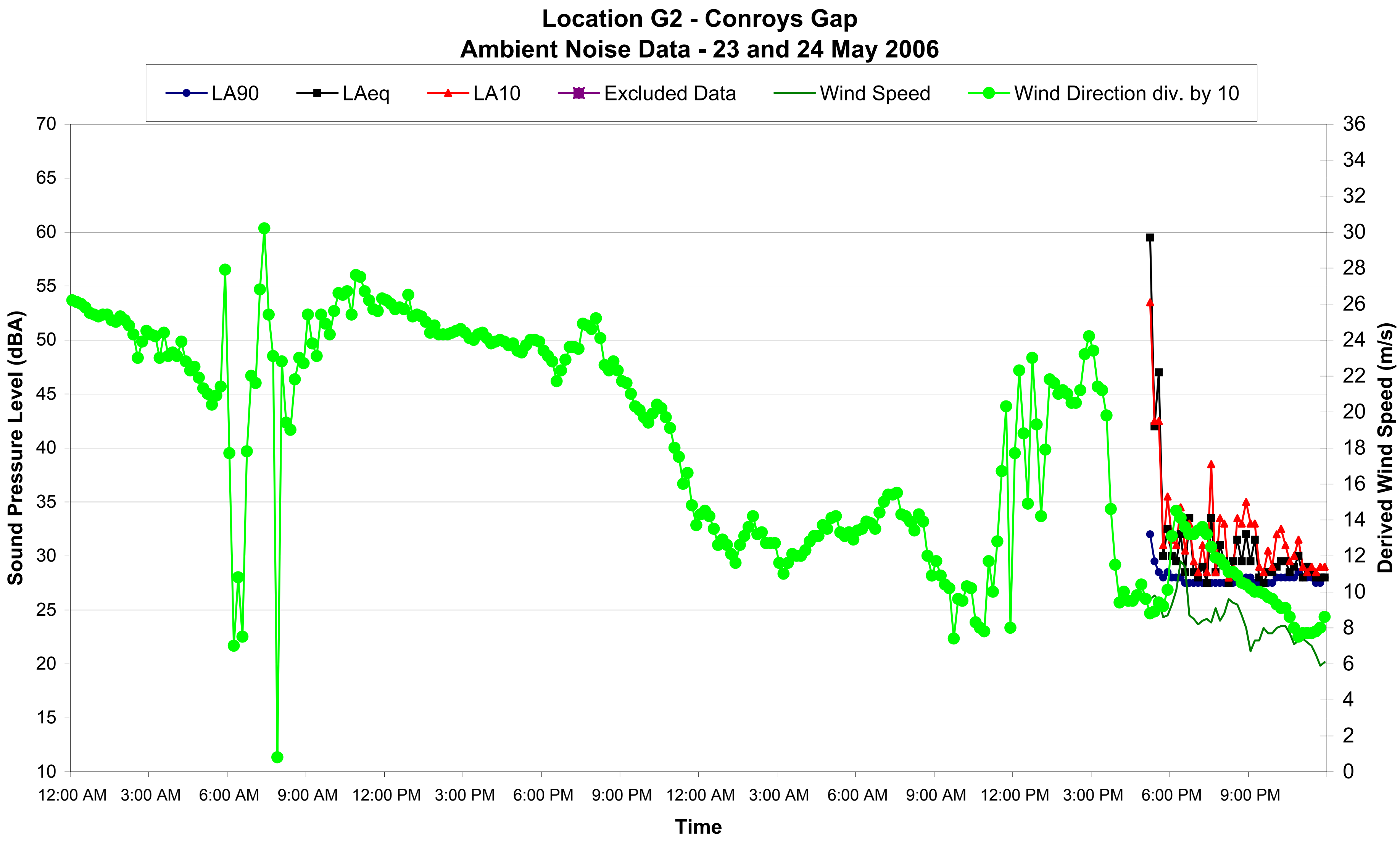


Appendix C3
40-1143
Level Wind vs Time



Appendix C3
40-1143
Level Wind vs Time



Appendix C3
40-1143
Level Wind vs Time

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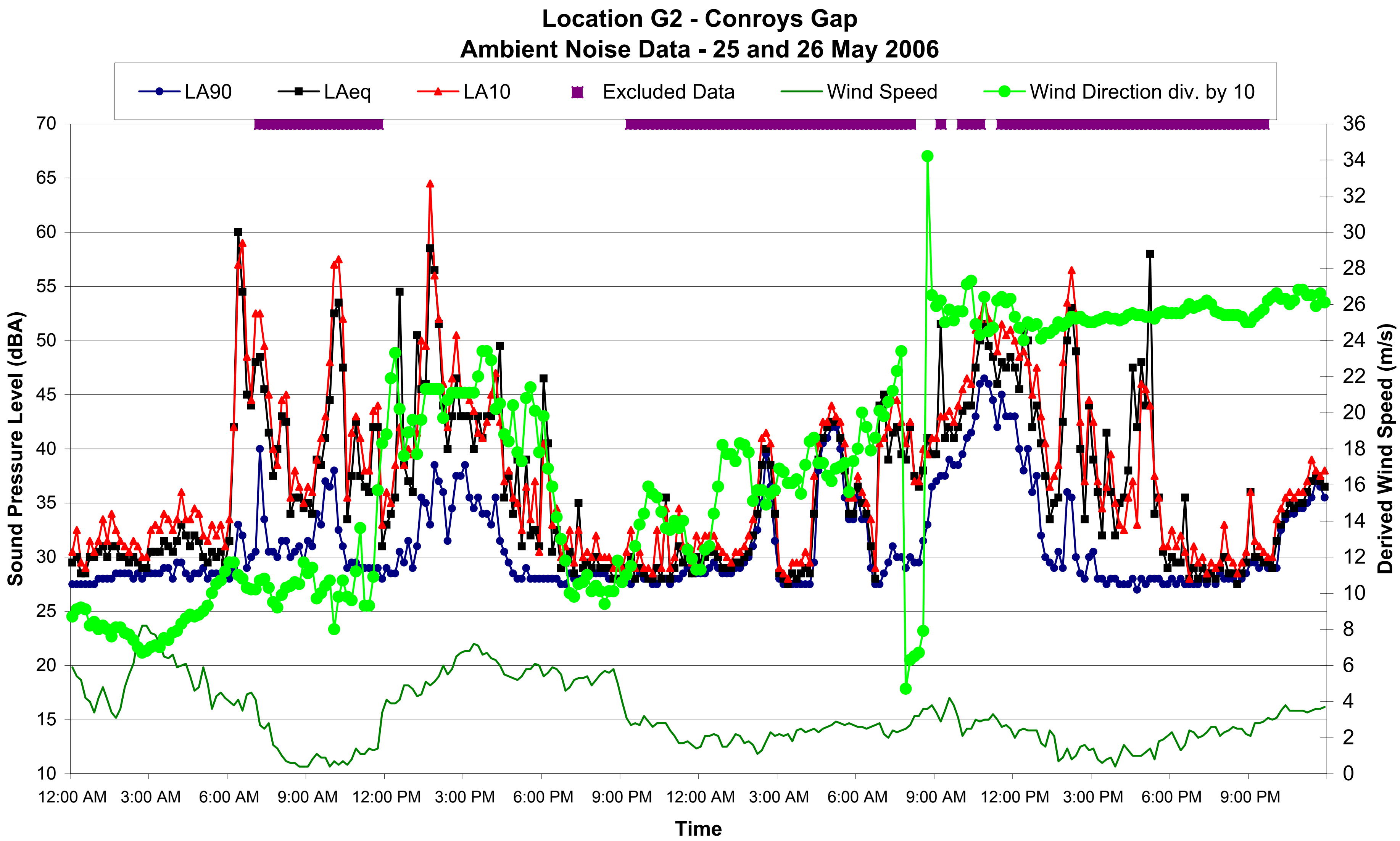

Appendix C3
40-1143
Level Wind vs Time

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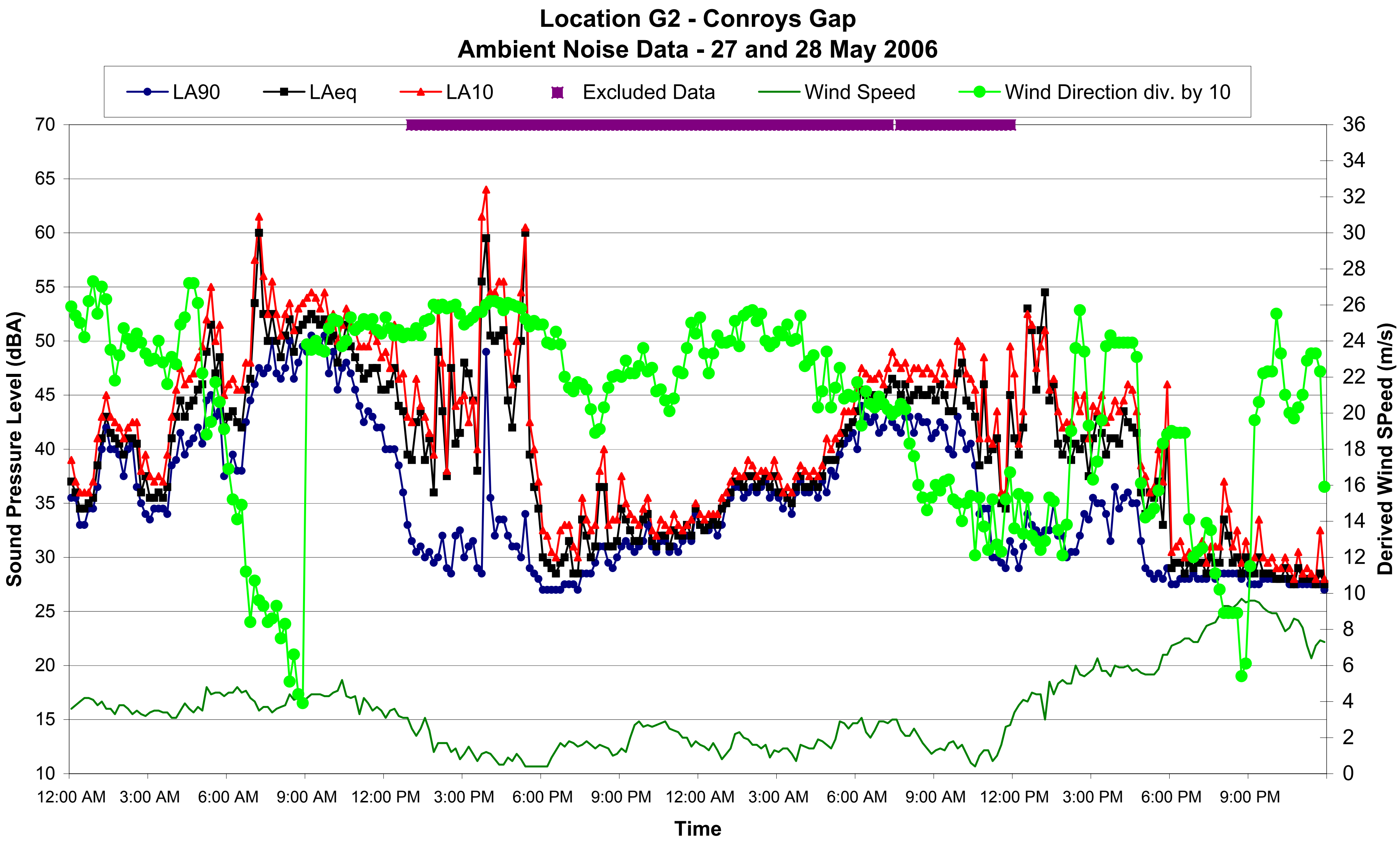

Appendix C3
40-1143
Level Wind vs Time

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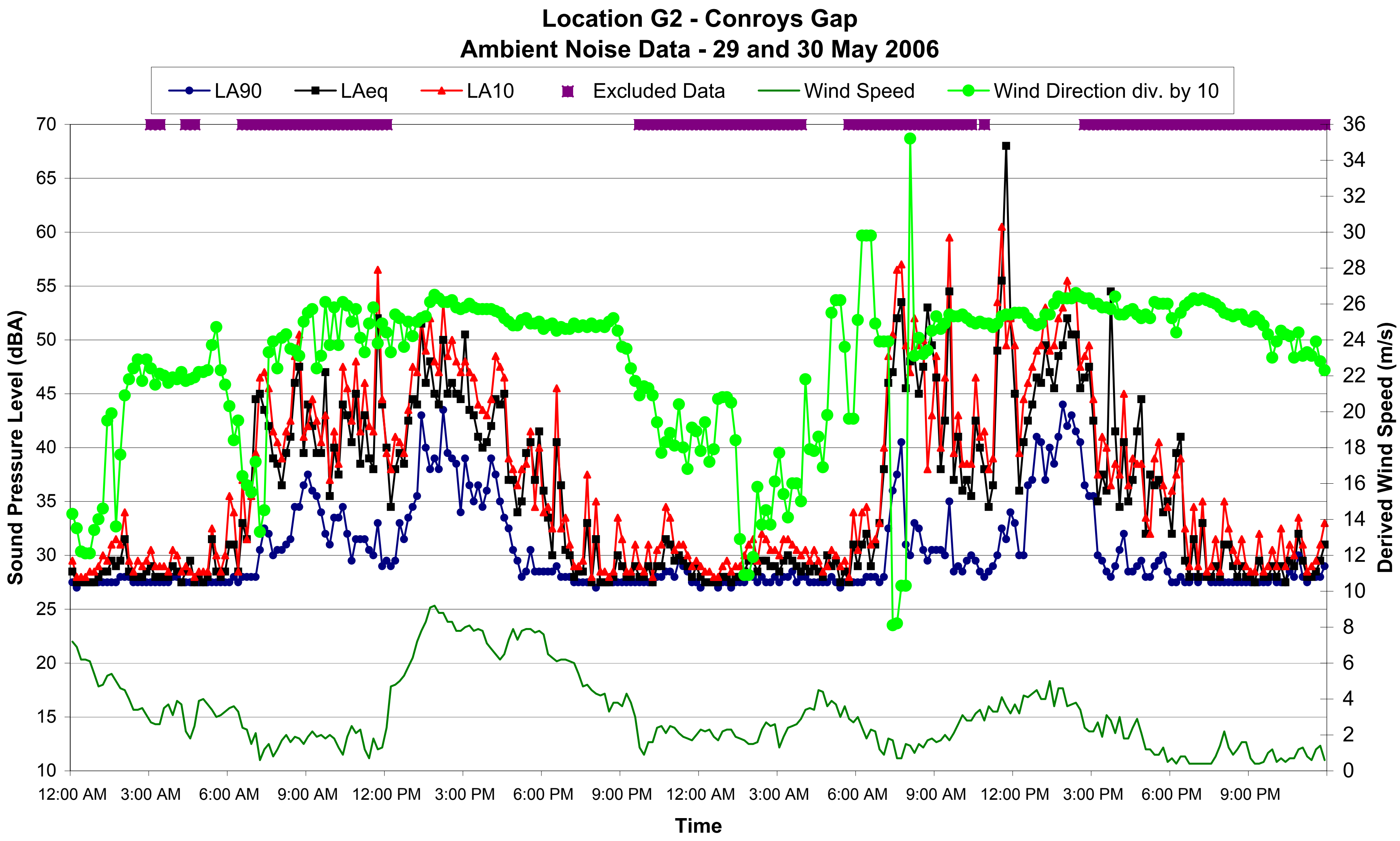

Appendix C3
40-1143
Level Wind vs Time

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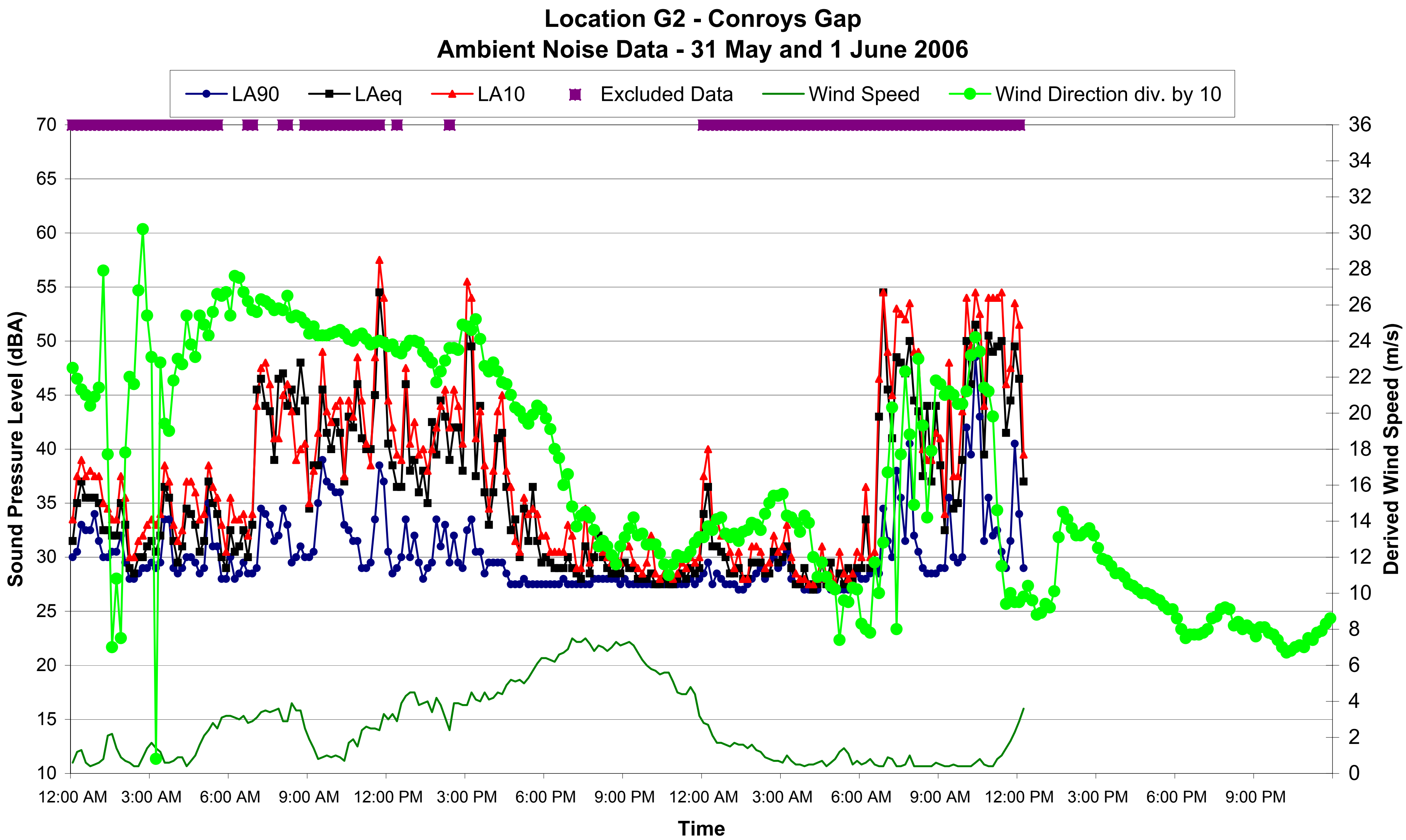

Appendix C3
40-1143
Level Wind vs Time

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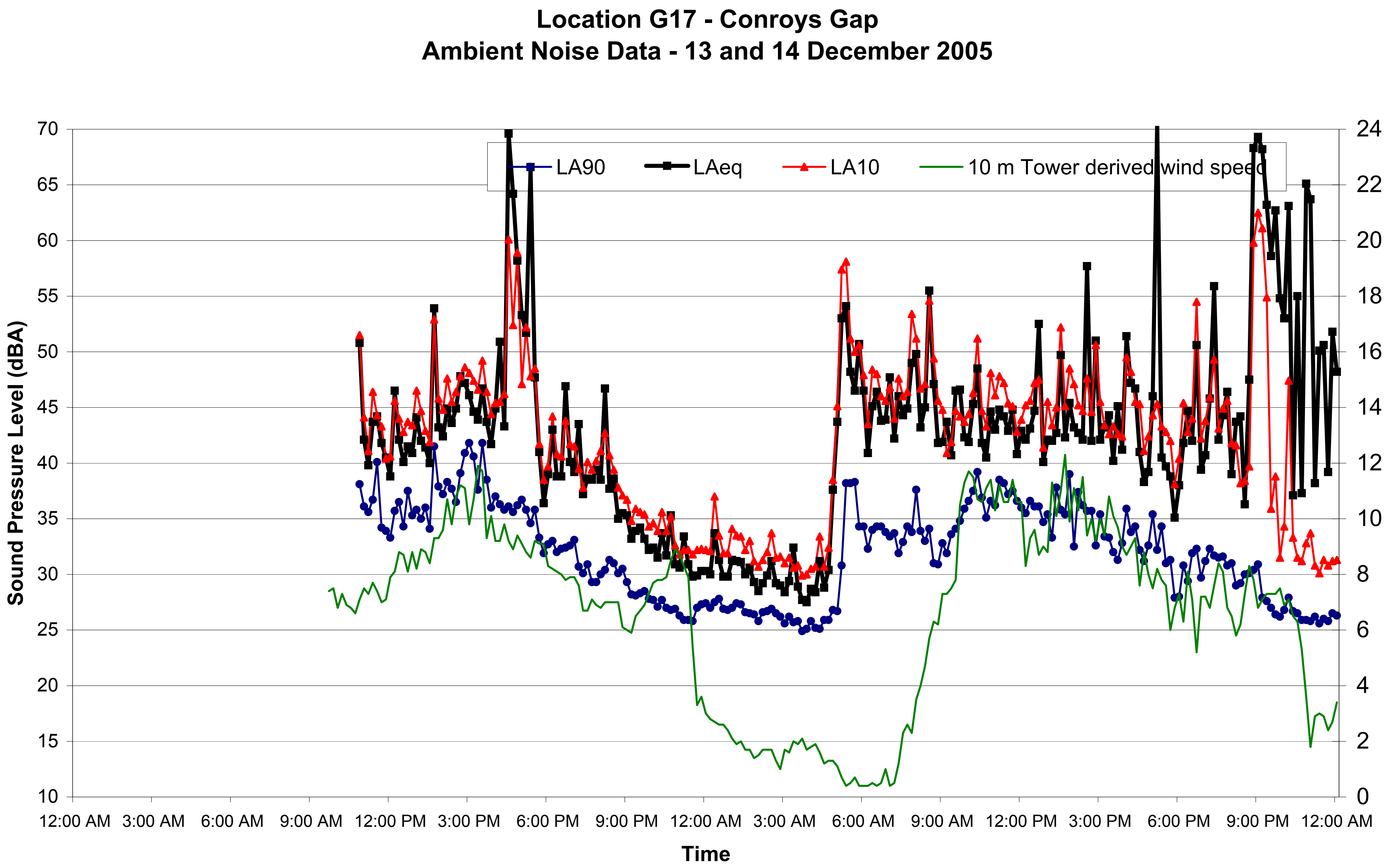

