THE RESULTS OF AN ACOUSTIC TESTING PROGRAM

CAPE BRIDGEWATER WIND FARM

Portland Golf Club

16th February 2015

Relationship of wind farm noise to impacts
Step 1

Use Acousticians & Psychoacousticians

- Acoustic measurements - of wind farm noise
- Psychoacoustic assessment of community response

Relationship of wind farm noise to health
Step 2

Following Step 1 + On site Sleep Studies (with acoustic measurements)

Multidisciplinary research involving acousticians and psychoacousticians, together with experienced medical practitioners, researchers and clinicians, including but not limited to the following speciality areas:

- Sleep Physicians & physiologists
- Ear Nose & throat physicians and physiologists
- Neuroscientists
- Psychiatrists & Psychologists
- Cardiologists and cardiac physiologists
- Endocrinologists
- Epidemiologists
- Rural General Practitioners
- Occupational Health Physicians

Clarification of the Study

Brief:

- Take measurements “to determine whether certain wind conditions or certain sound levels give rise to disturbances experienced by specific local residents at Cape Bridgewater.”

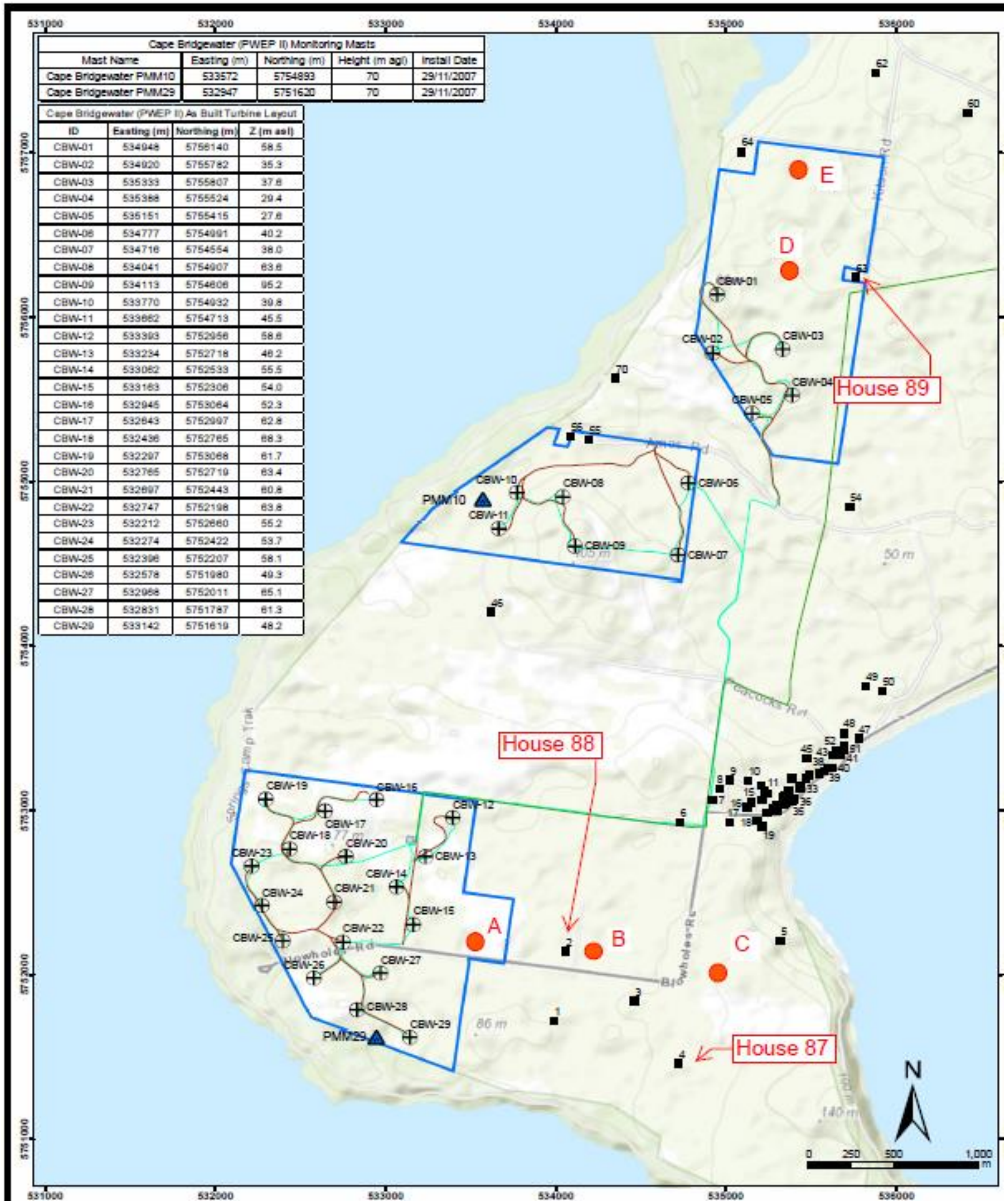
- The local residents numbered only 6 (the three houses)