Appendix C4
40-1143
Level Wind vs Time

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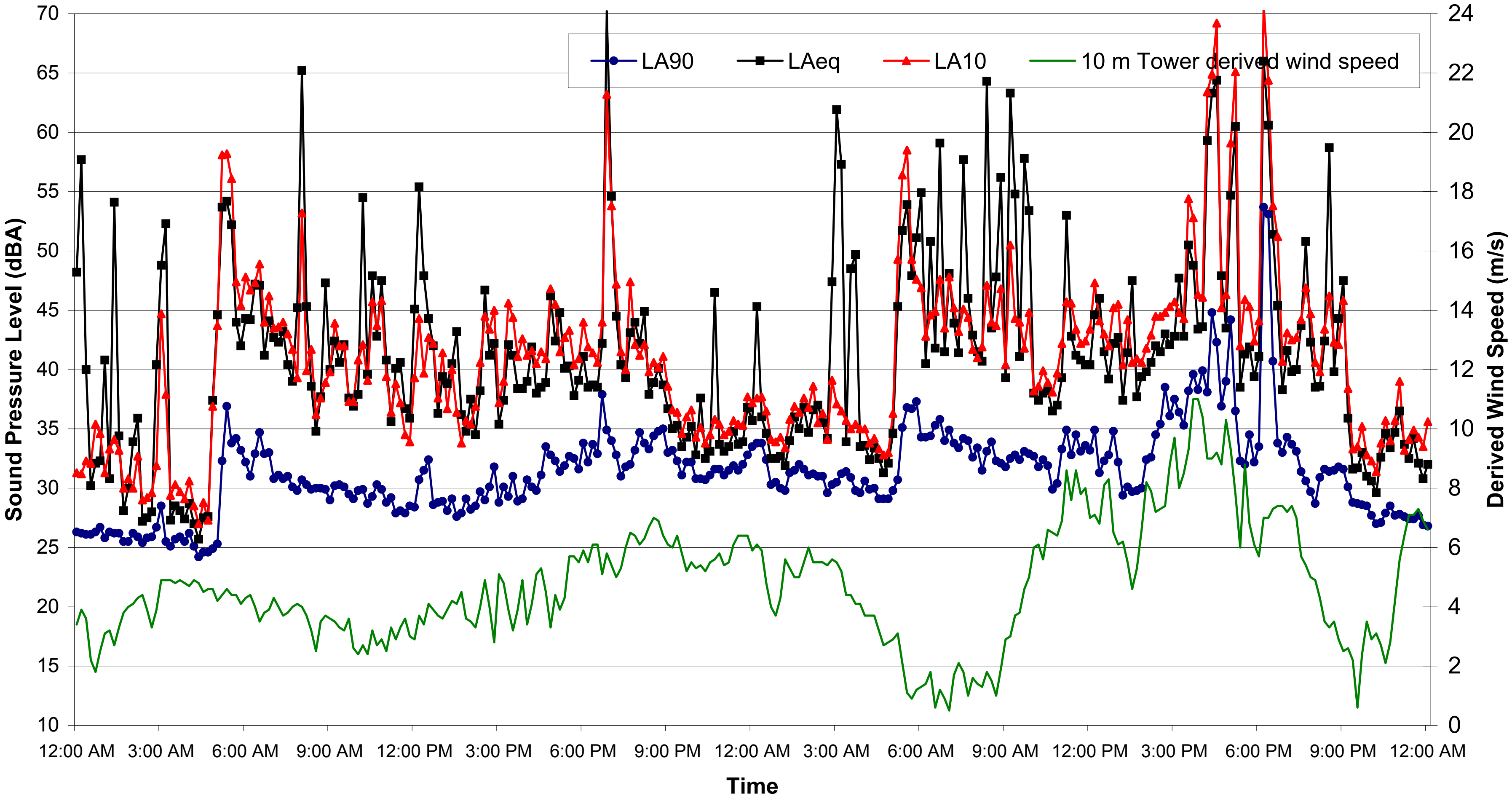
Location G17 - Conroys Gap
Ambient Noise Data - 15 and 16 December 2005



Appendix C4
40-1143
Level Wind vs Time

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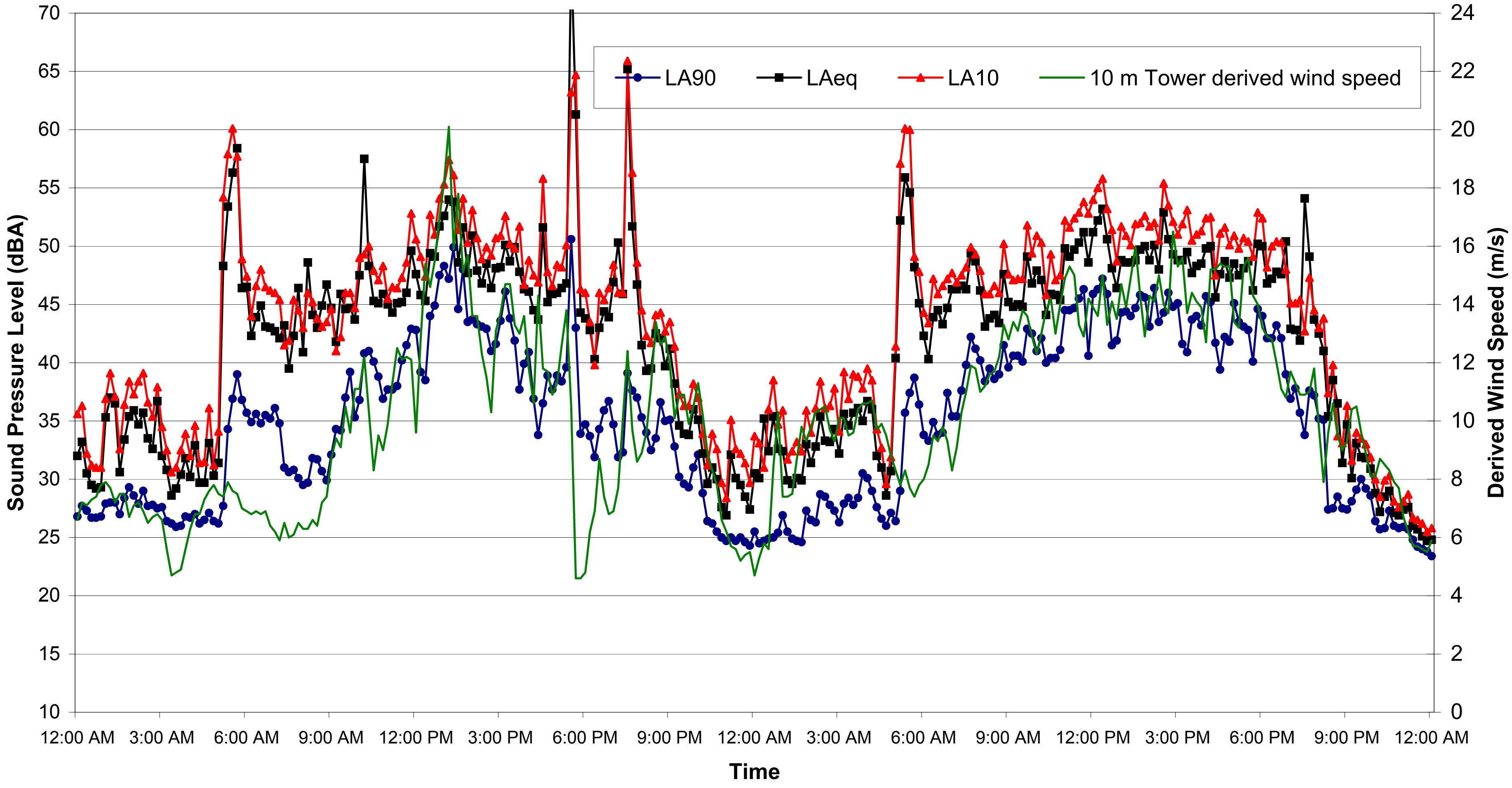
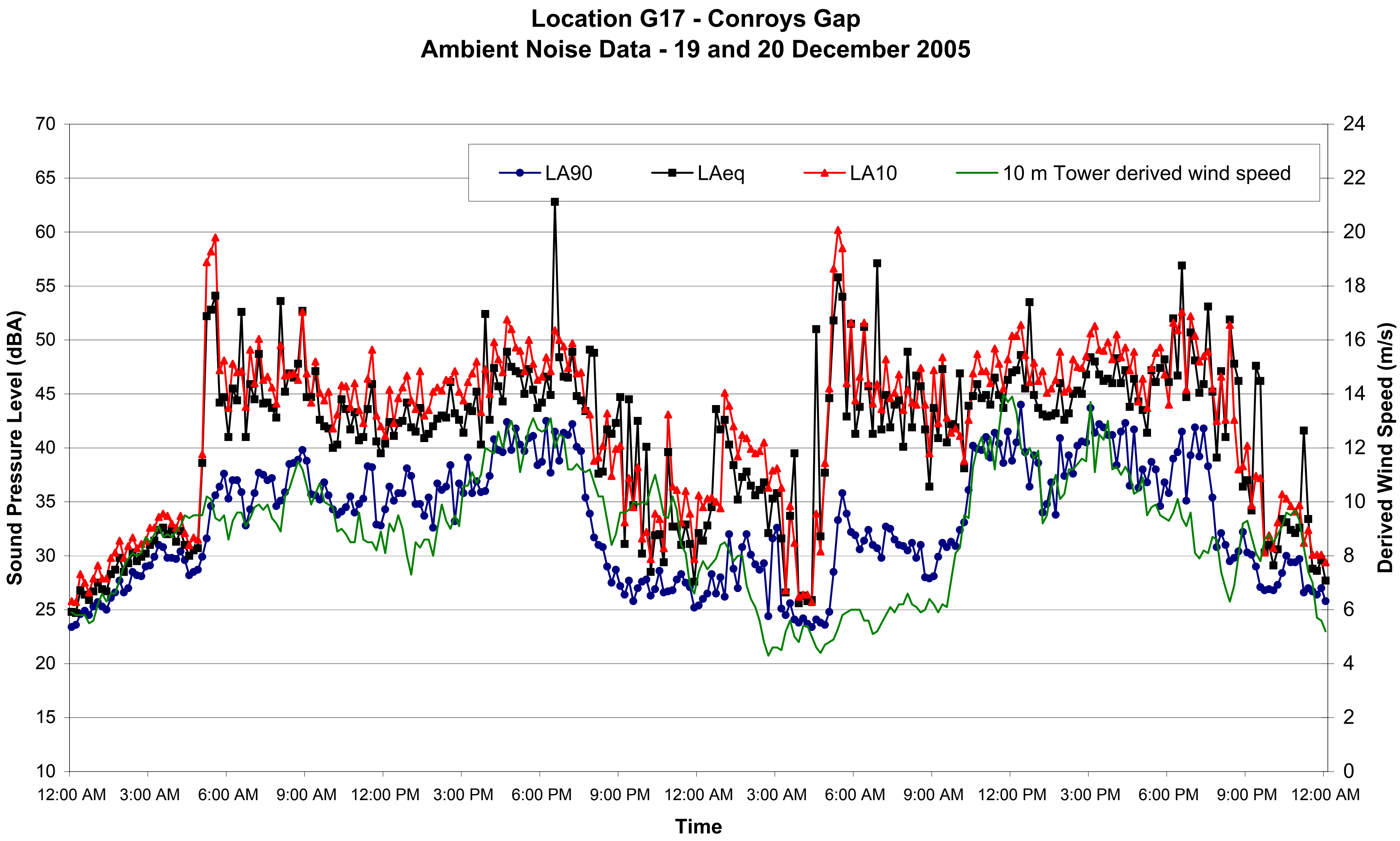
Location G17 - Conroys Gap
Ambient Noise Data - 17 and 18 December 2005



Appendix C4
40-1143
Level Wind vs Time



Appendix C4
40-1143
Level Wind vs Time

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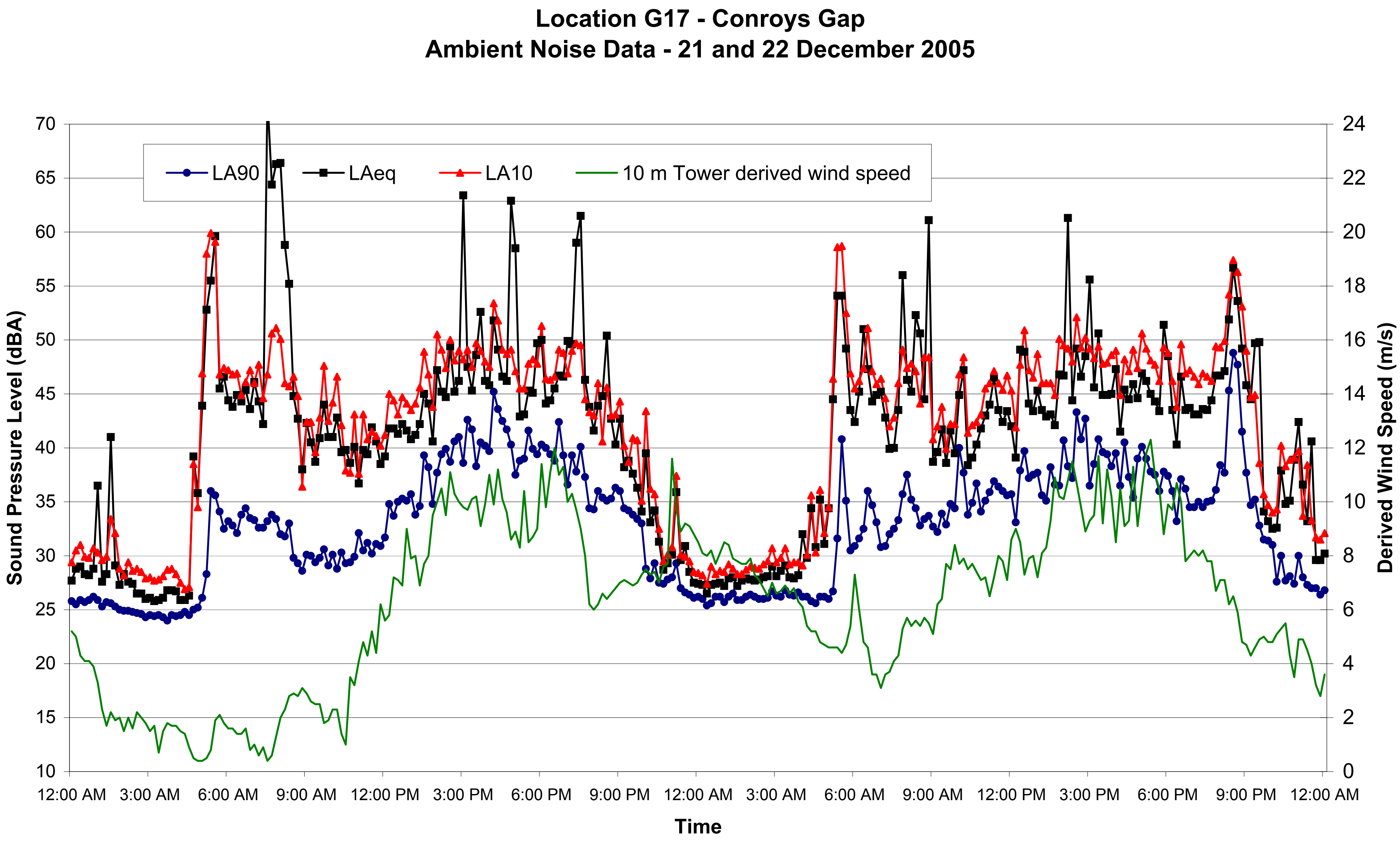

Appendix C4
40-1143
Level Wind vs Time

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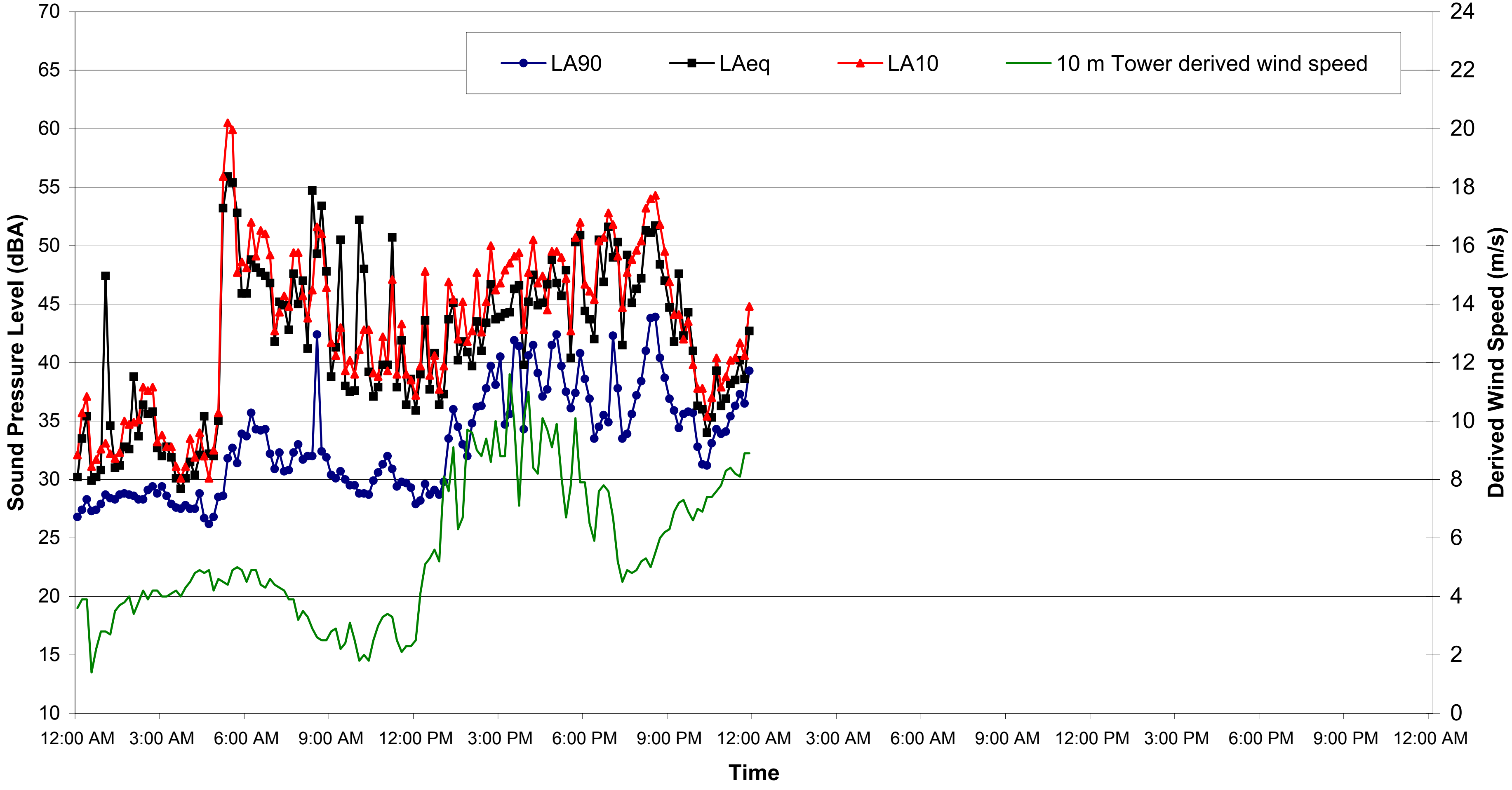
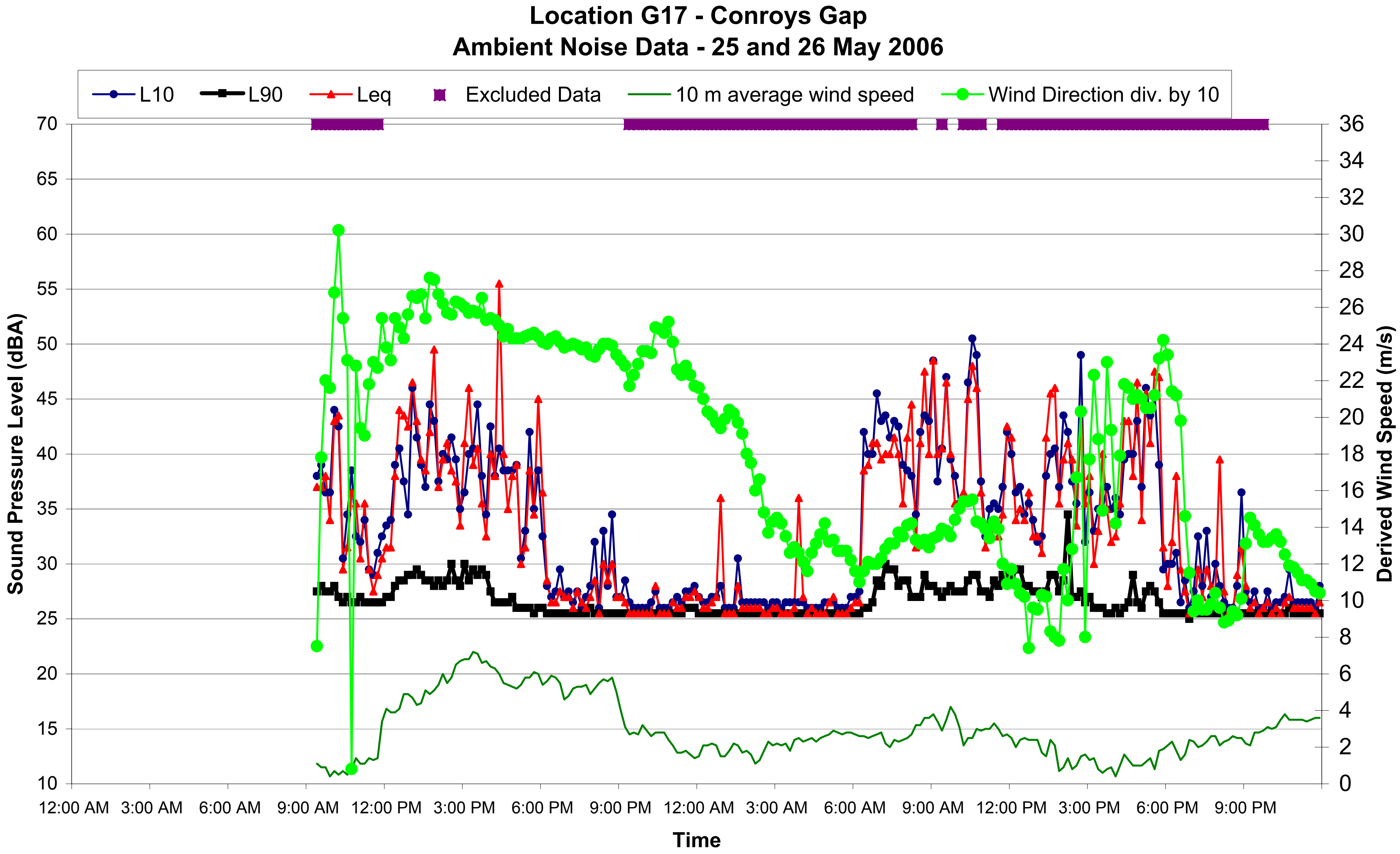
Location G17 - Conroys Gap
Ambient Noise Data - 23 and 24 December 2005



Appendix C4
40-1143
Level Wind vs Time



Appendix C4
40-1143
Level Wind vs Time

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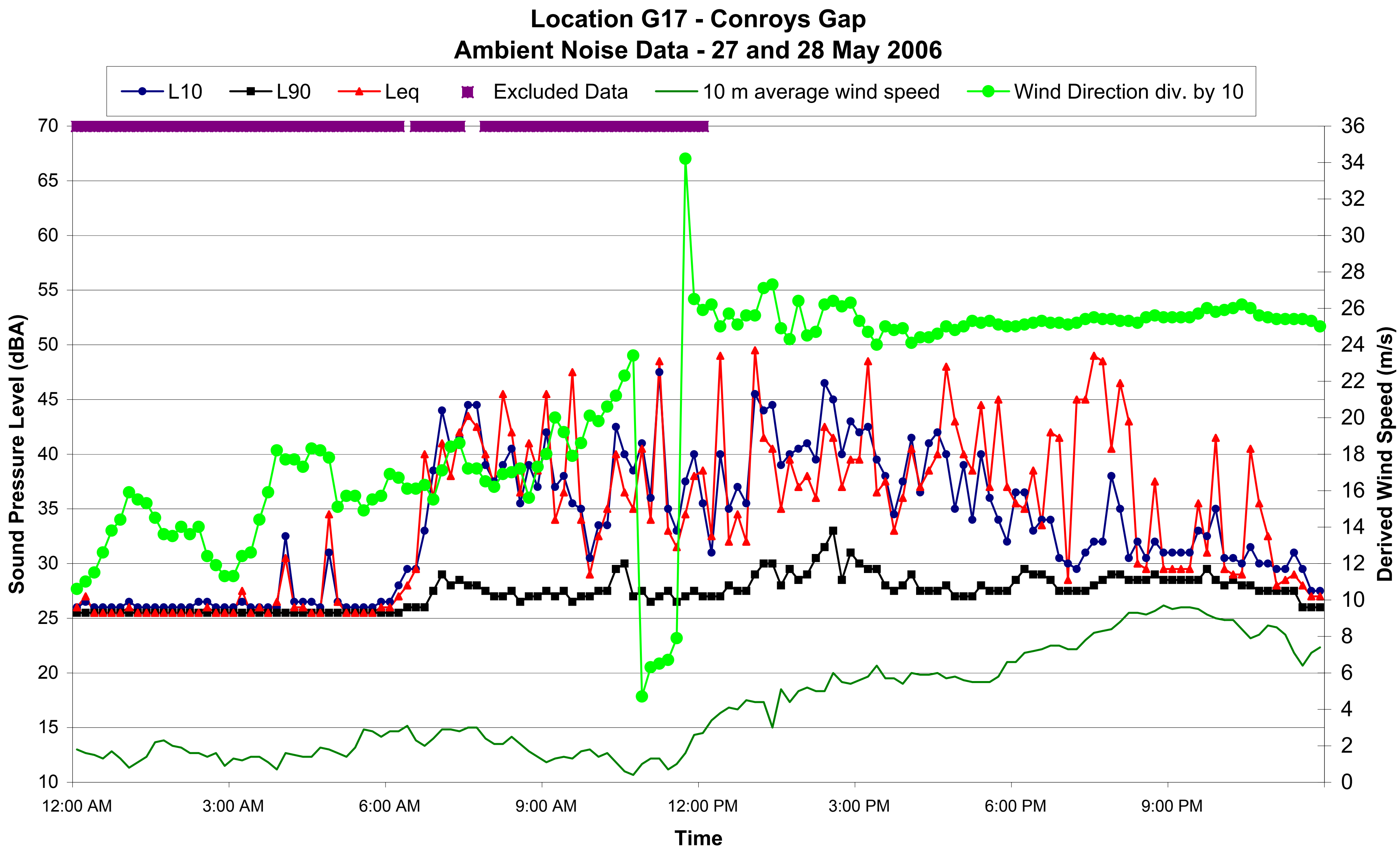