The study that was undertaken was from the outset a totally different concept to undertaking an assessment of a wind farm.

In light of various comments in the media following the release of the report it is necessary to note that the Brief was specific as to:

- No requirement for more people. (Pacific Hydro have identified the report was commissioned at the request of 6 residents in an attempt to better understand their specific issues. It was an investigation to see what we could find not a formal scientific study.)
- No requirement for a control group
- No requirement to undertake compliance testing - specifically instructed not to do so. (Pacific Hydro advised that wind farm compliance had already been demonstrated and a compliance review was not part of the scope of the investigation.)
- No requirement to look at health impacts. It was agreed health impacts is not our area of expertise.
- No requirement to look at impacts on quality of life. If considered as a medical concept outside of our expertise. If considered as a socio-acoustic concept also outside of our expertise.
- No external peer review permitted, unless a sub-contractor subject to the same contract. Draft report was reviewed by both Pacific Hydro and the residents before release.

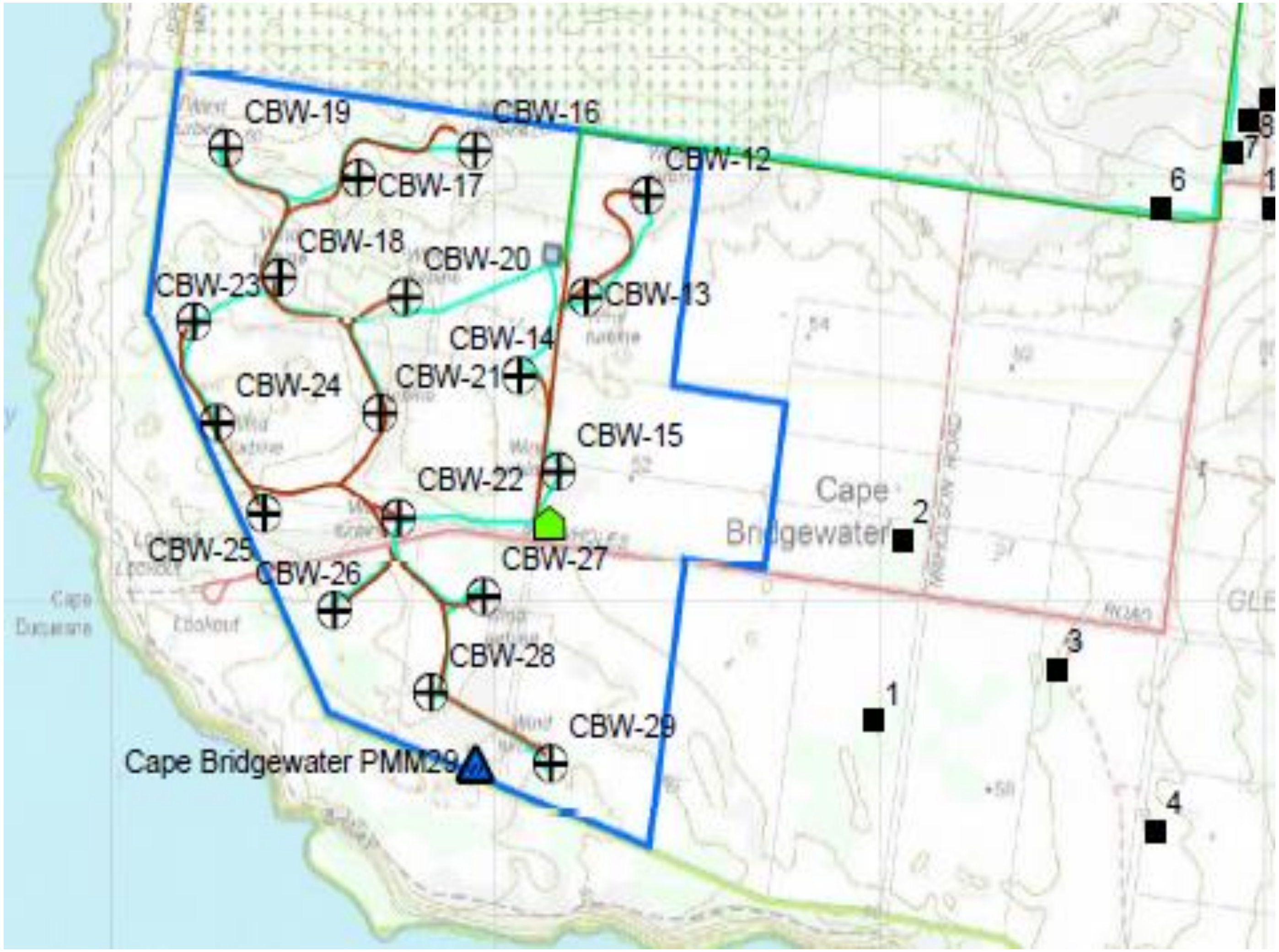
The findings of the report identified measurements and analysis not included in the current permit conditions and indicated more work was required to obtain supplementary criteria to be used for wind farms. The author’s opinion was that the use of the WTS as a tool to positively identify the operation of the turbine could assist in medical studies.



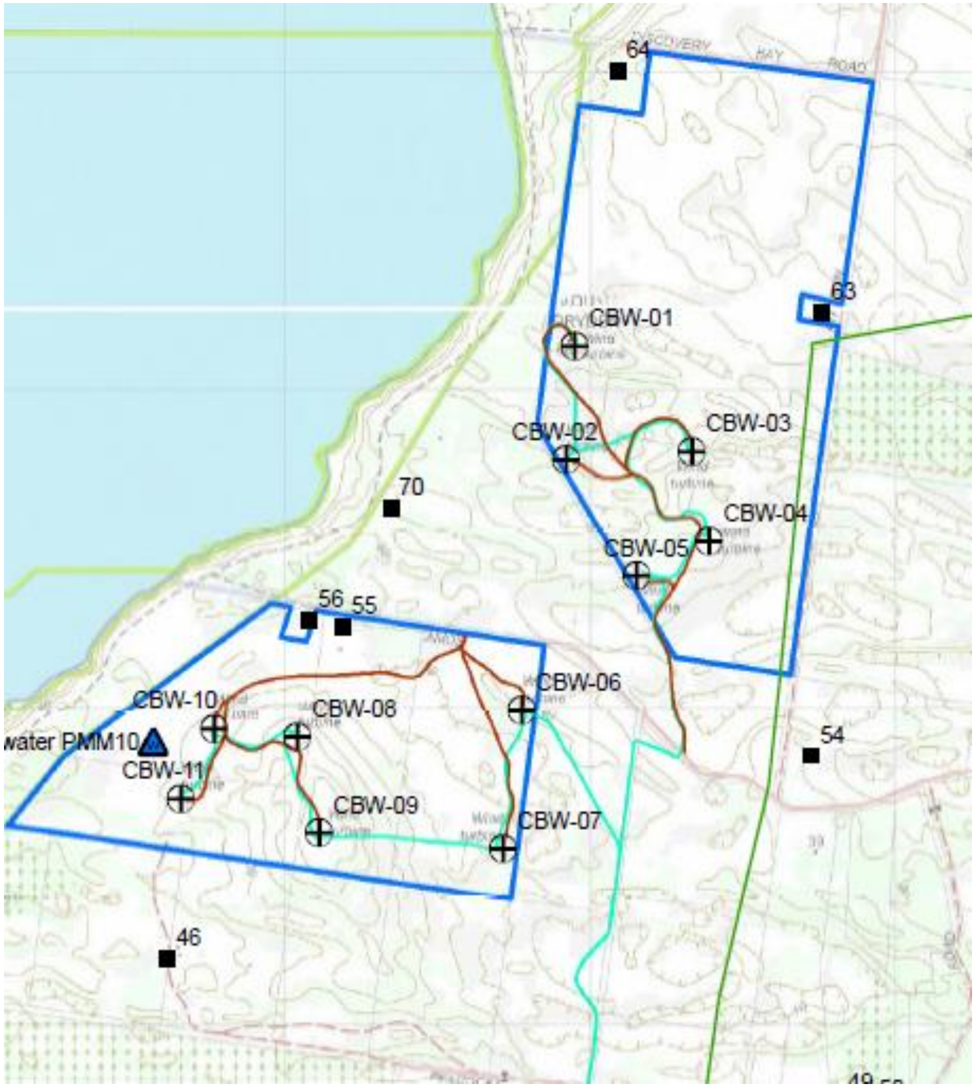
Cape Bridgewater (PWEP II) Monitoring Masts				
Mast Name	Easting (m)	Northing (m)	Height (m agl)	Install Date
Cape Bridgewater PMM10	533572	5754893	70	29/11/2007
Cape Bridgewater PMM29	532947	5751620	70	29/11/2007