Appendix C4
40-1143
Level Wind vs Time

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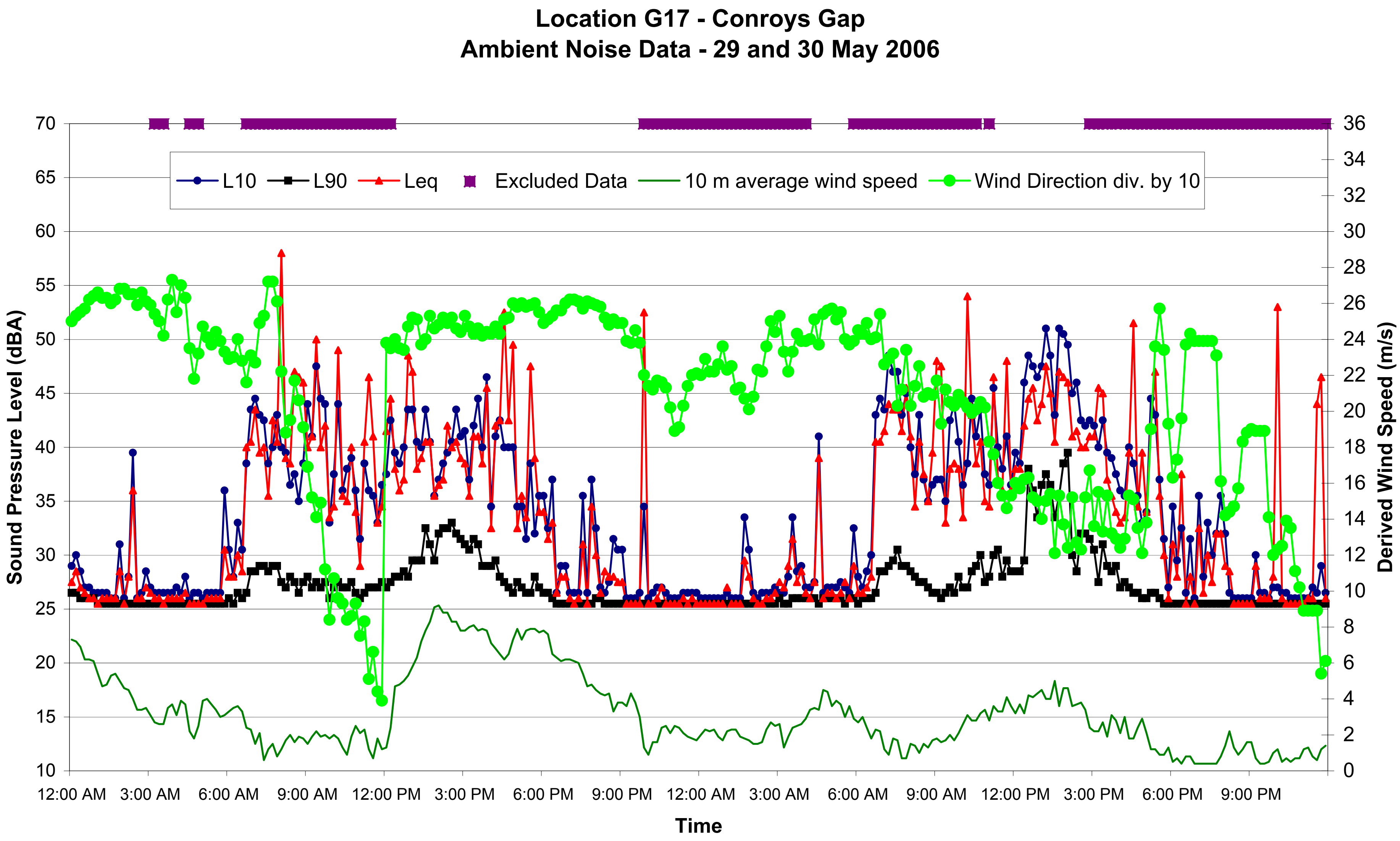
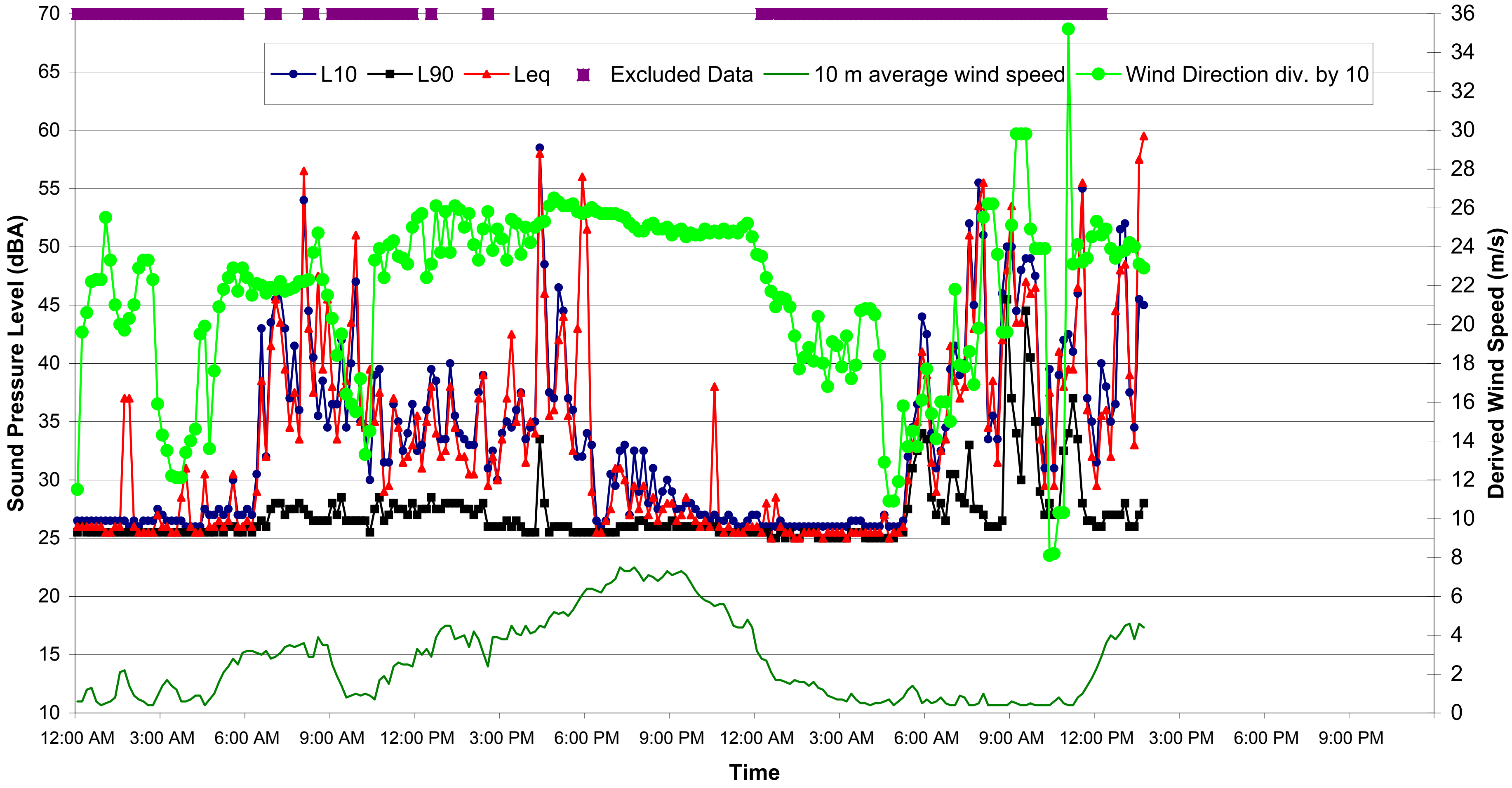


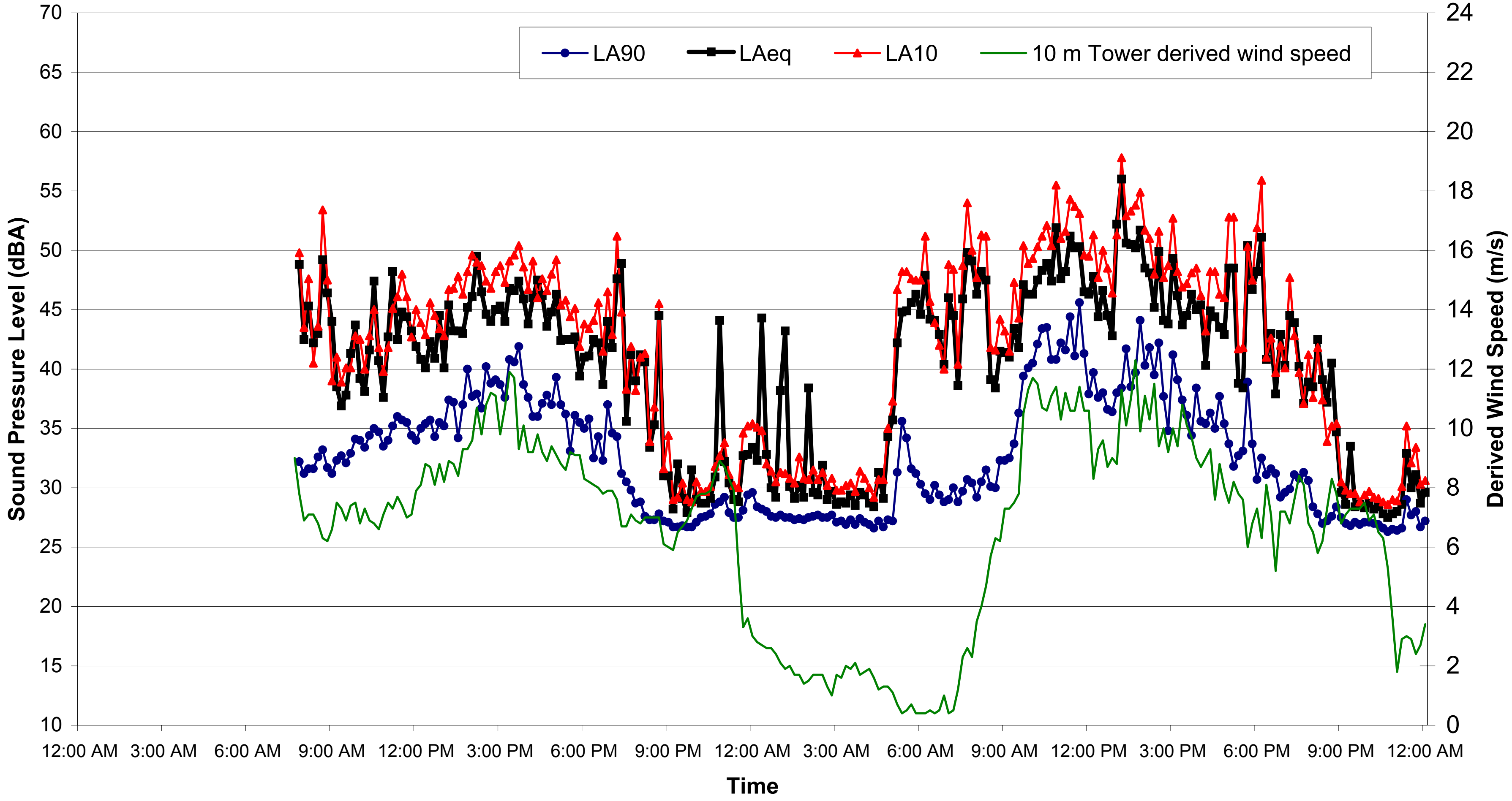
Appendix C4
40-1143
Level Wind vs Time

Location G17 - Conroys Gap
Ambient Noise Data - 31 May and 1 June 2006



Appendix C4
40-1143
Level Wind vs Time

Location G24 - Conroys Gap
Ambient Noise Data - 13 and 14 December 2005



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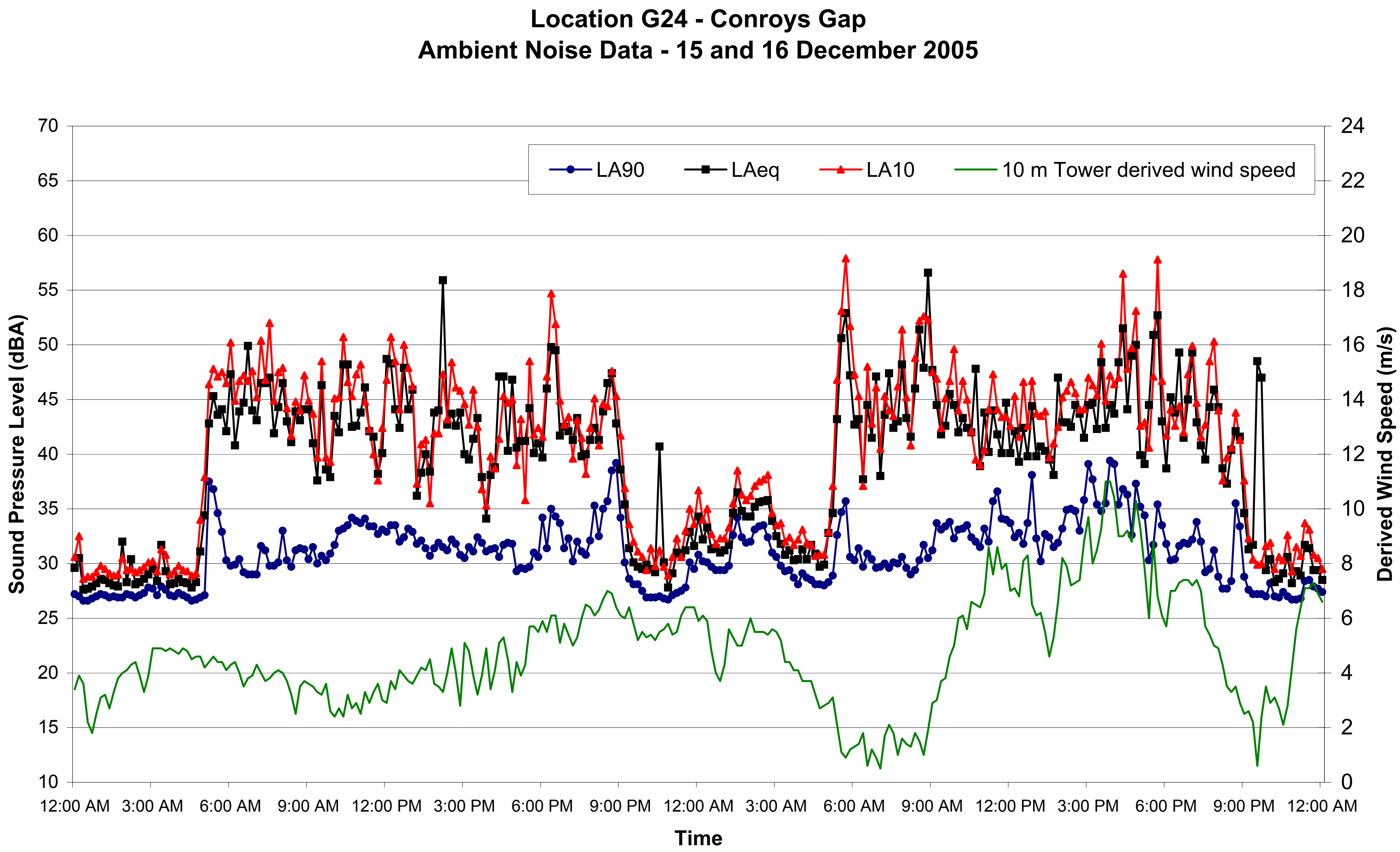
40-1143
Level Wind vs Time



Appendix C5
40-1143
Level Wind vs Time

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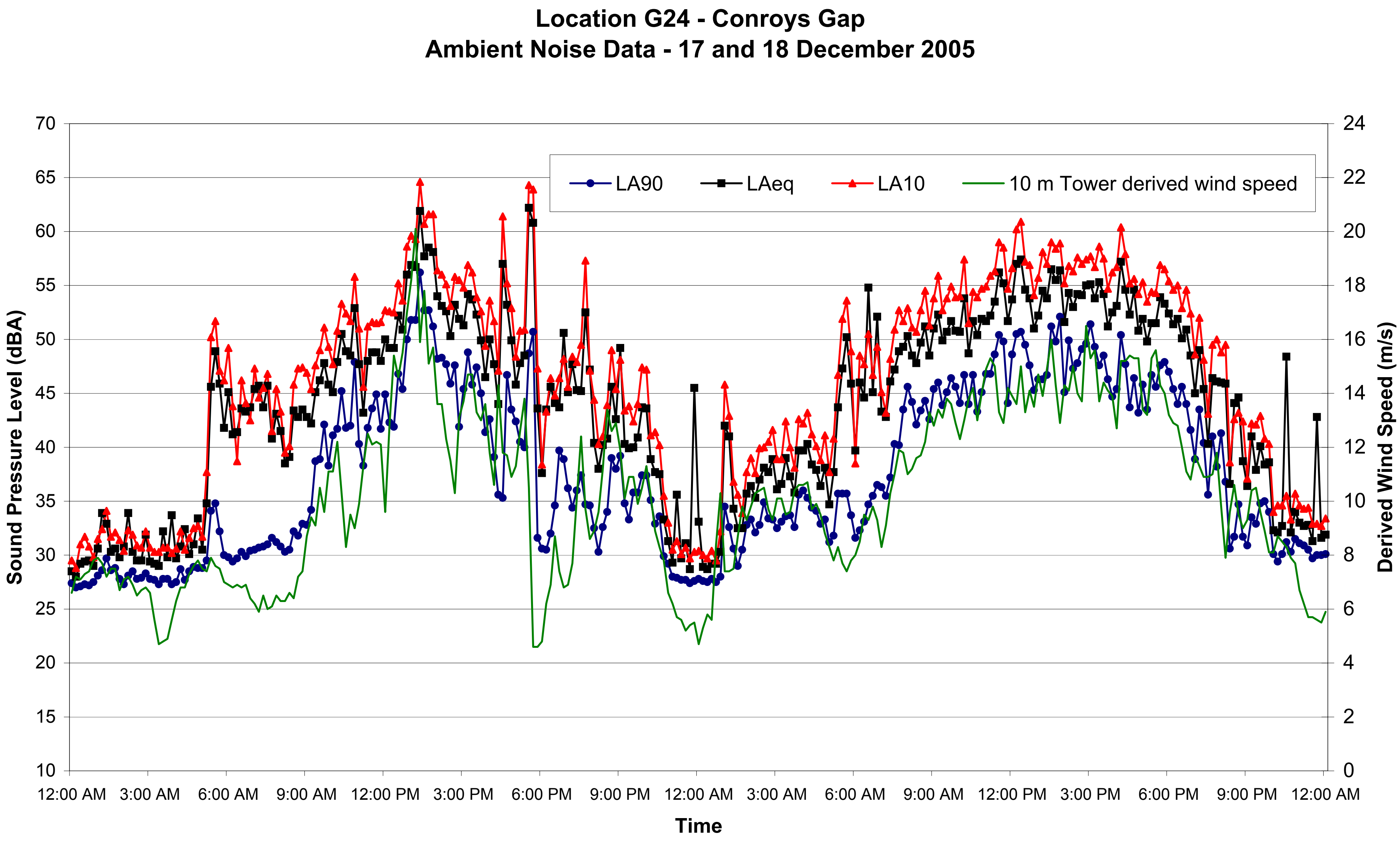
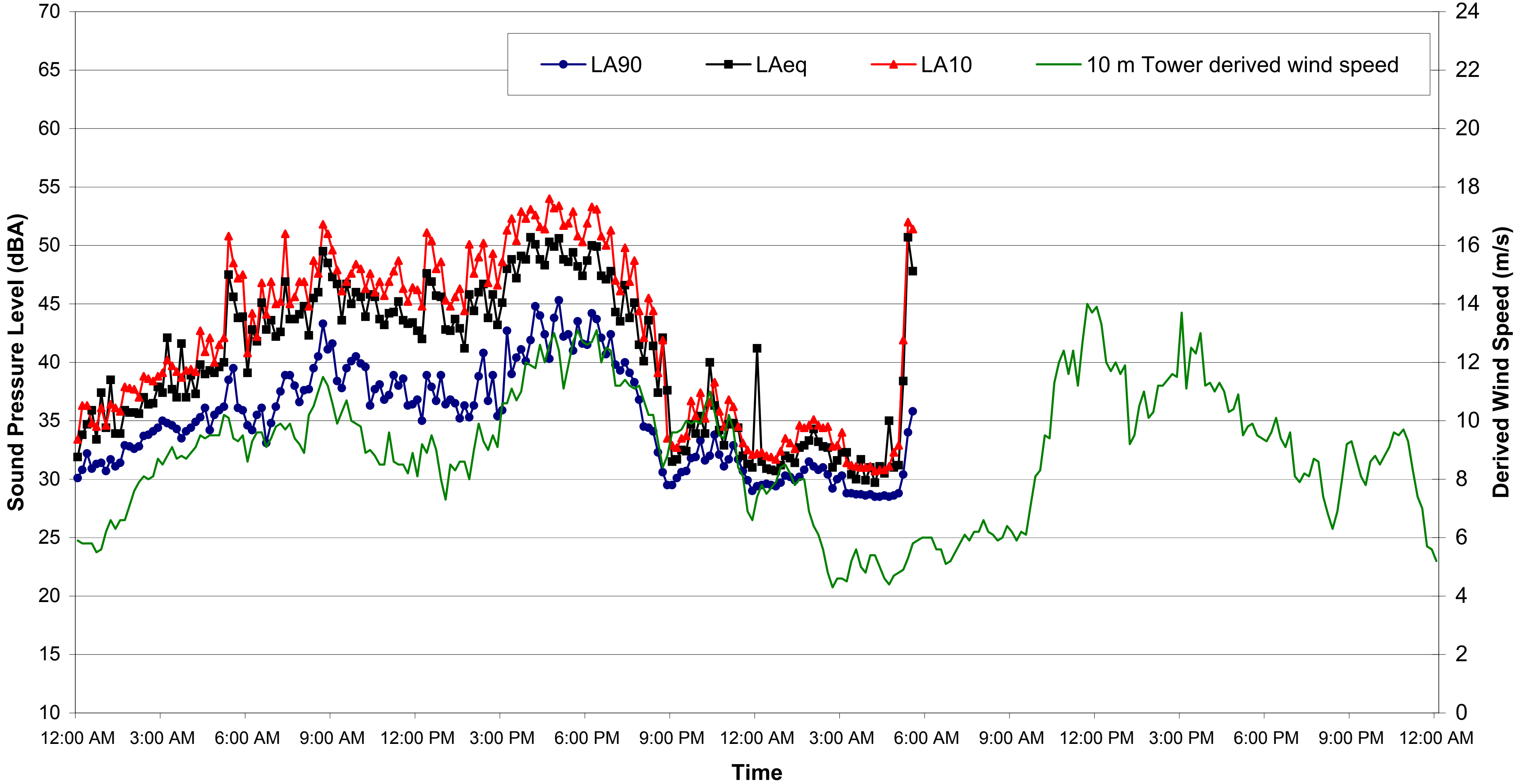


Appendix C5
40-1143
Level Wind vs Time

Location G24 - Conroys Gap
Ambient Noise Data - 19 and 20 December 2005



Appendix C5
40-1143
Level Wind vs Time

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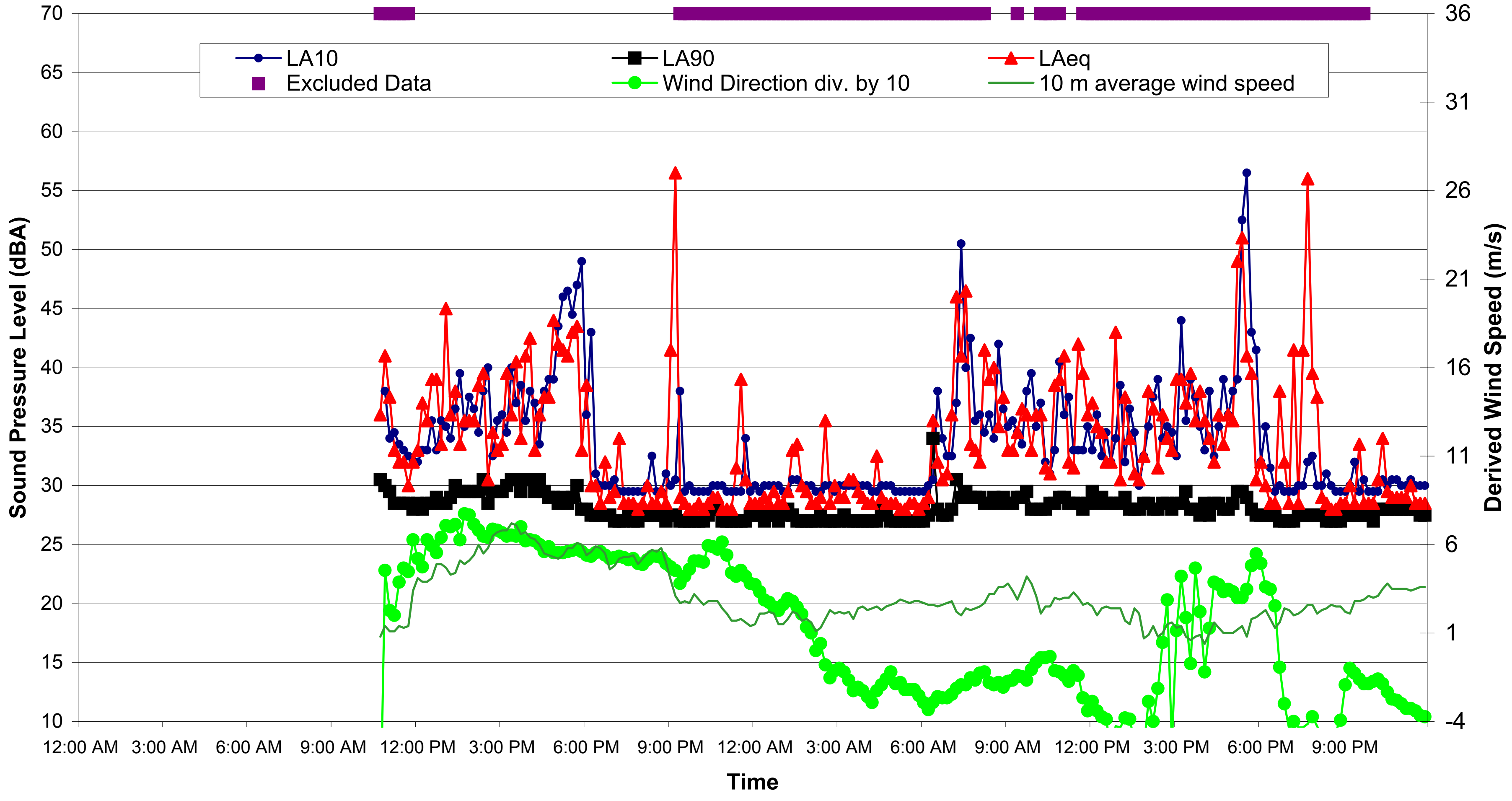
Location G24 - Conroys Gap
Ambient Noise Data - 25 and 26 May 2006



Appendix C5
40-1143
Level Wind vs Time

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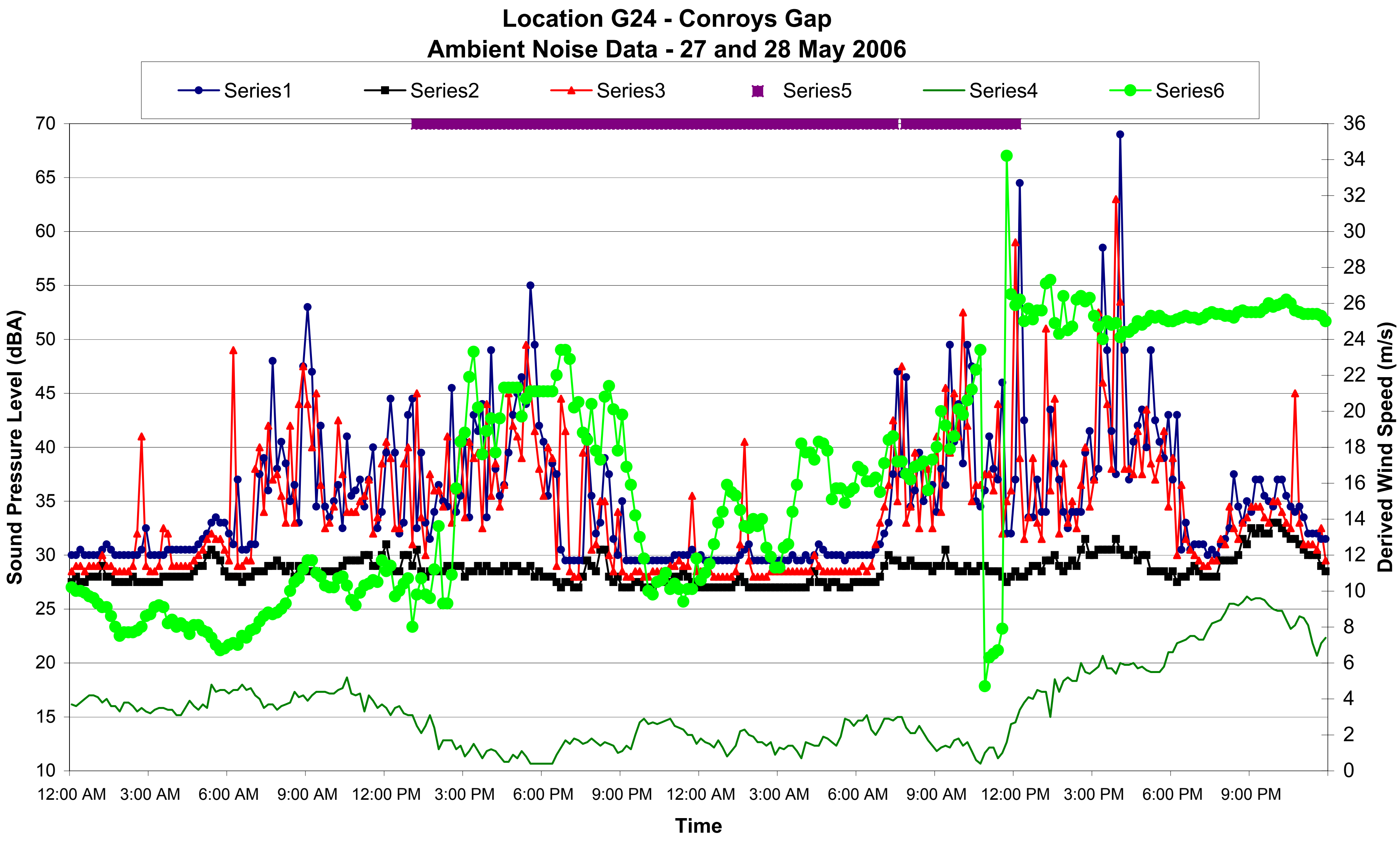
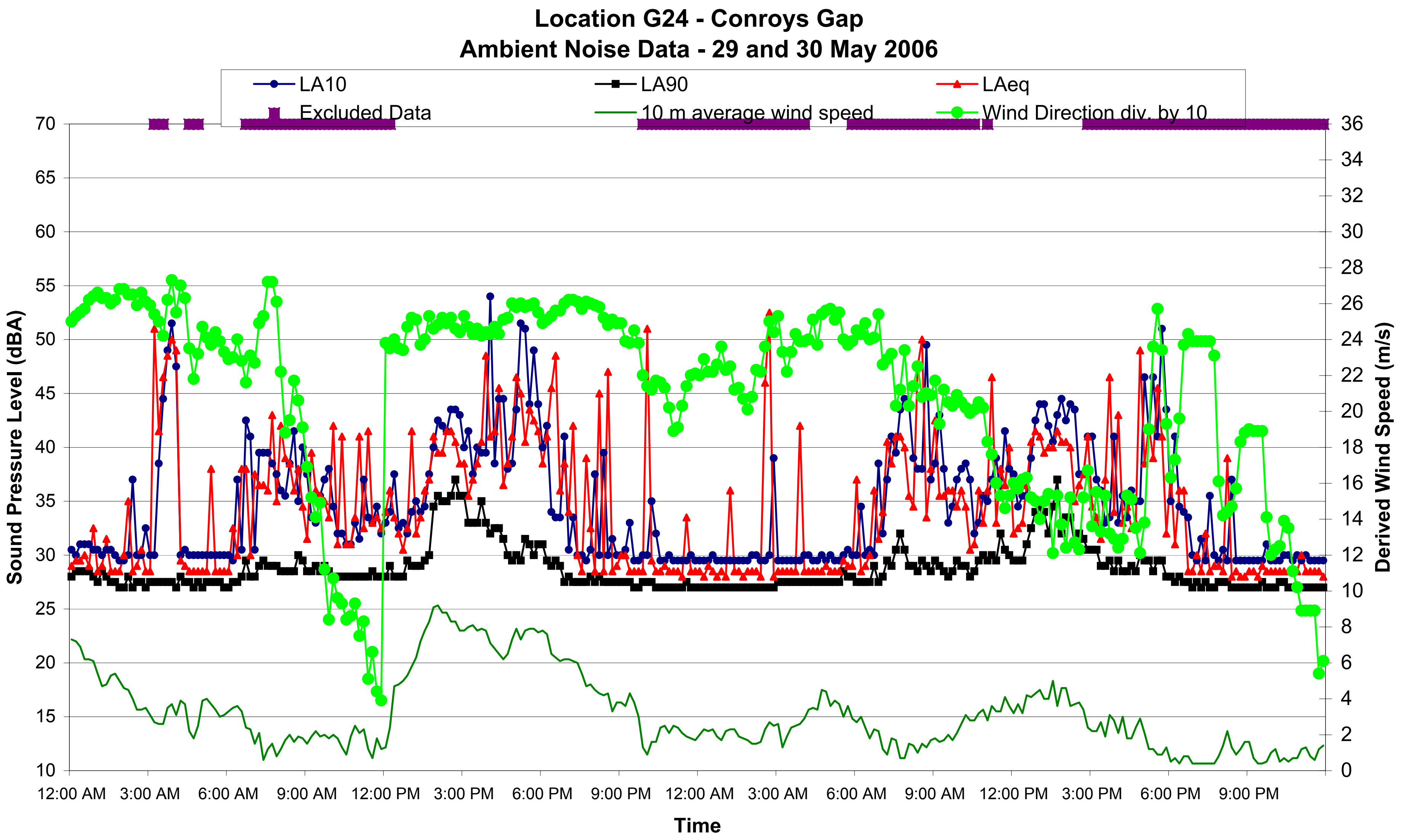


Appendix C5
40-1143
Level Wind vs Time



Appendix C5
40-1143
Level Wind vs Time

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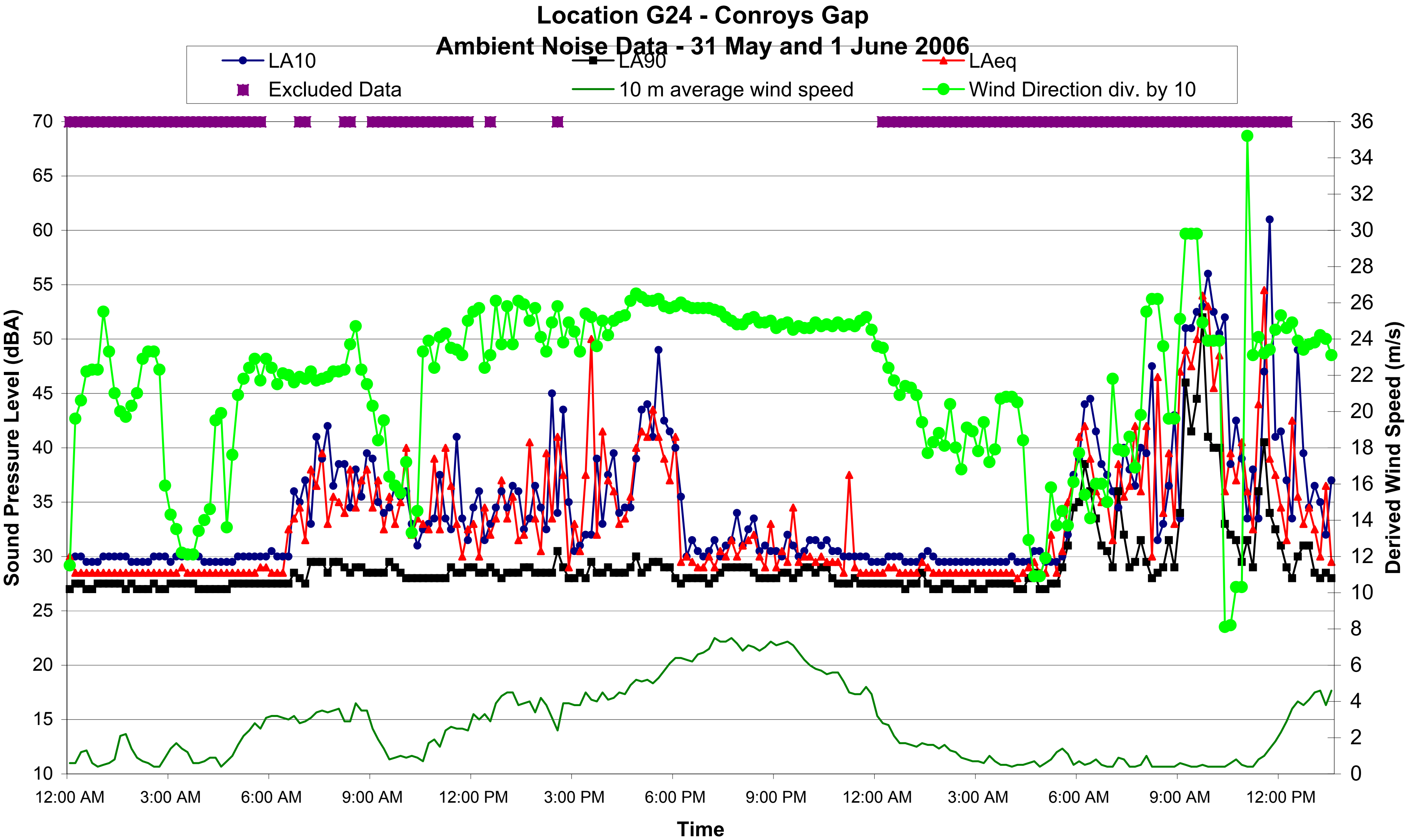

Appendix C5
40-1143
Level Wind vs Time

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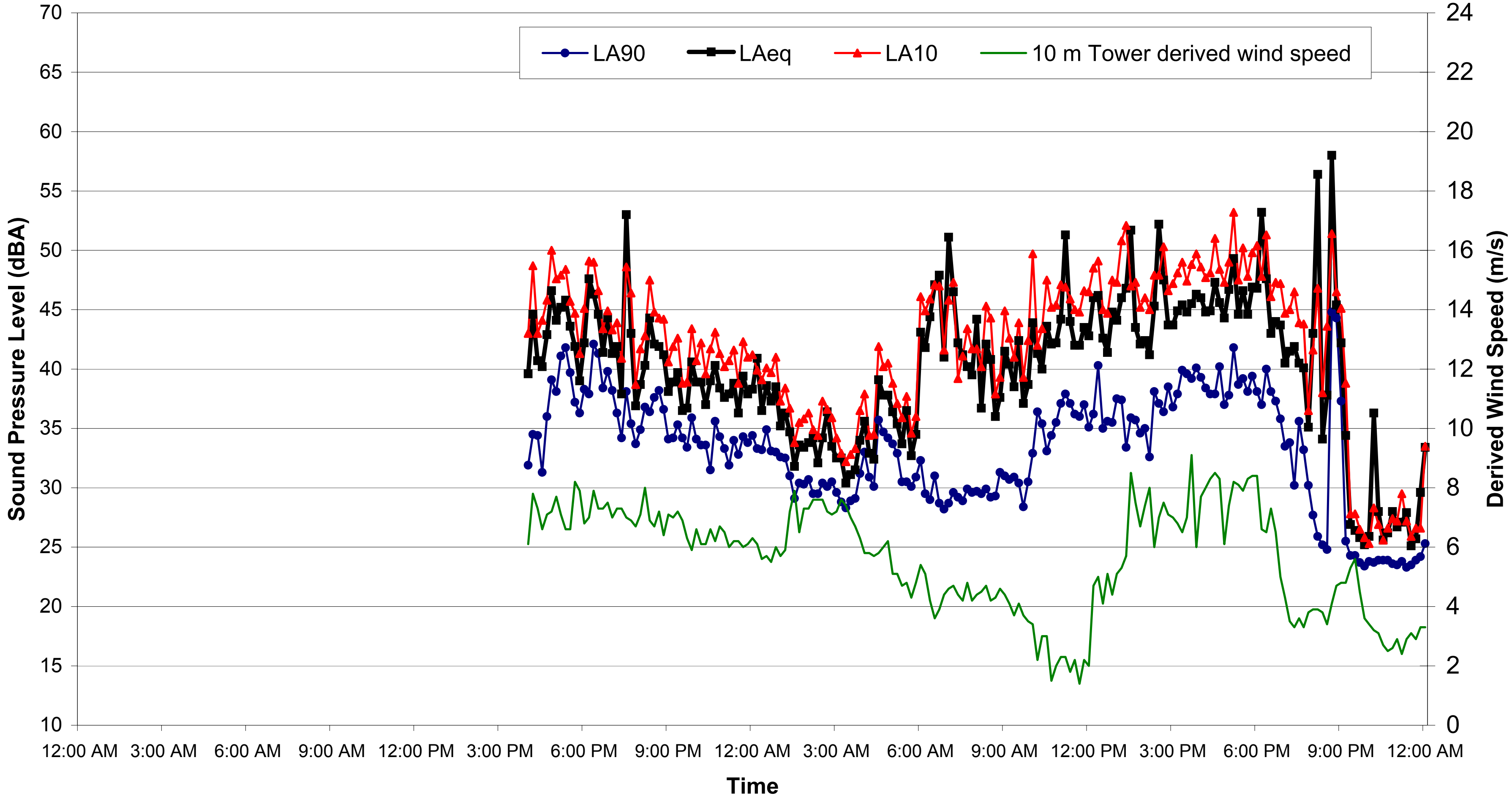
Location G4 - Conroys Gap
Ambient Noise Data - 11 and 12 January 2005



Appendix C6
40-1143
Level Wind vs Time

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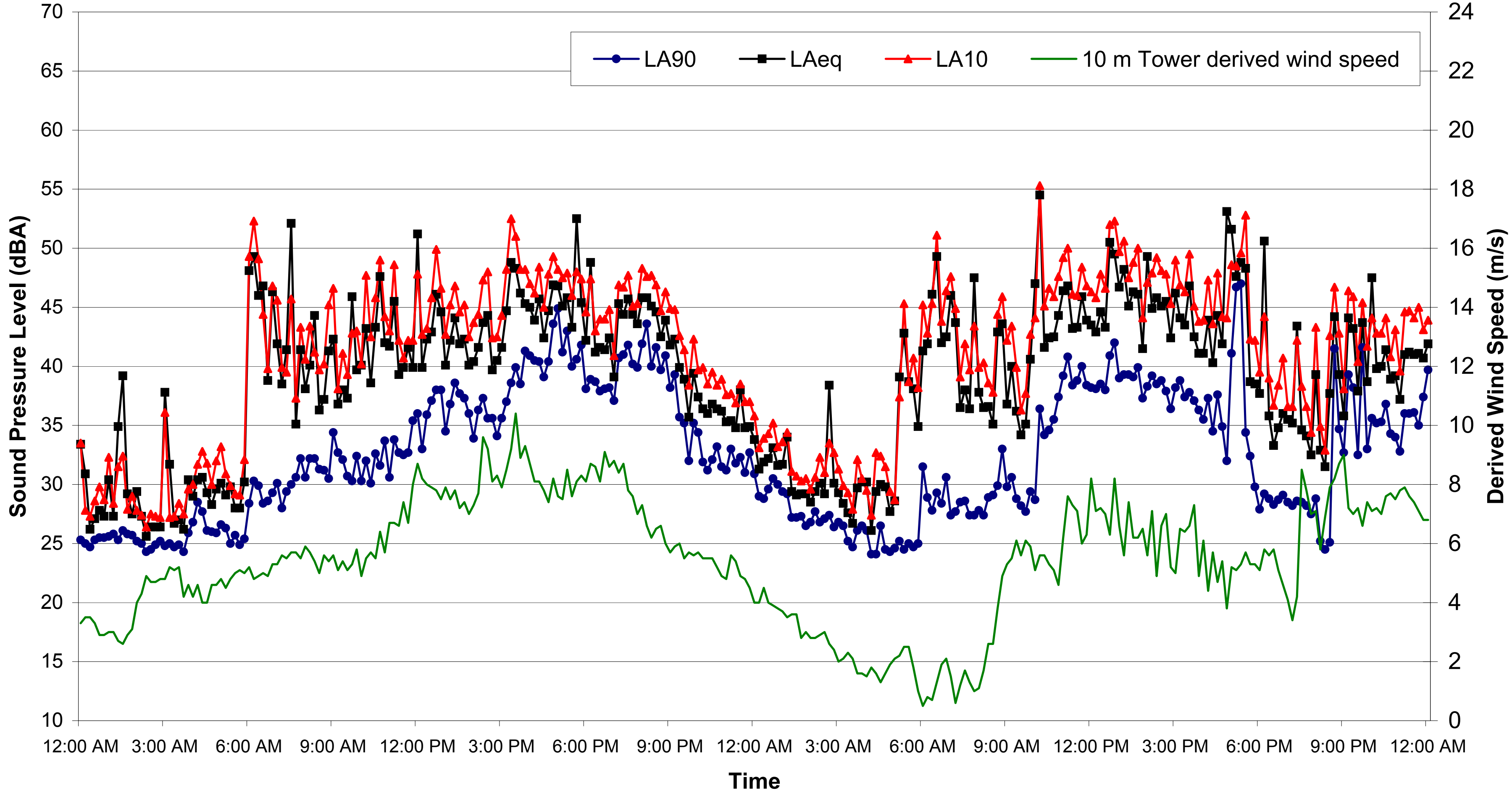
Location G4 - Conroys Gap
Ambient Noise Data - 13 and 14 January 2005