Cape Bridgewater (PWEP II) As Built Turbine Layout			
ID	Easting (m)	Northing (m)	Z (m asl)
CBW-01	534948	5756140	58.5
CBW-02	534920	5755782	35.3
CBW-03	535333	5755807	37.6
CBW-04	535388	5755524	29.4
CBW-05	535151	5755415	27.6
CBW-06	534777	5754991	40.2
CBW-07	534716	5754554	38.0
CBW-08	534041	5754907	63.6
CBW-09	534113	5754606	95.2
CBW-10	533770	5754932	39.8
CBW-11	533662	5754713	45.5
CBW-12	533393	5752956	58.6
CBW-13	533234	5752718	46.2
CBW-14	533062	5752533	55.5
CBW-15	533163	5752306	54.0
CBW-16	532945	5753064	52.3
CBW-17	532643	5752997	62.8
CBW-18	532436	5752765	68.3
CBW-19	532297	5753068	61.7
CBW-20	532765	5752719	63.4
CBW-21	532697	5752443	60.8
CBW-22	532747	5752198	63.8
CBW-23	532212	5752660	55.2
CBW-24	532274	5752422	53.7
CBW-25	532398	5752207	58.1
CBW-26	532578	5751980	49.3
CBW-27	532968	5752011	65.1
CBW-28	532831	5751787	61.3
CBW-29	533142	5751619	48.2

Expanded view of southern section of wind farm



Expanded view of northern section of wind farm



Study Process

- Residents record observations in diaries. No information of noise testing or wind farm operations provided to residents prior to or at time of their observations.
- Unattended loggers were used for a few days to examine the propagation of dB(A) and infrasound.
- Multi-channel attended measurements at each house undertaken for a few nights and days, then system moved to house 87 for majority of survey period. Noise measurements using loggers were undertaken inside and outside homes recording full spectrum data. Multichannel system concentrated on low frequency and infrasound.
- Unattended noise loggers (full spectrum) inside and outside houses intended for entire survey period. Instrumentation issues (electrical interference?) affected some data. Some loggers reverted back to logging without Wave files.
- Attendance every two weeks to download data and after post-processing review resident's observations.
- Attend community consultative meetings to provide preliminary (and then progressive) findings as to progress of study.
- Attended measurements of noise and vibration at residential properties at locations identified as “hotspots”.
- Attended measurements on wind farm (CBW 13, 14, 22, 27, 29 and substation) and on Blowholes Road.
- Survey period included full shutdown of wind farm over a number of days whilst high voltage cabling work was carried out. No power to turbines to run computers or various ventilation fans during shutdown – this is identified as “complete shutdown”, rather than a “shutdown” that only stops some (or all) turbines but still has ventilation fans, pumps etc. still operating.
- Draft report provided to Pacific Hydro and residents for review before finalisation.

Measurement/Analysis Procedures

In terms of basic measurements no difference to measurements undertaken by others looking at low frequency and infrasound. However there is a very significant advantage in this study by having the wind farm data and unlimited access to the wind farm.

First step consider dB(A) versus the wind speed/direction and power output of wind farm

Analysis included general acoustic descriptors and also narrow band and time displays previously used for investigation of infrasound by:

- Bray & James pulsating infrasound at blade pass of 1 Hz and harmonics exceeding 90 dB from a GE 1.5MW turbine
- Rand & Ambrose Bruce McPherson Study at Falmouth
- Schomer, Rand , Walker and Hessler for the Shirley Wind Farm.
- Cooper for Waterloo, Waubra and Hallett wind farms
- Adelaide University for the Waterloo Wind Farm

By using 1/3 octave data analysis consider various alternative acoustic parameters with respect to residents observations

Consider narrow band results with respect to resident's observations and wind farm data

Compare measurement data for wind farm ON versus OFF

Evaluate measurements recorded on wind farm, outside wind farm and at resident hotspots.