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Level Wind vs Time

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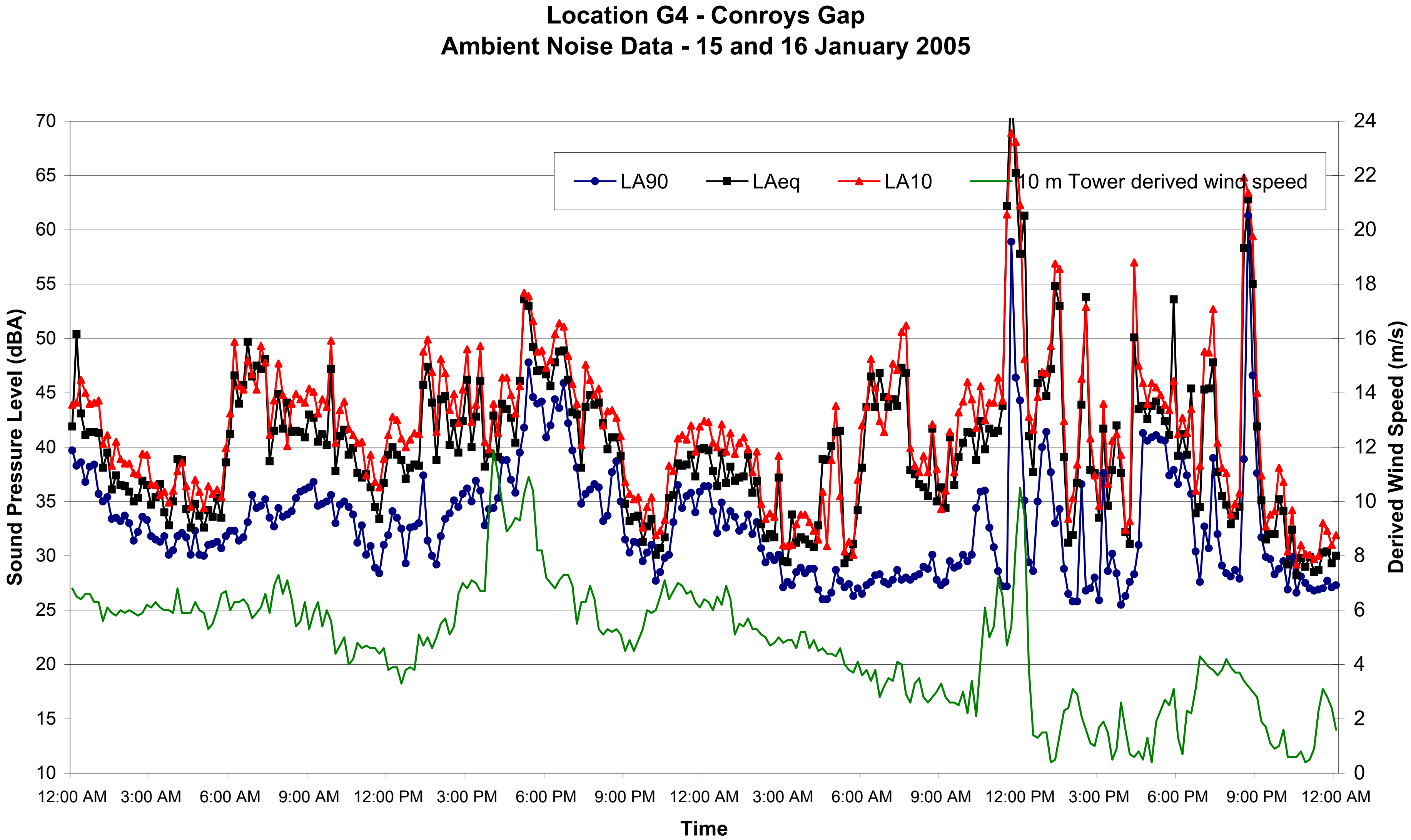

Appendix C6
40-1143
Level Wind vs Time

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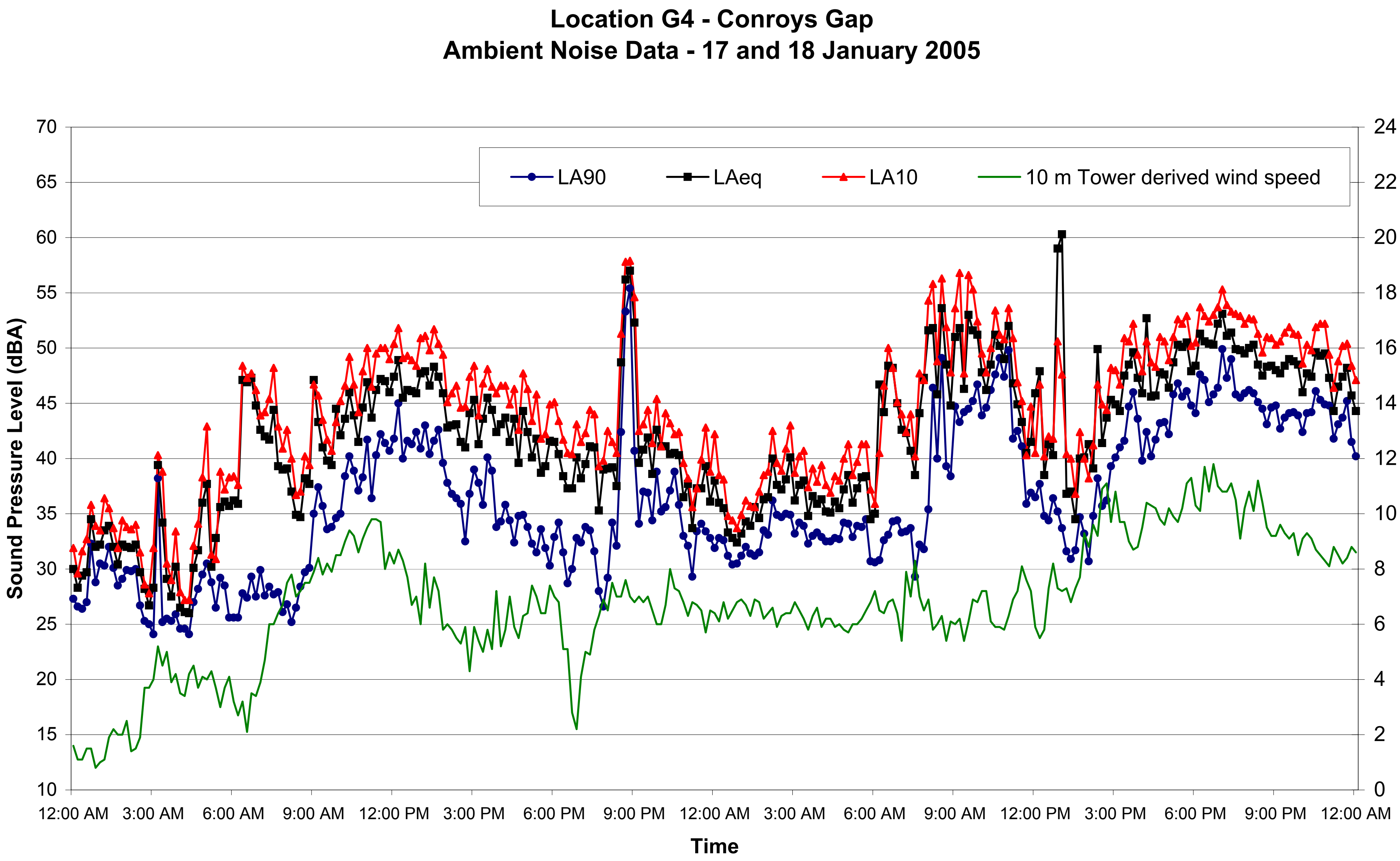
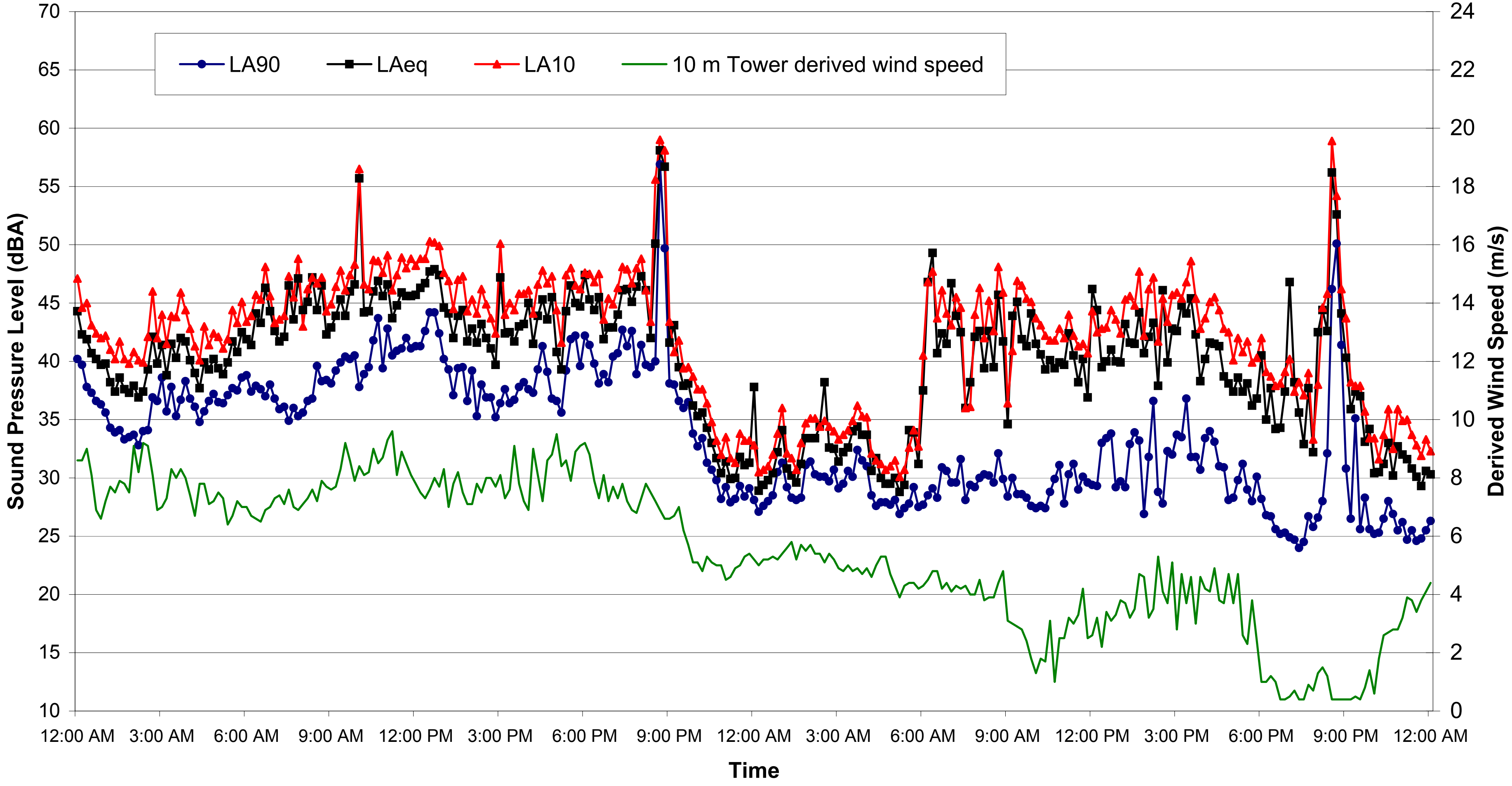


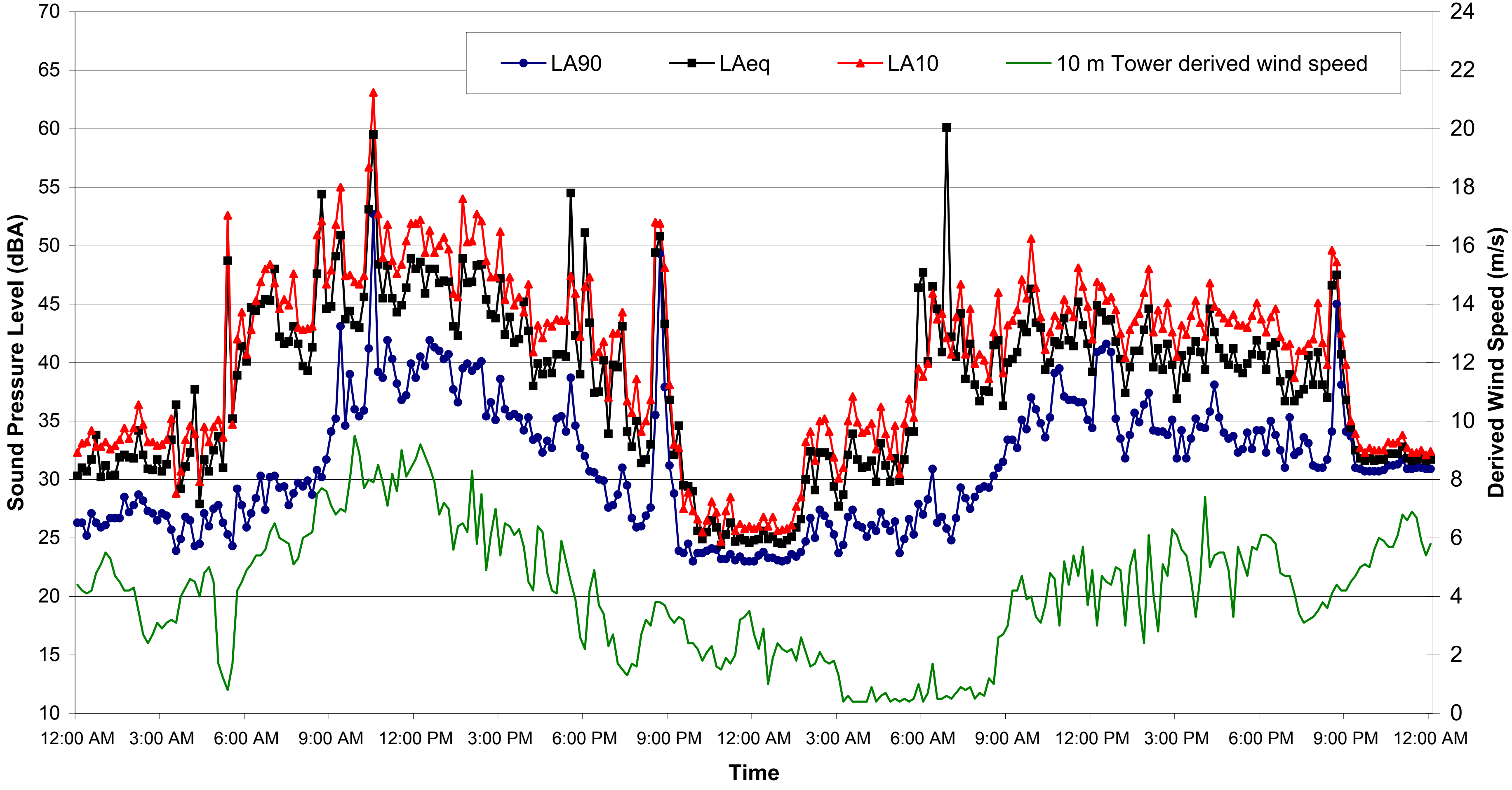
Appendix C6
40-1143
Level Wind vs Time

Location G4 - Conroys Gap
Ambient Noise Data - 19 and 20 January 2005

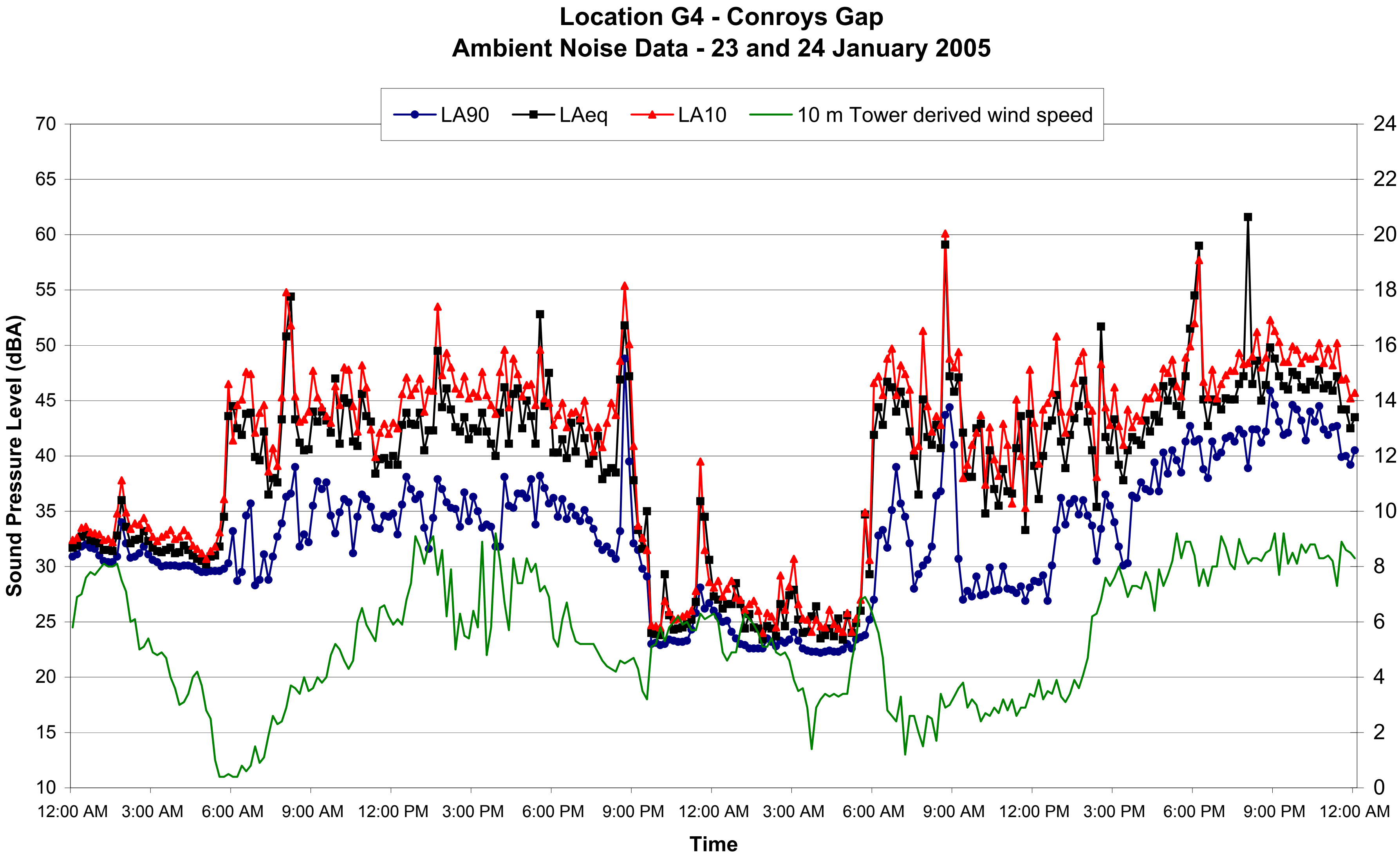


Appendix C6
40-1143
Level Wind vs Time

Location G4 - Conroys Gap
Ambient Noise Data - 21 and 22 January 2005



Appendix C6
40-1143
Level Wind vs Time



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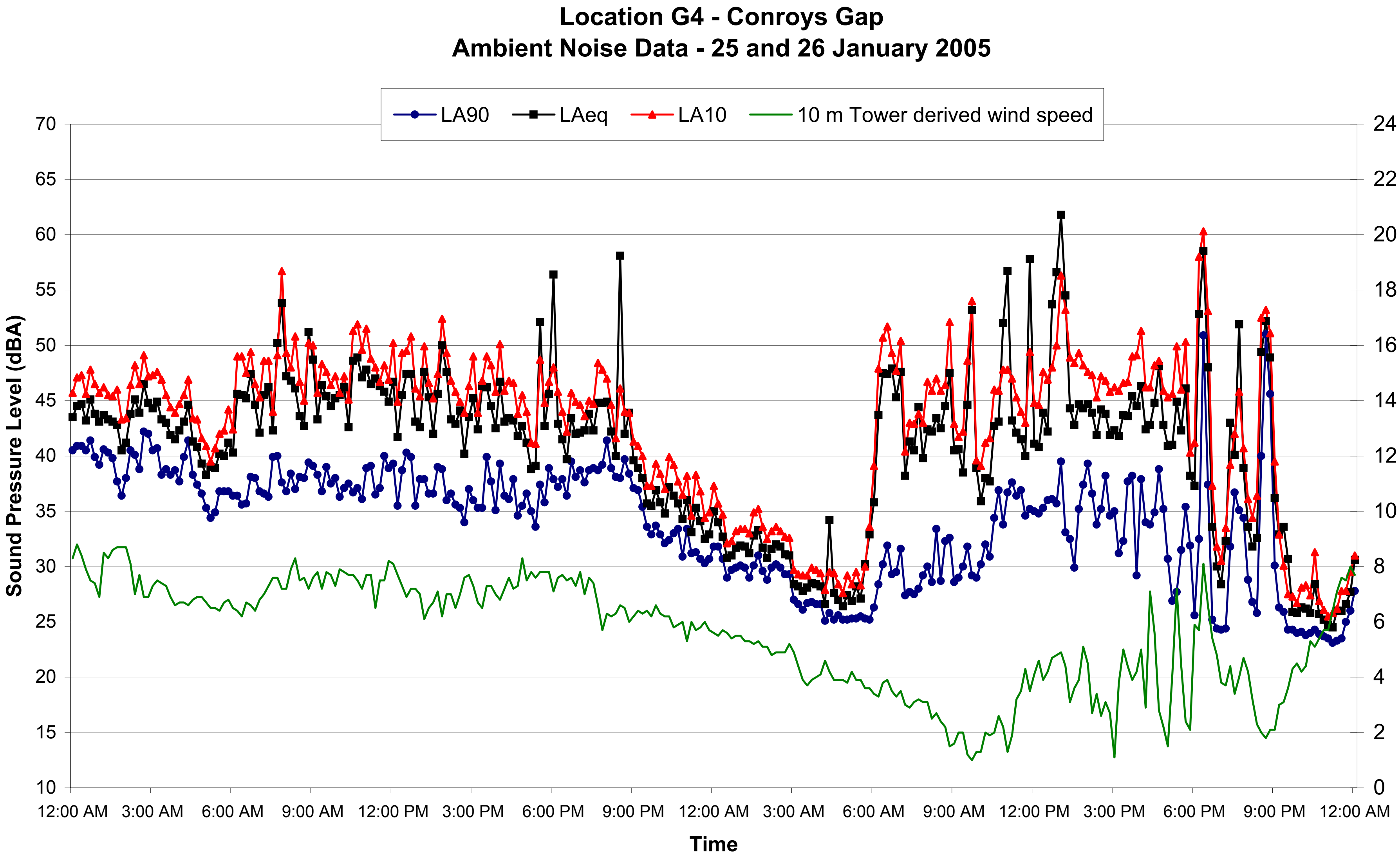
40-1143
Level Wind vs Time



Appendix C6
40-1143
Level Wind vs Time

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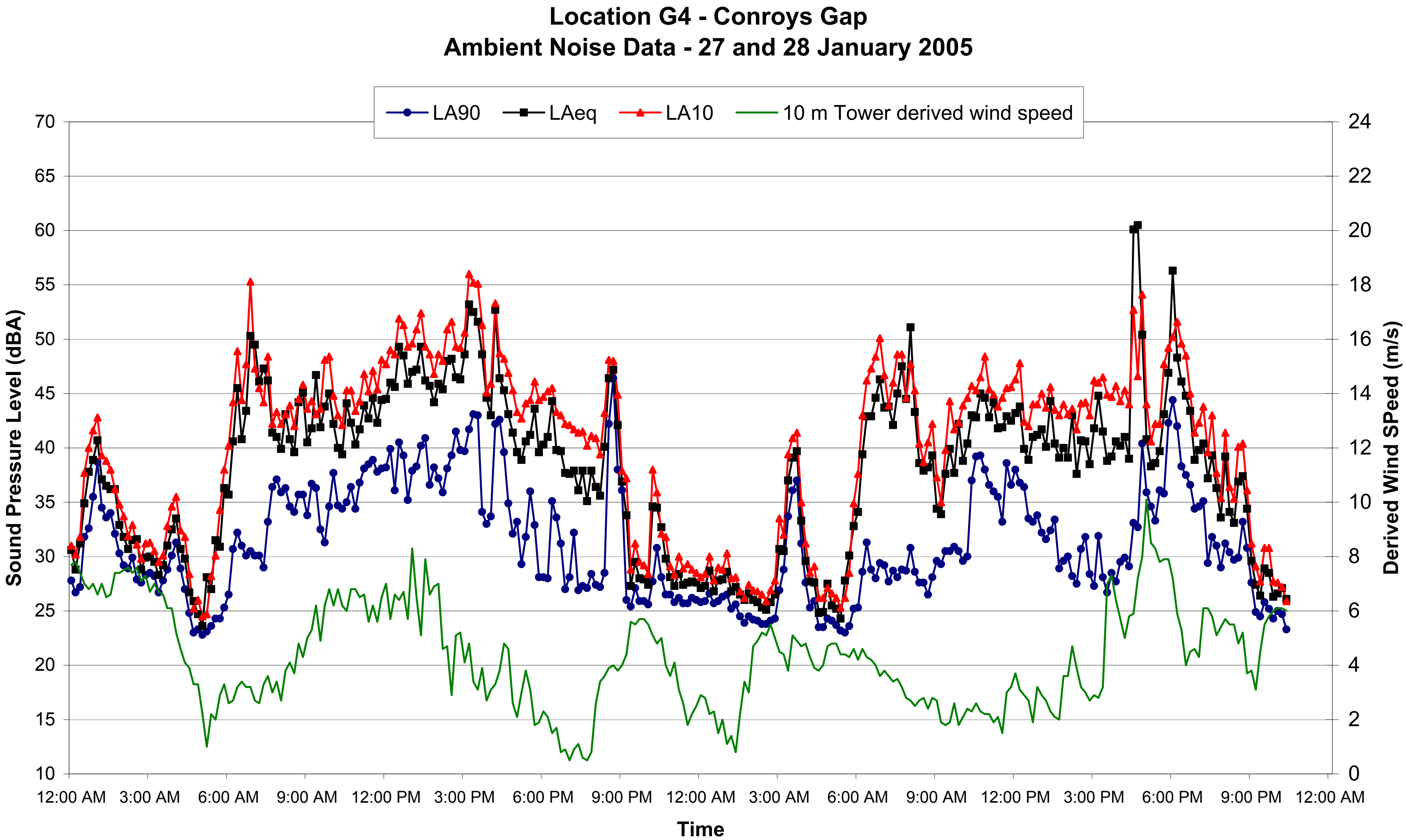
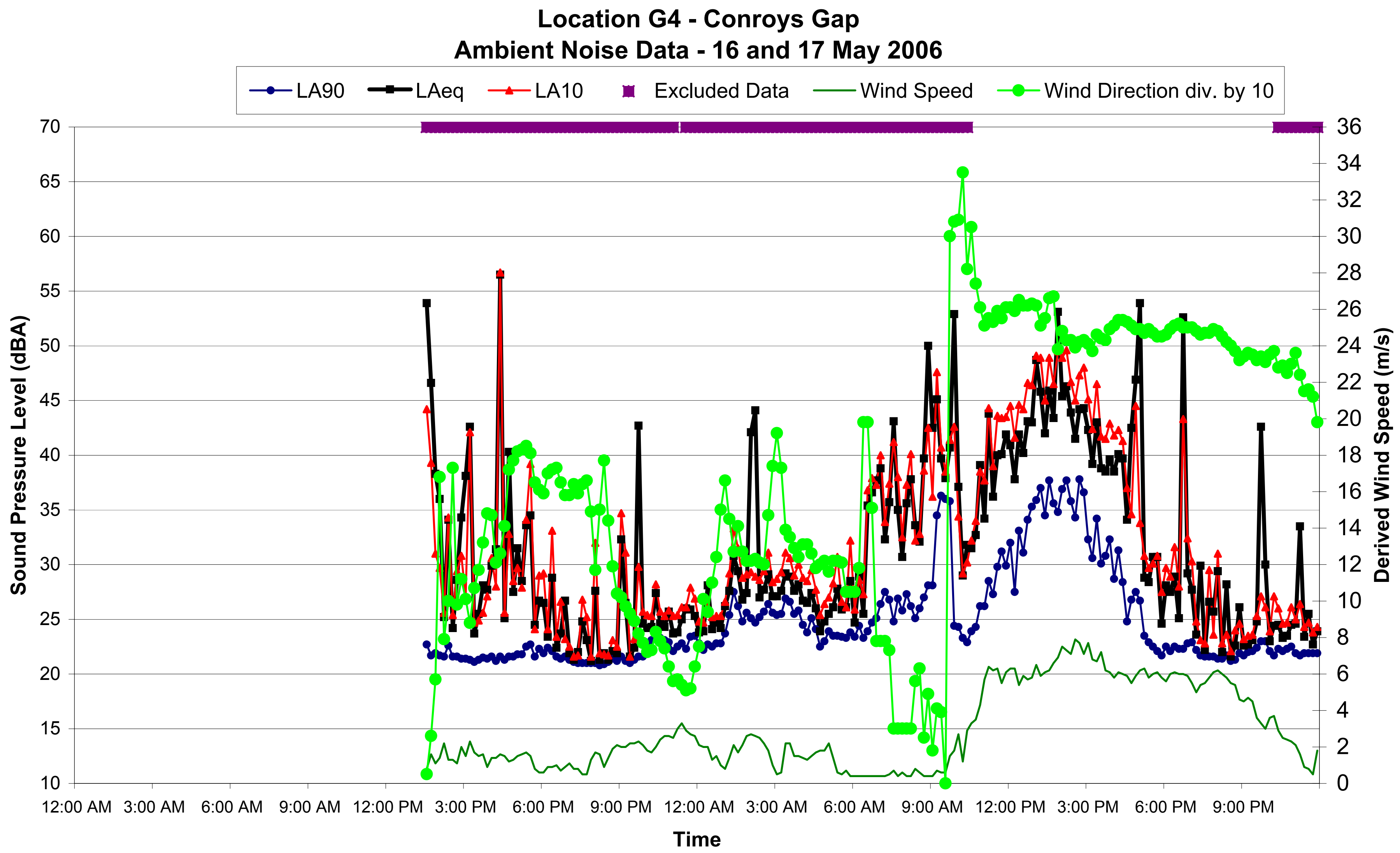


Appendix C6
40-1143
Level Wind vs Time



Appendix C6
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Level Wind vs Time

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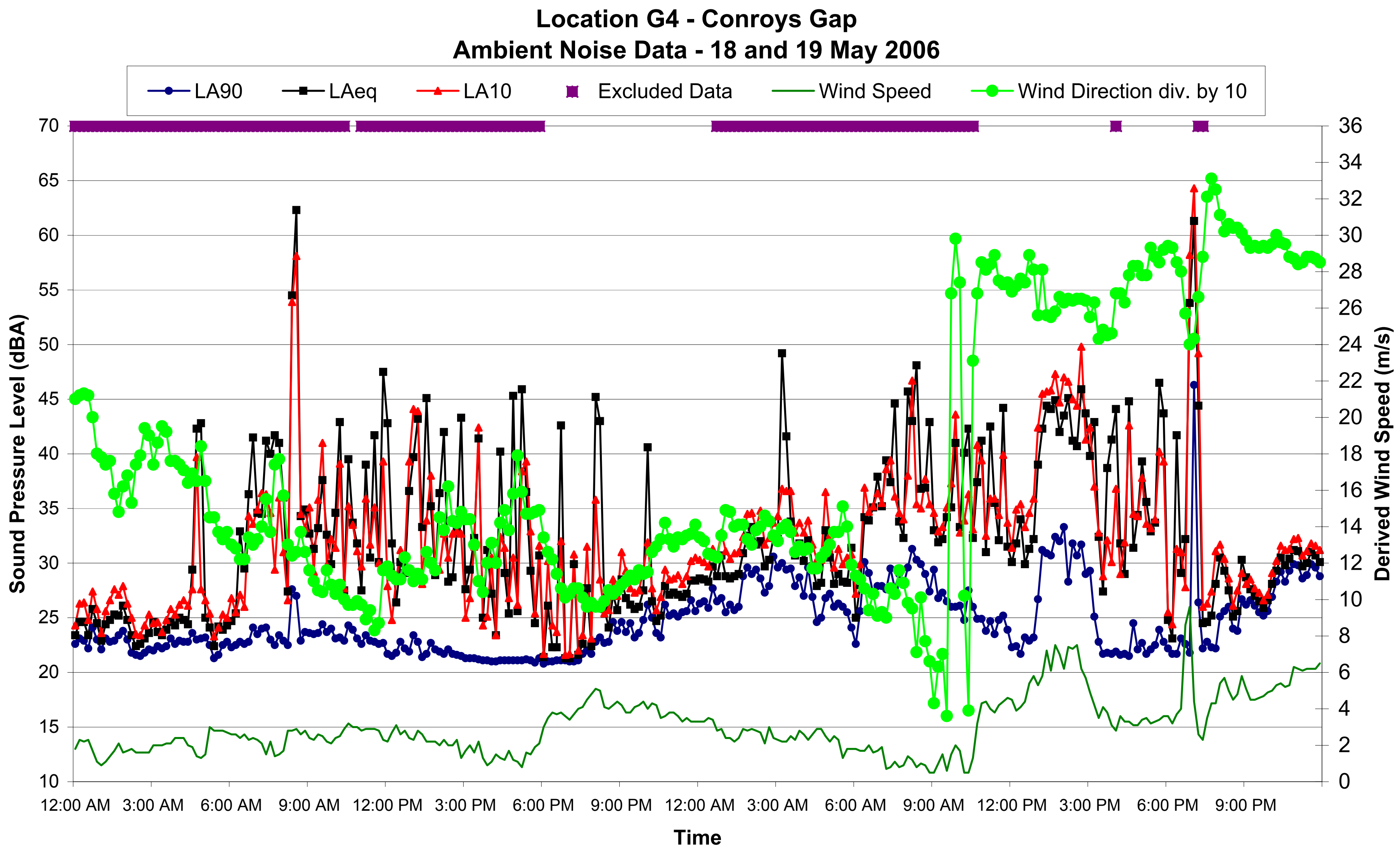

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Level Wind vs Time

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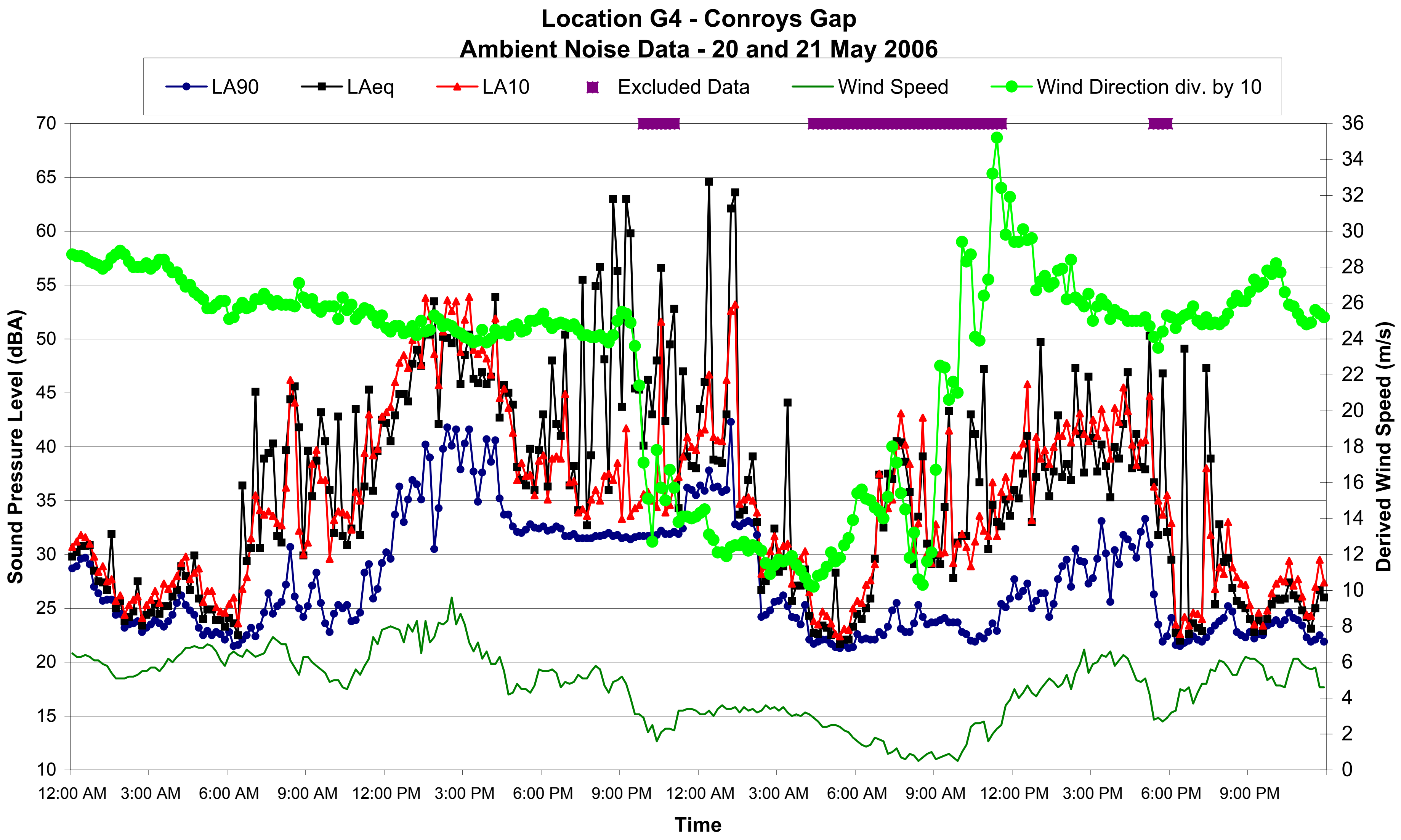

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Level Wind vs Time

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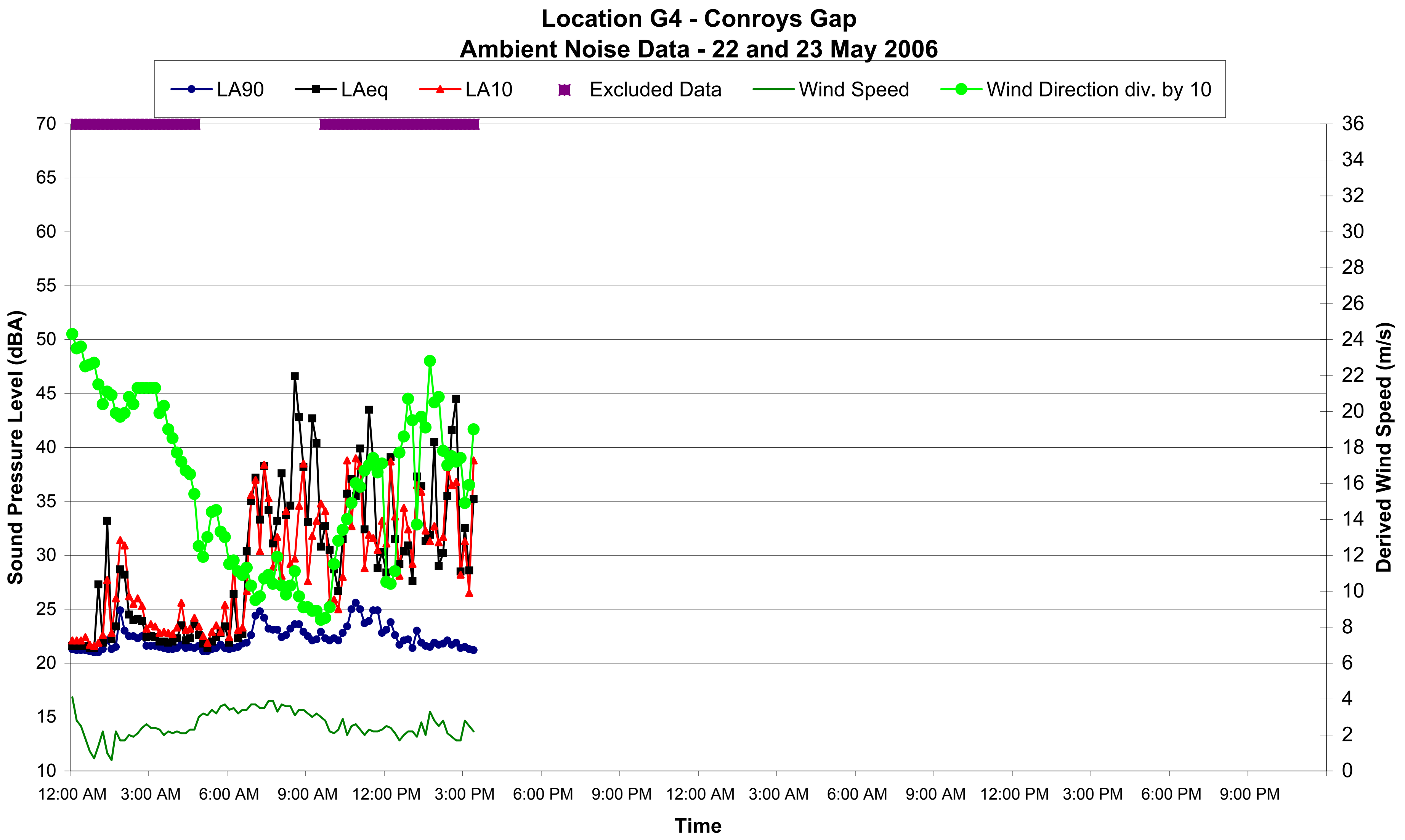
Location G4 - Conroys Gap
Ambient Noise Data - 22 and 23 May 2006
LA90
LAeq
LA10
Excluded Data
Wind Speed
Wind Direction div. by 10
Sound Pressure Level (dBA)
Derived Wind Speed (m/s)
Time
70
65
60
55
50
45
40
35
30
25
20
15
10
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
12:00 AM
3:00 AM
6:00 AM
9:00 AM
12:00 PM
3:00 PM
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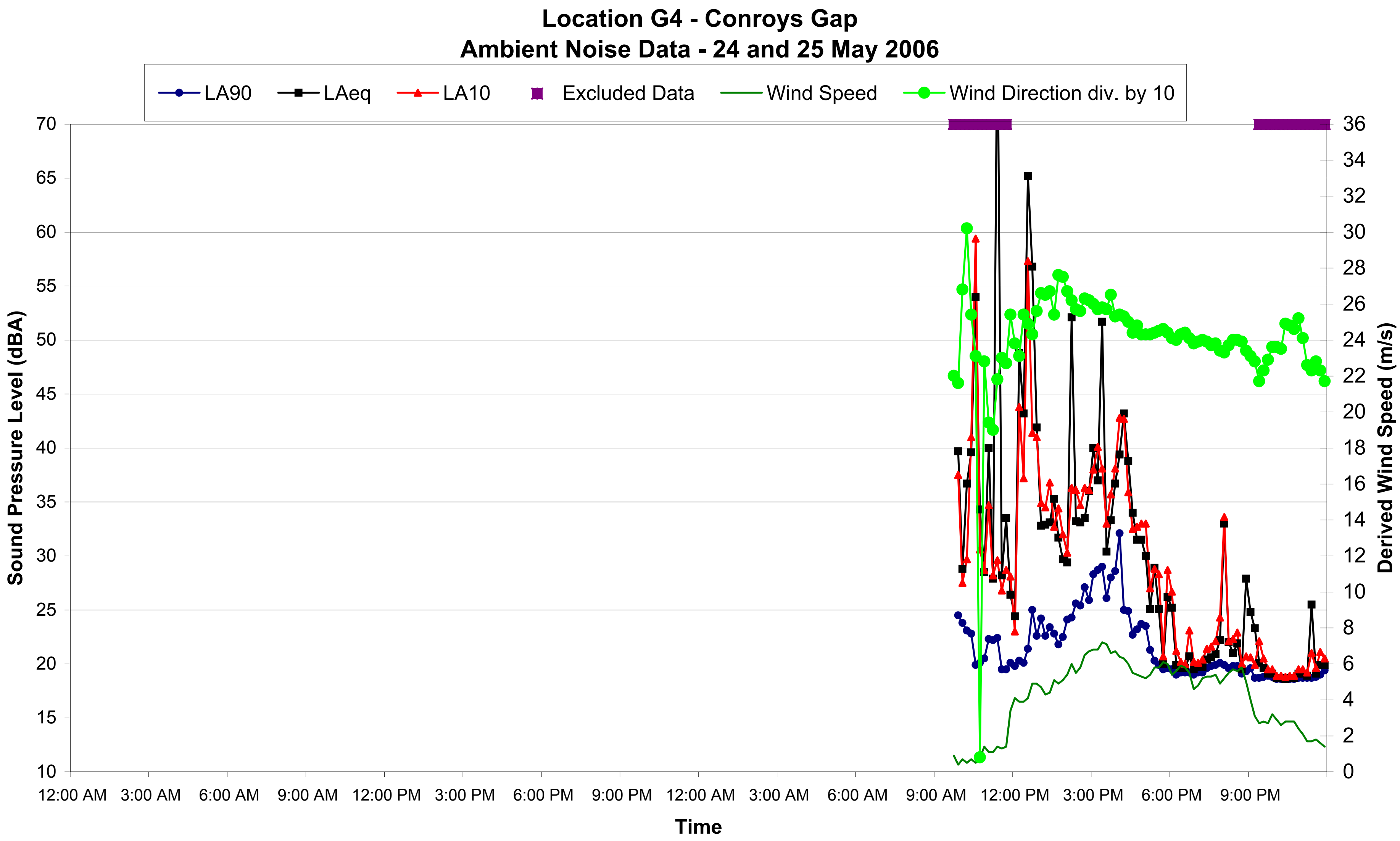

Appendix C6
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Level Wind vs Time

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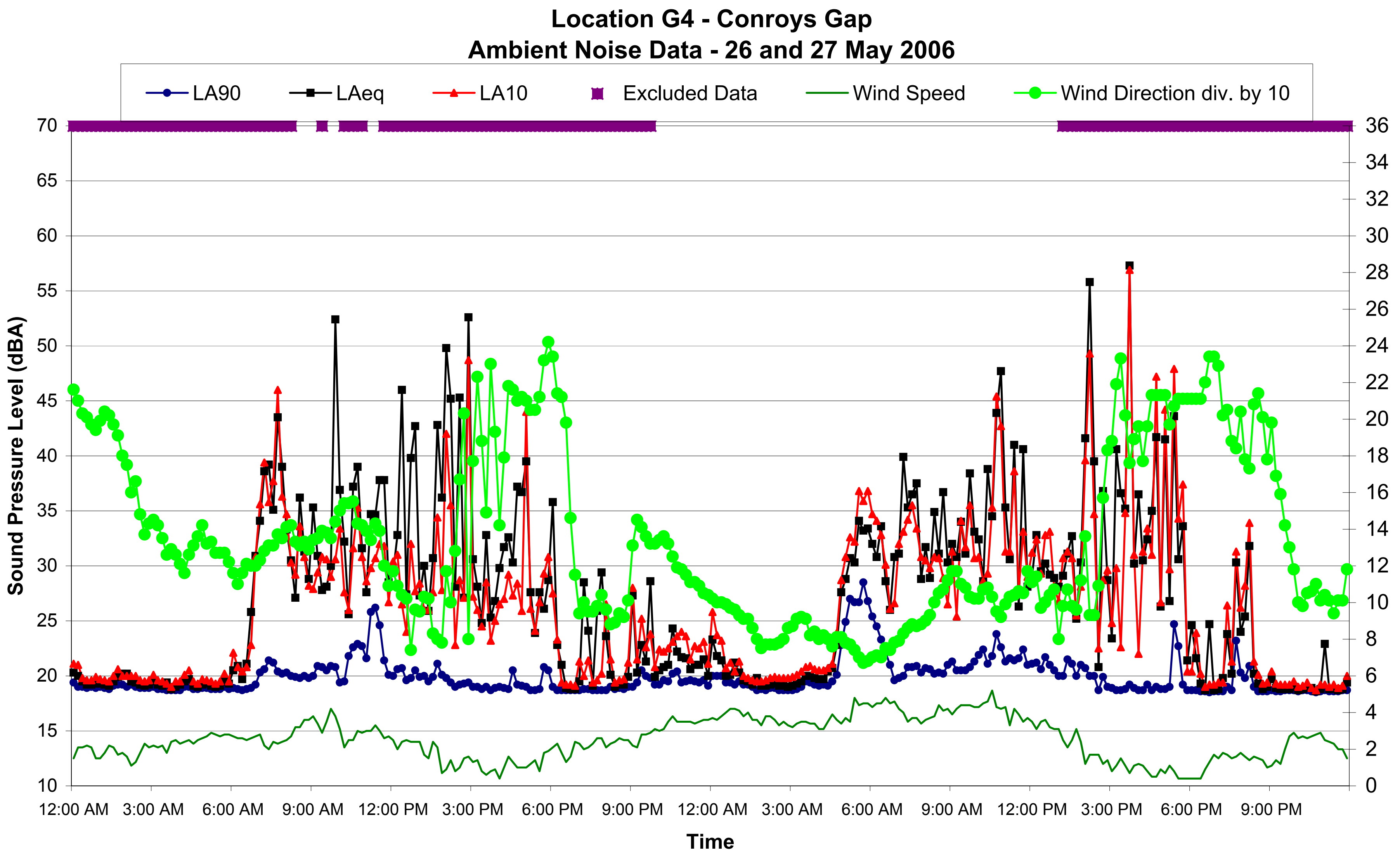

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Level Wind vs Time

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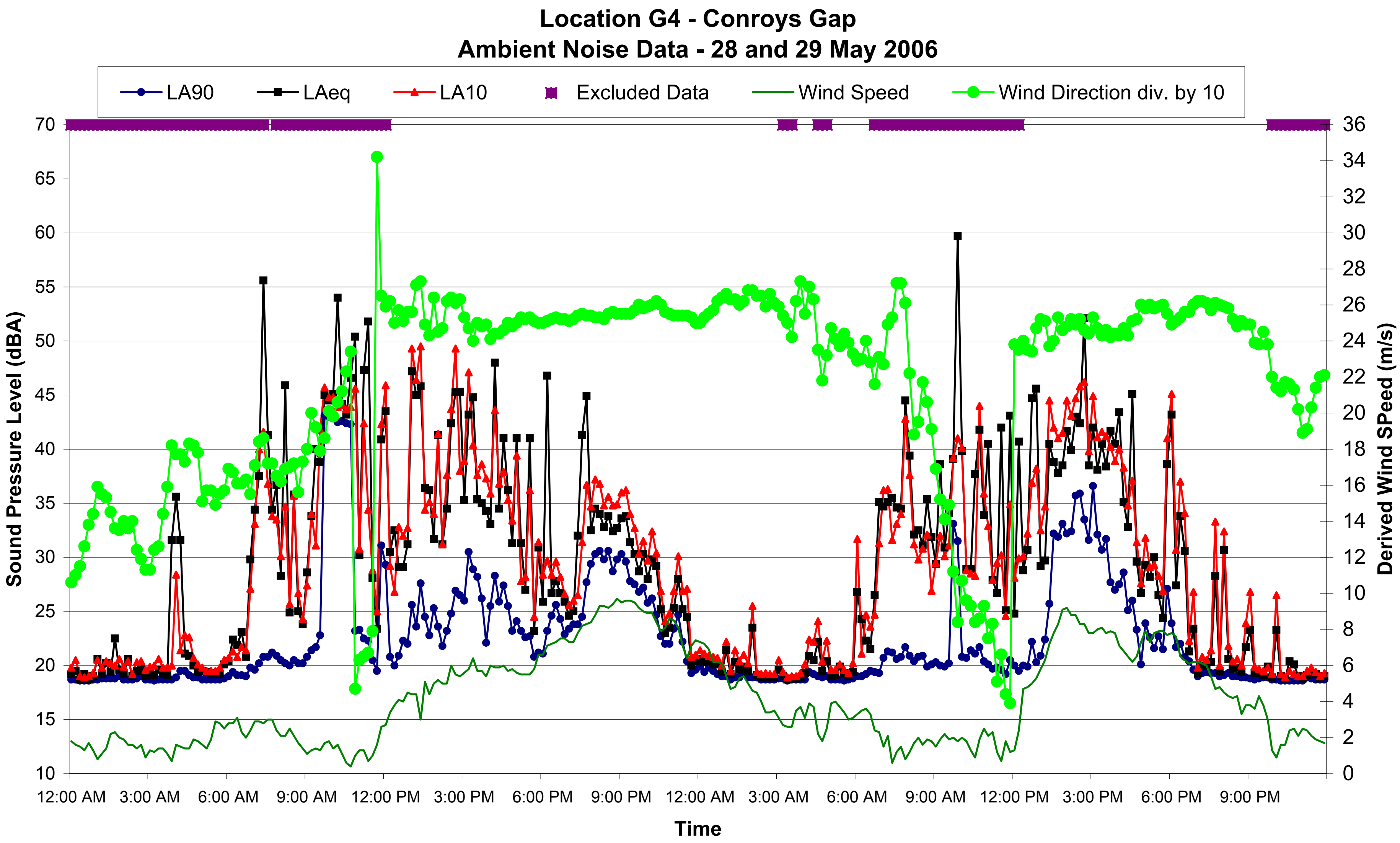

Appendix C6
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Level Wind vs Time

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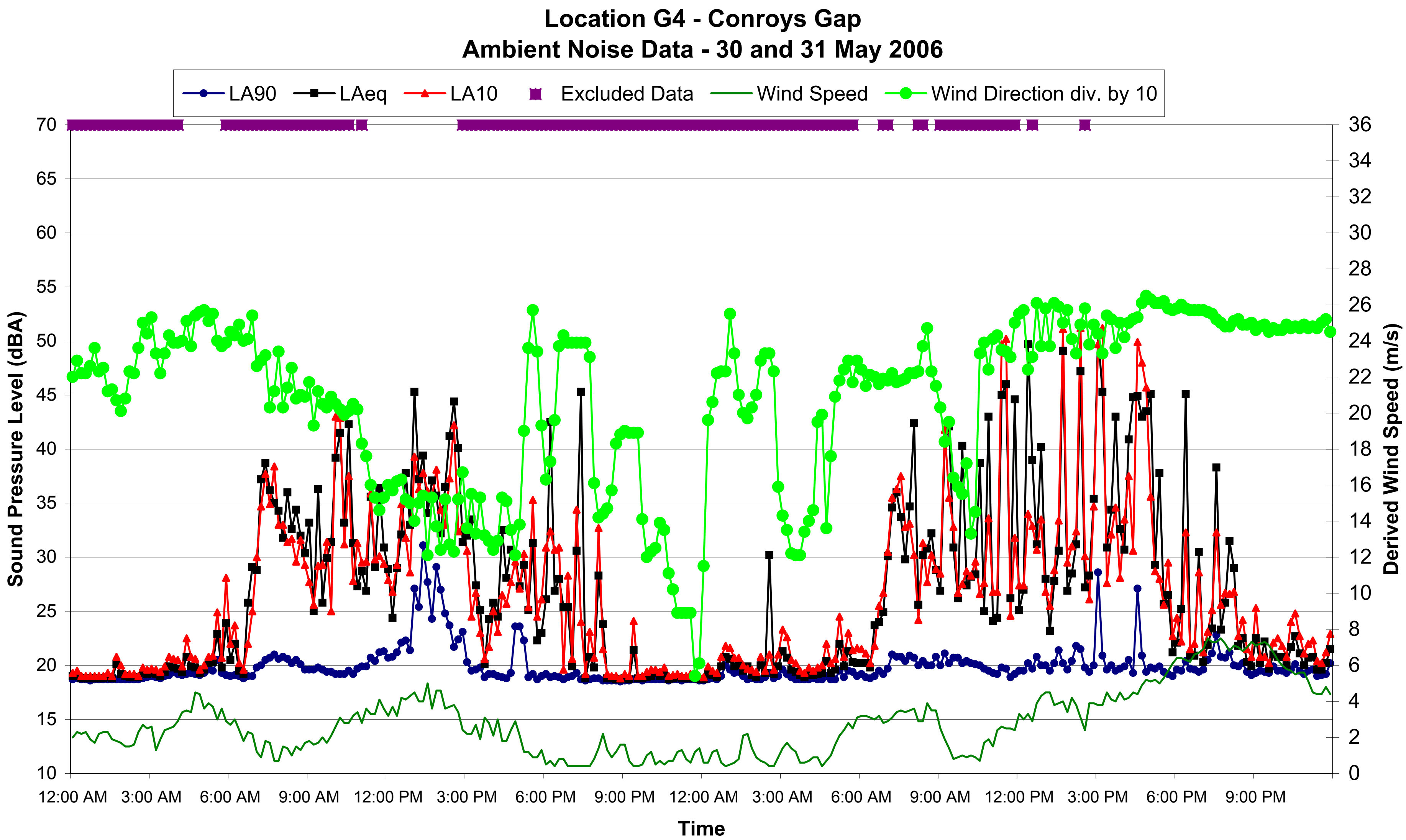

Appendix C6
40-1143
Level Wind vs Time

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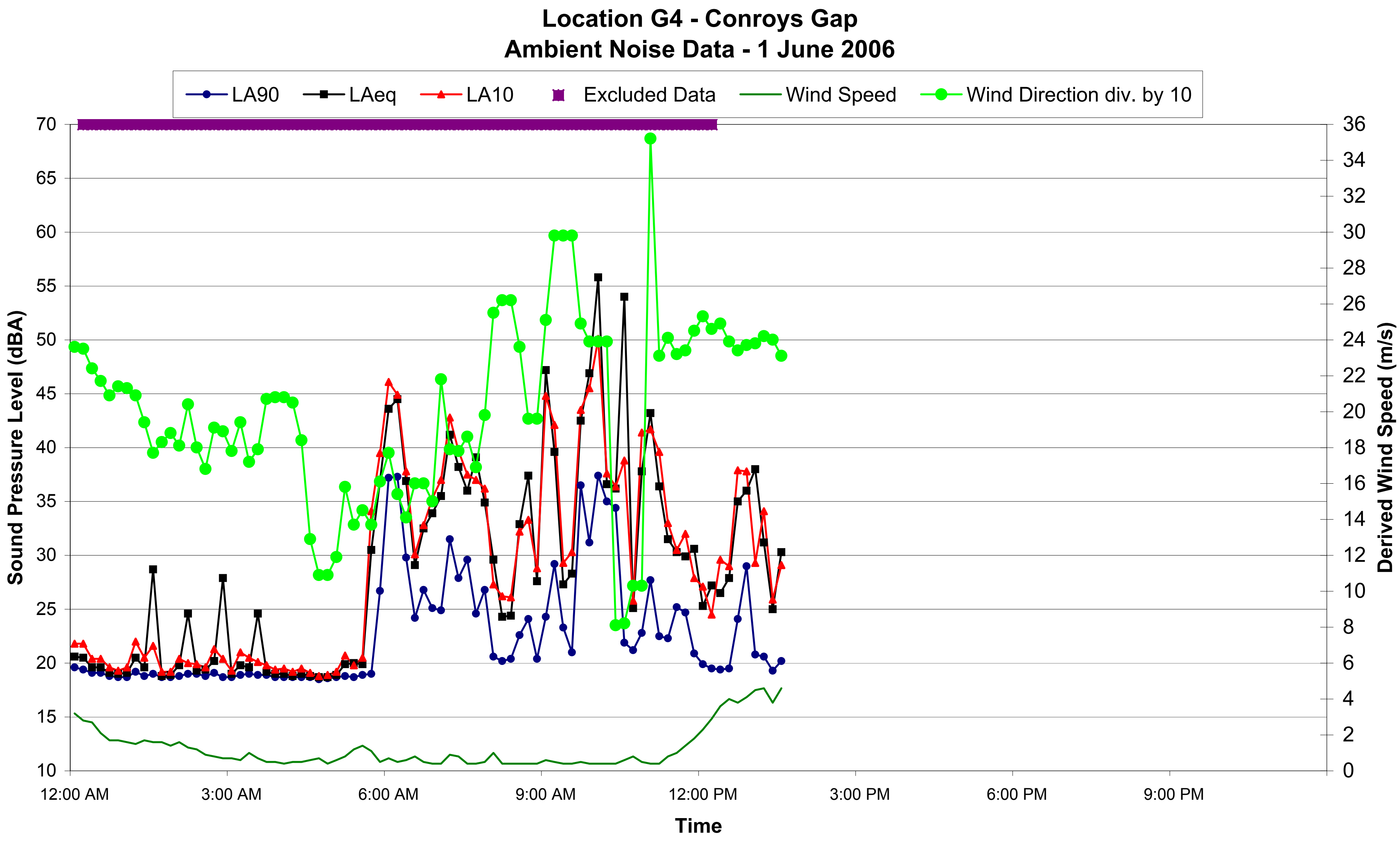

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Level Wind vs Time

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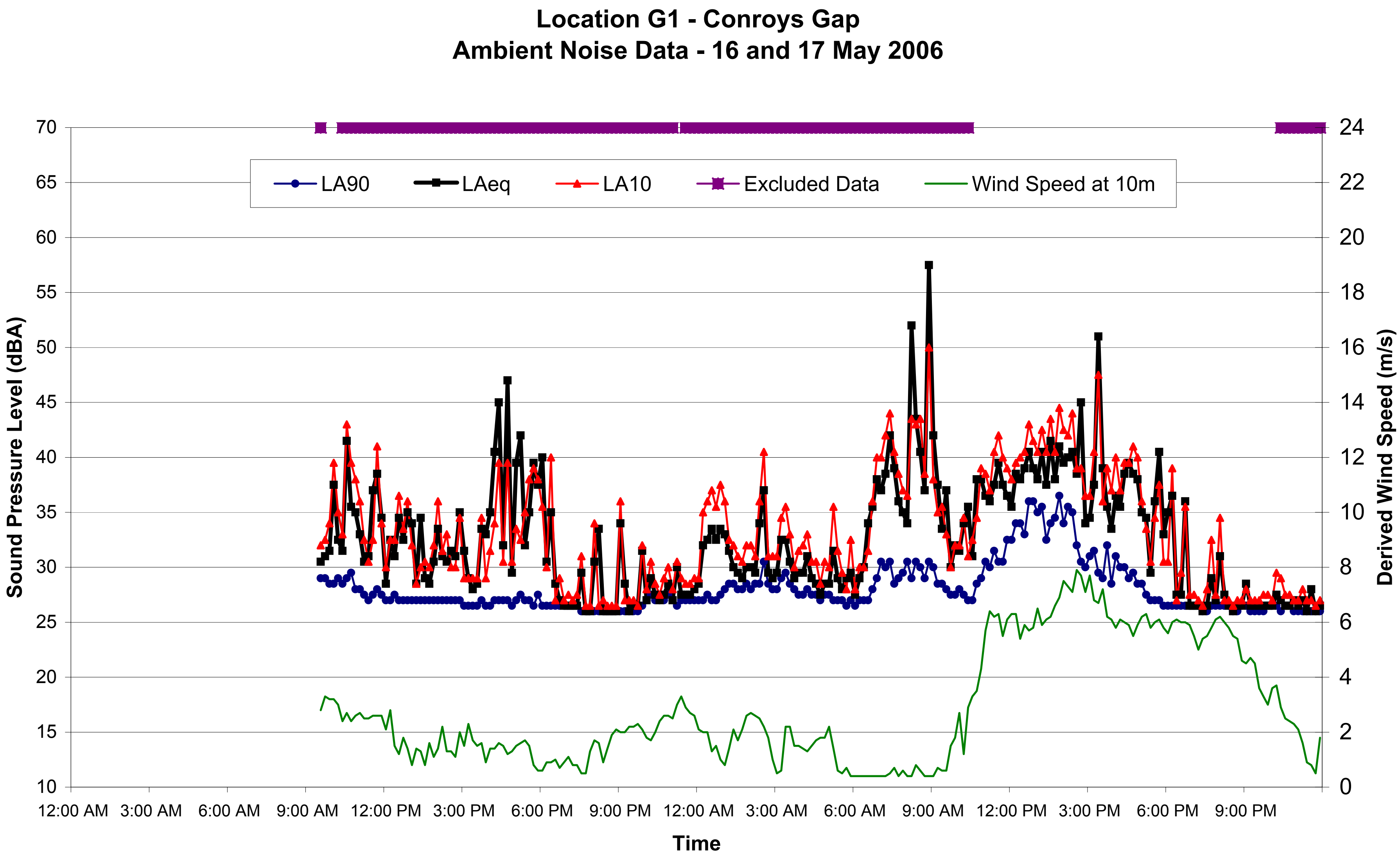
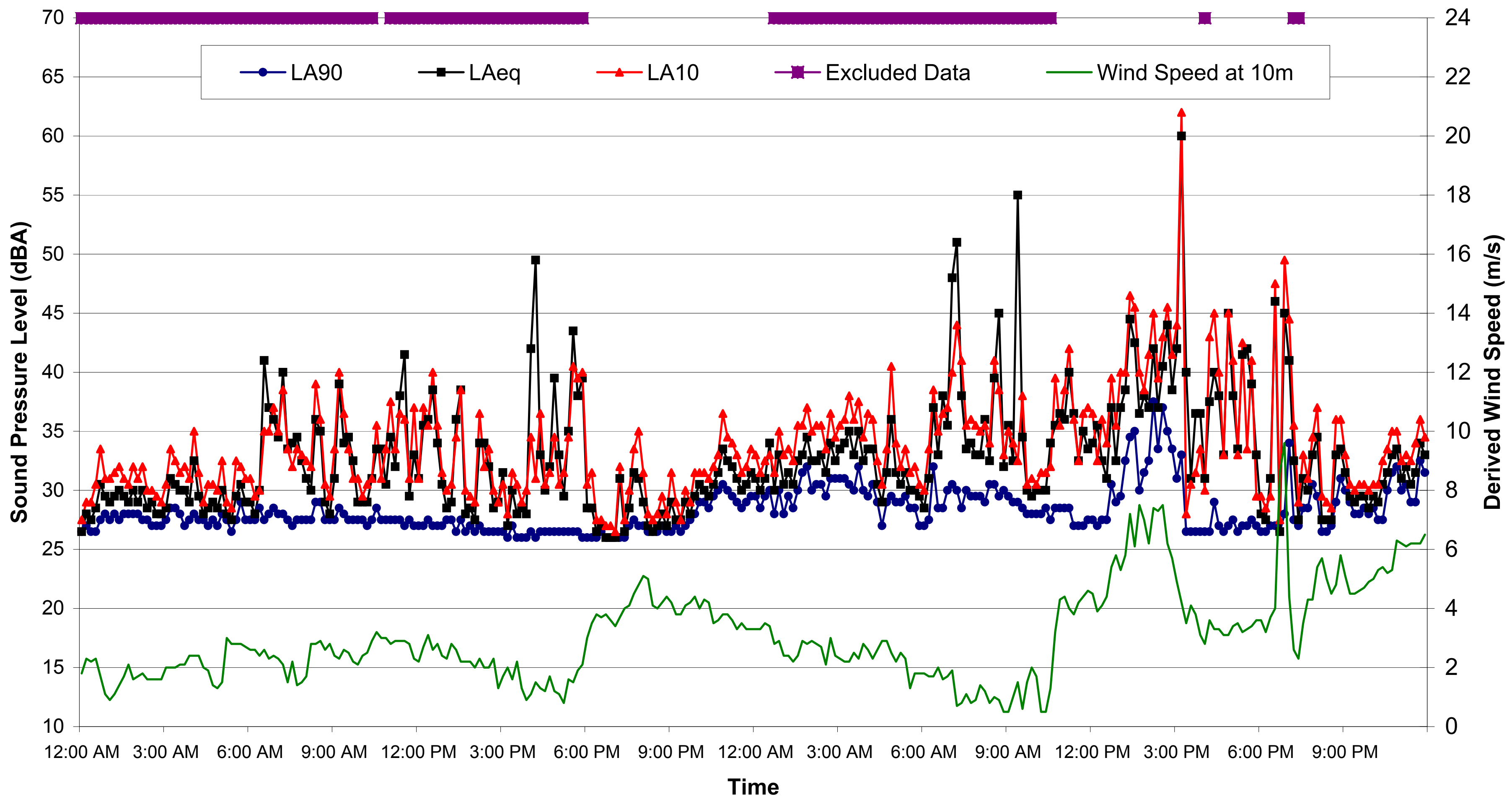


Appendix C7
40-1143
Level Wind vs Time

Location G1 - Conroys Gap
Ambient Noise Data - 18 and 19 May 2006



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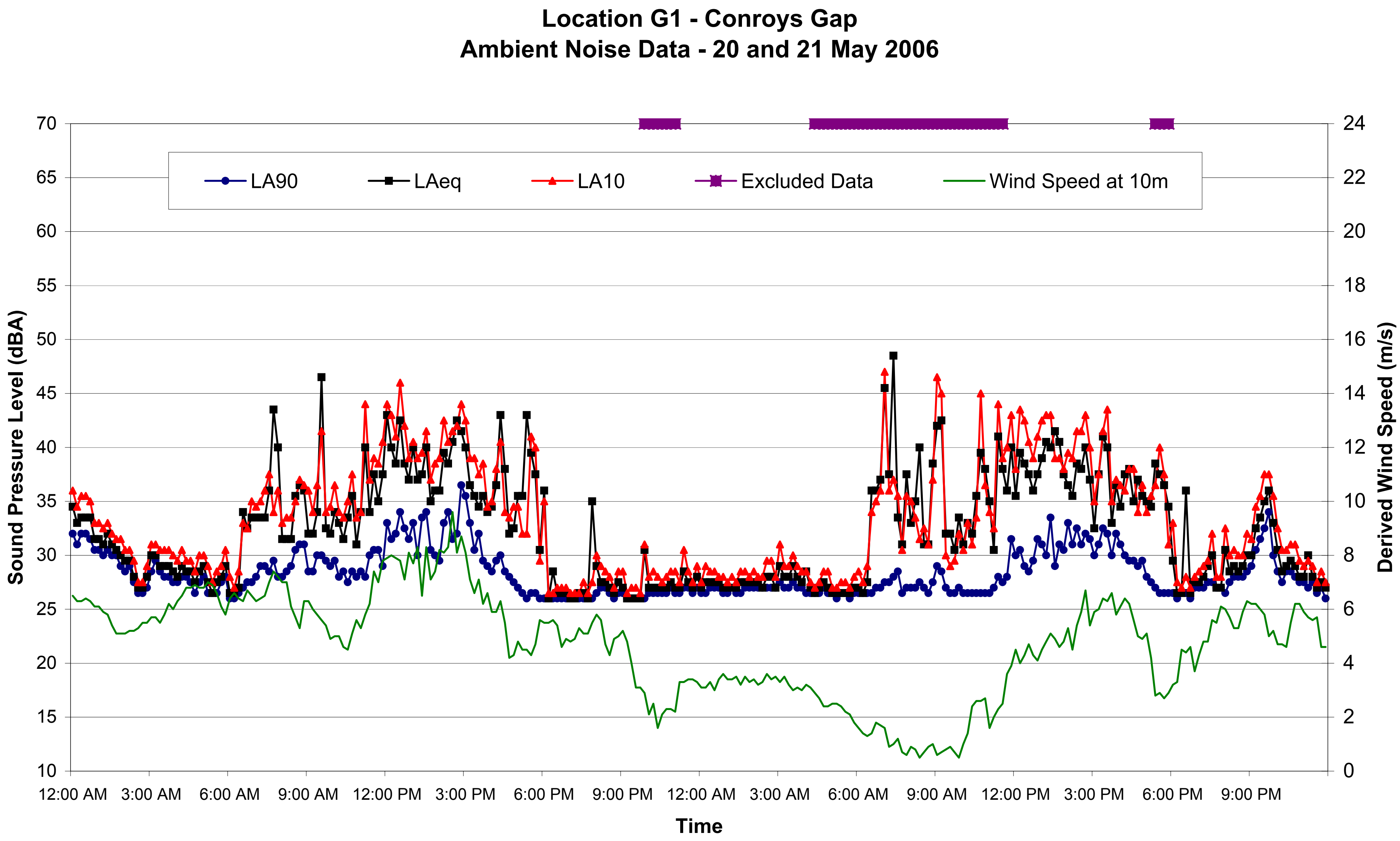
40-1143
Level Wind vs Time



Appendix C7
40-1143
Level Wind vs Time

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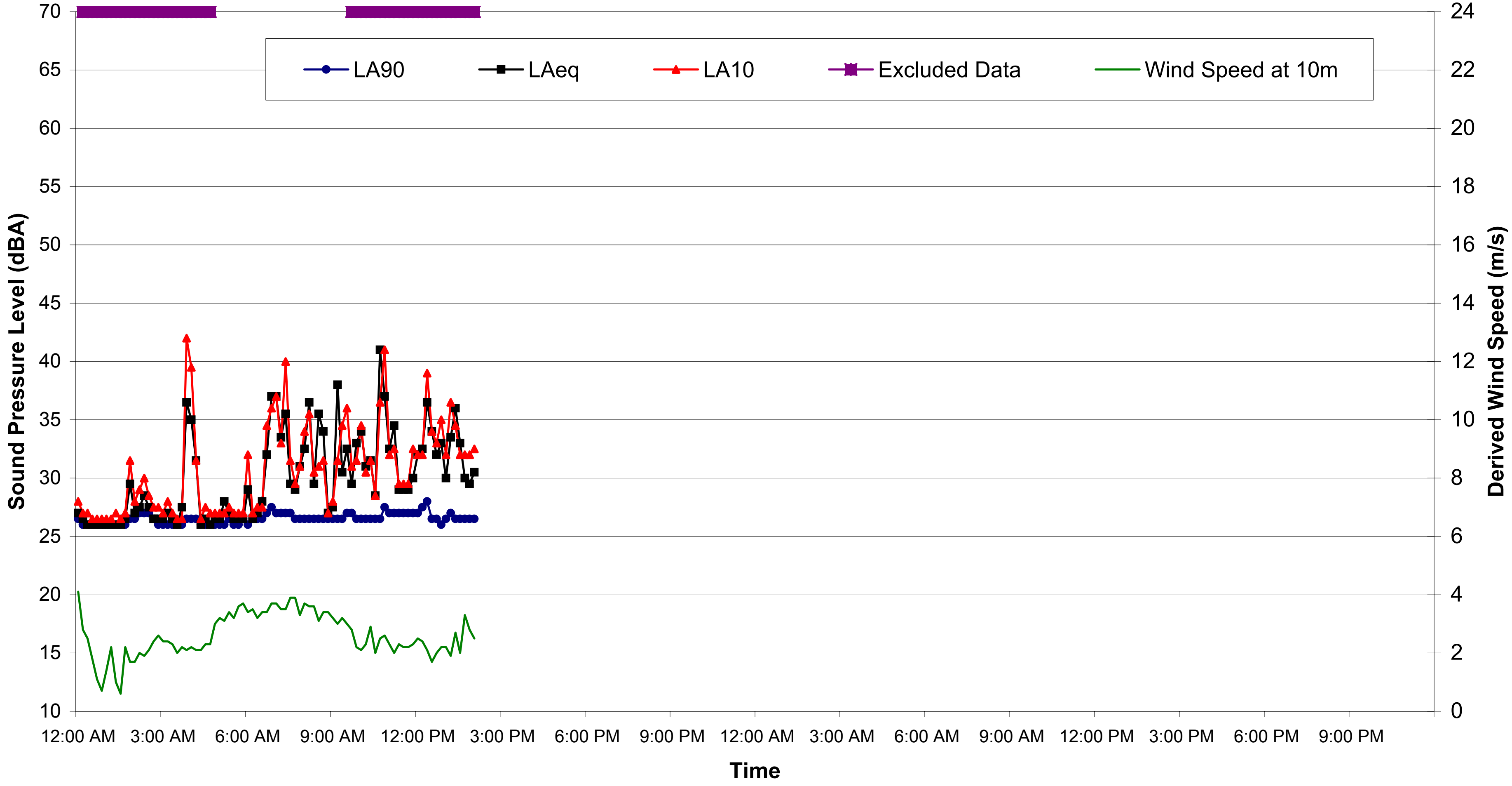
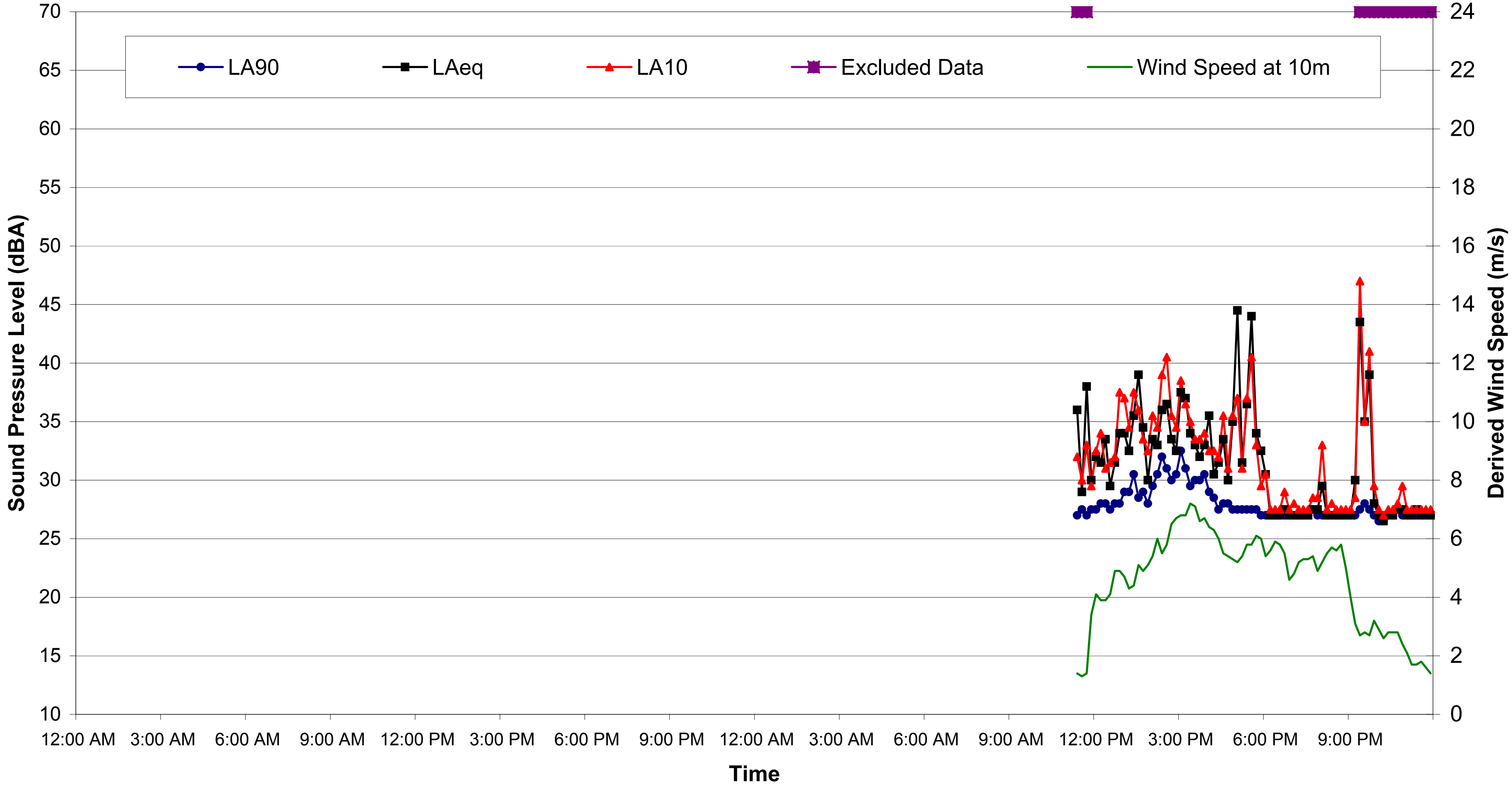
Chart3 Printed 20-07-2006 18:16

Location G1 - Conroys Gap
Ambient Noise Data - 22 and 23 May 2006



Appendix C7
40-1143
Level Wind vs Time

Location G1 - Conroys Gap
Ambient Noise Data - 24 and 25 May 2006



Appendix C7
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Level Wind vs Time

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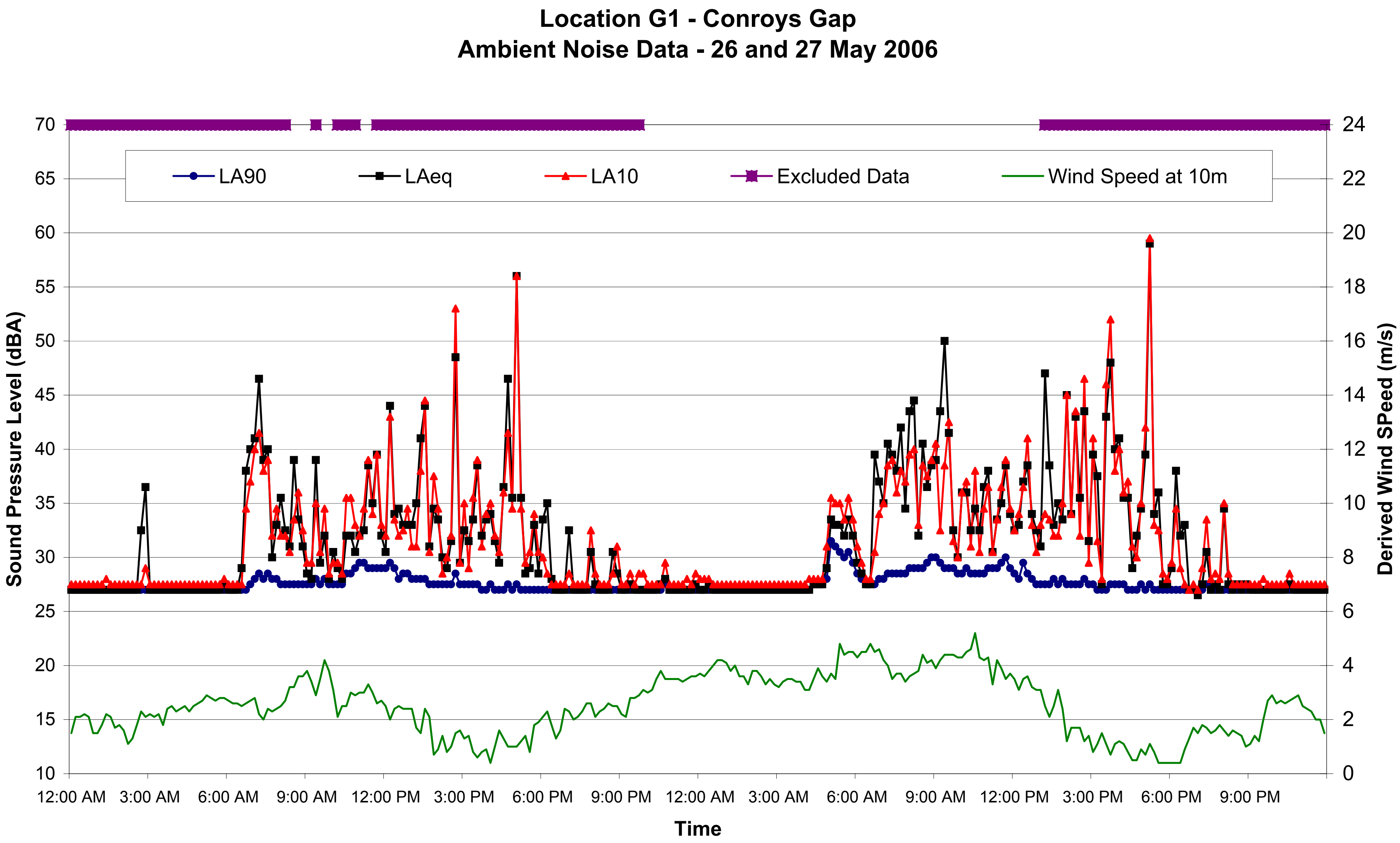

Appendix C7
40-1143
Level Wind vs Time

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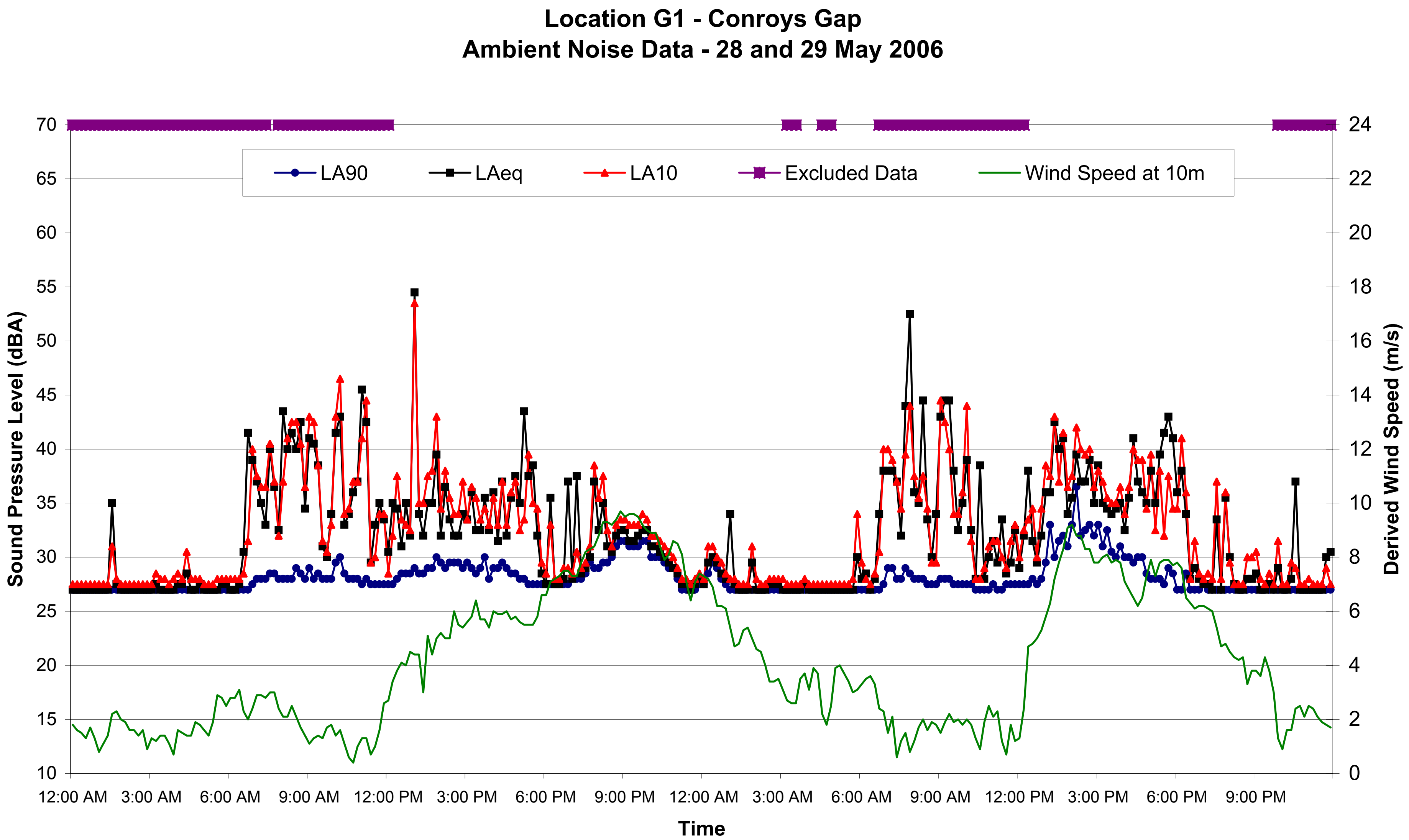

Appendix C7
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Level Wind vs Time

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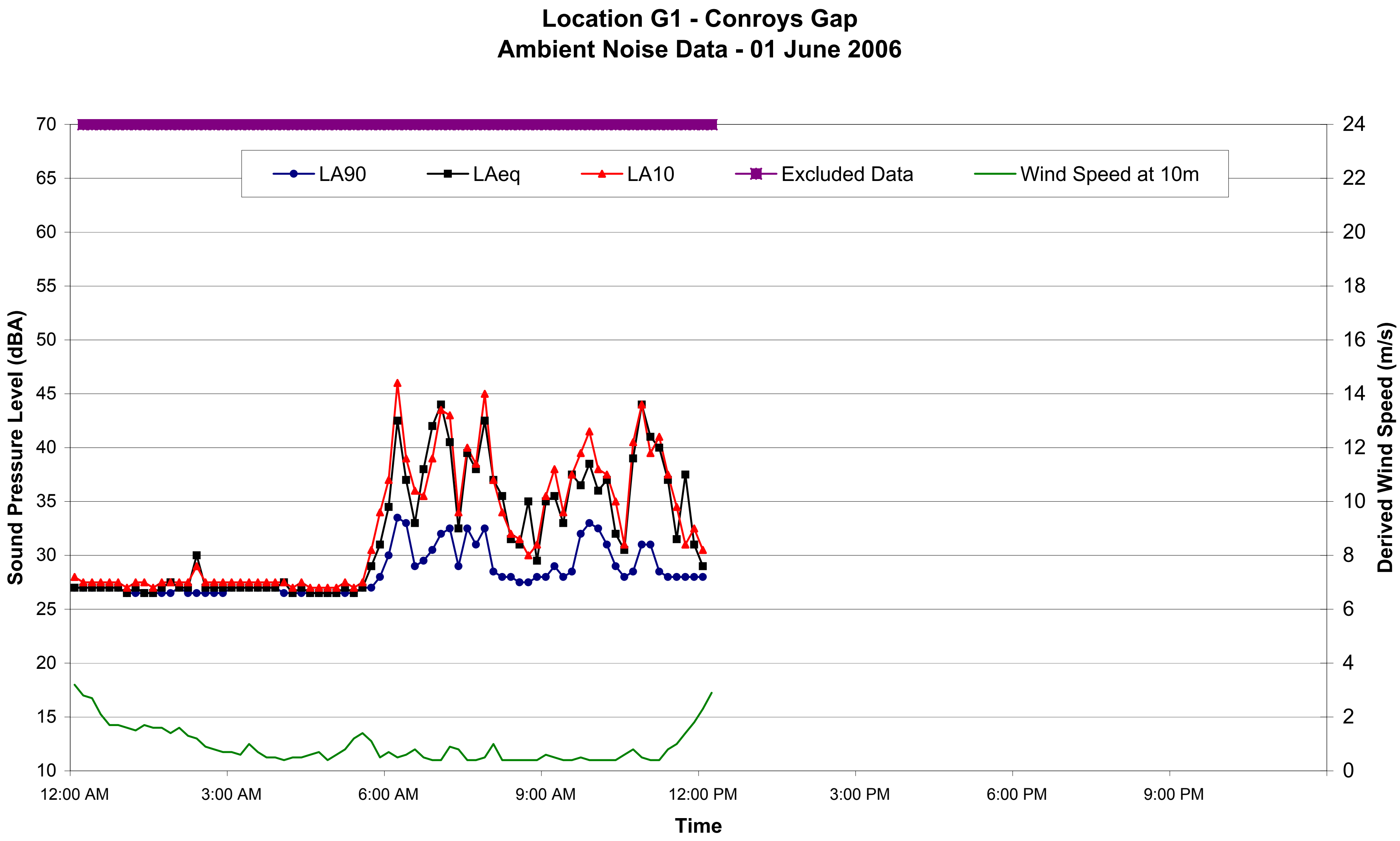

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40-1143
Level Wind vs Time

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Chart9 Printed 25-07-2006 12:23

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 2E-5 Pa.

2 "A" Weighted Sound Pressure Level

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

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

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

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
130	Threshold of pain	Intolerable
120 110	Heavy rock concert Grinding on steel	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

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

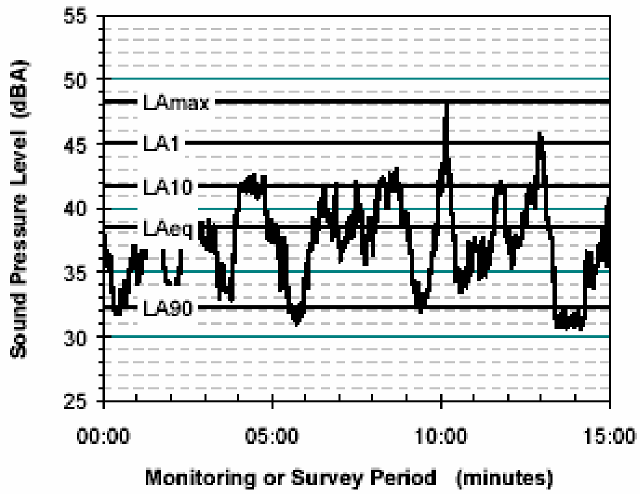
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 1E-12 W.

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_{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" L_{A90} 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 (L_{Aeq}, L_{A10}, etc).

5 Tonality

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

6 Impulsiveness

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

7 Frequency Analysis

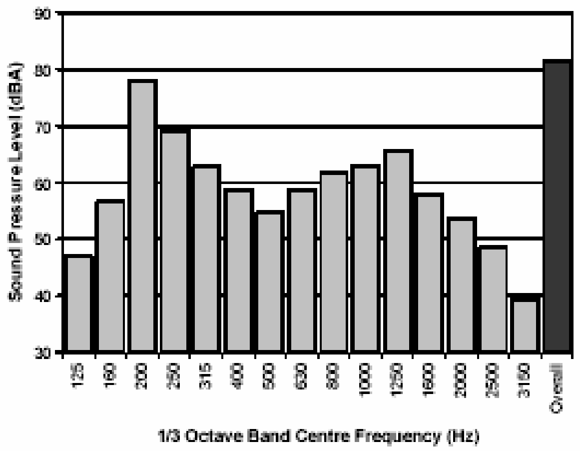
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

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

Frequency analysis can be in:

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

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



8 Vibration

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

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

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

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (1E-6 mm/s). Care is required in this regard, as other reference levels are 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

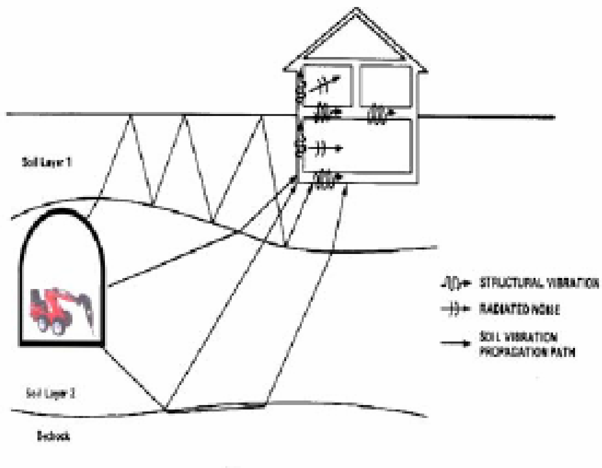
The term "over-pressure" is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

11 Regenerated Noise

Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed "regenerated noise", "structure-borne noise", or sometimes "ground-borne noise". Regenerated 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 regenerated 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 regenerated noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.



The term "regenerated noise" is also used to describe other types of noise that are emitted from the primary source as a different form of energy. One example would be a fan with a silencer, where the fan is the energy source and primary noise source. The silencer may effectively reduce the fan noise, but some additional noise may be created by the aerodynamic effect of the silencer in the airstream. This "secondary" noise may be referred to as regenerated noise.