Propagation of Infrasound

The rate of attenuation of infrasound is different to audible sound. The initial testing was to provide data for that situation for the subject turbines.

The Massachusetts Turbine Impact Study (in my opinion being one of the peer reviews often misrepresented) states on page 10:

> *It is known that low frequency waves propagate with less attenuation than high-frequency waves. Measurements have shown that the amplitude for the airborne infrasonic waves can be cylindrical in nature, decaying at a rate inversely proportional to the square root of the distance from the source. Normally the decay of the amplitude of an acoustic wave is inversely proportional to the distance (Shepherd & Hubbard, 1991).*

The Massachusetts Turbine Impact Study on page 11 discusses some results for Linear measurements but indicates there is an absence of a description of the methodology used to derive the results. On page 61 of that study report there are recommendations for more comprehensive assessment of wind turbine noise in populated areas that should be done with reference to the broader ongoing international research in wind turbine noise production and its effects.

Pre House Test

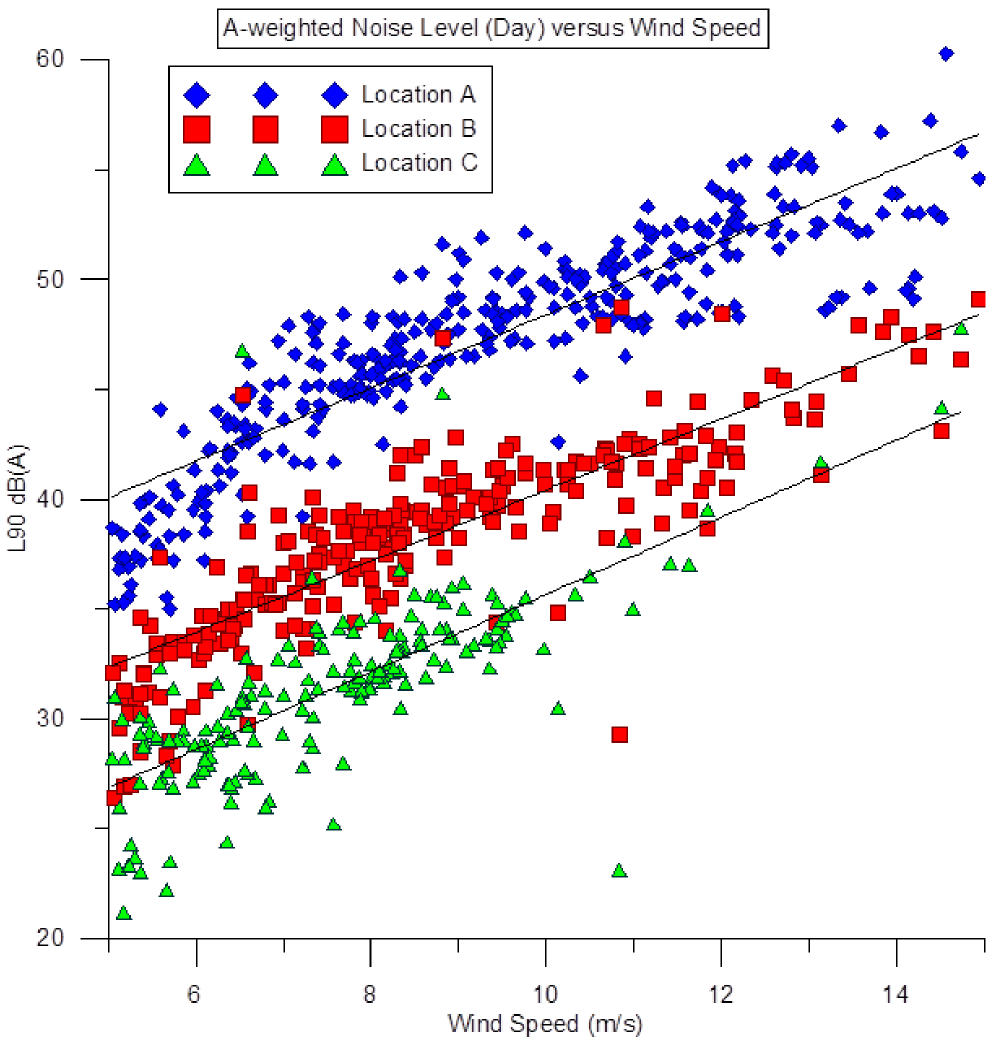
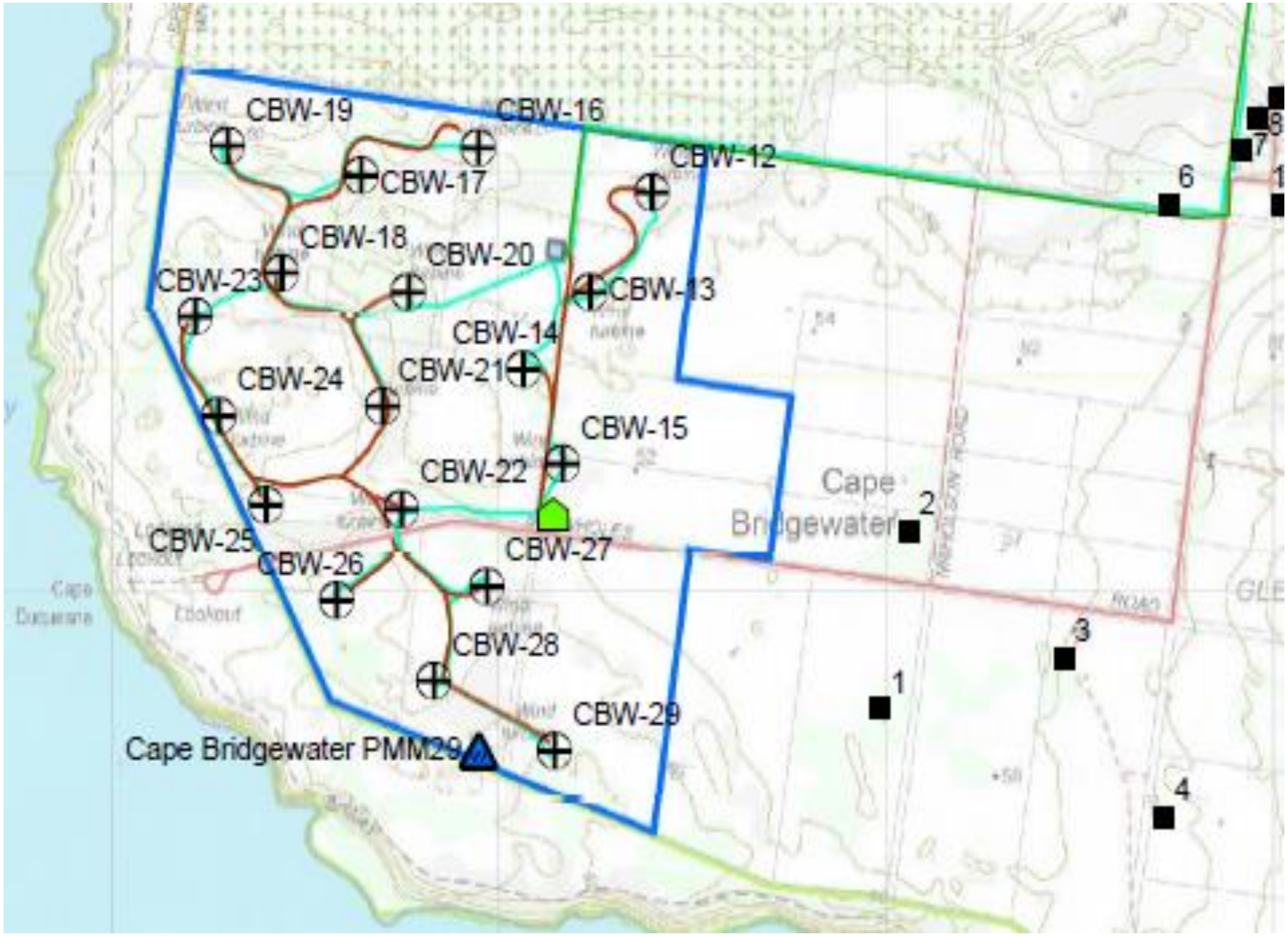


FIGURE 3: Regression for Pre Test Measurements Loggers A, B & C – Day time


CBW-19
CBW-16
CBW-12
CBW-17
CBW-18
CBW-20
CBW-23
CBW-13
CBW-14
CBW-21
CBW-24
CBW-15
CBW-22
CBW-27
CBW-25
CBW-26
CBW-28
CBW-29
Cape Bridgewater PMM29
Cape
Bridgewater
1
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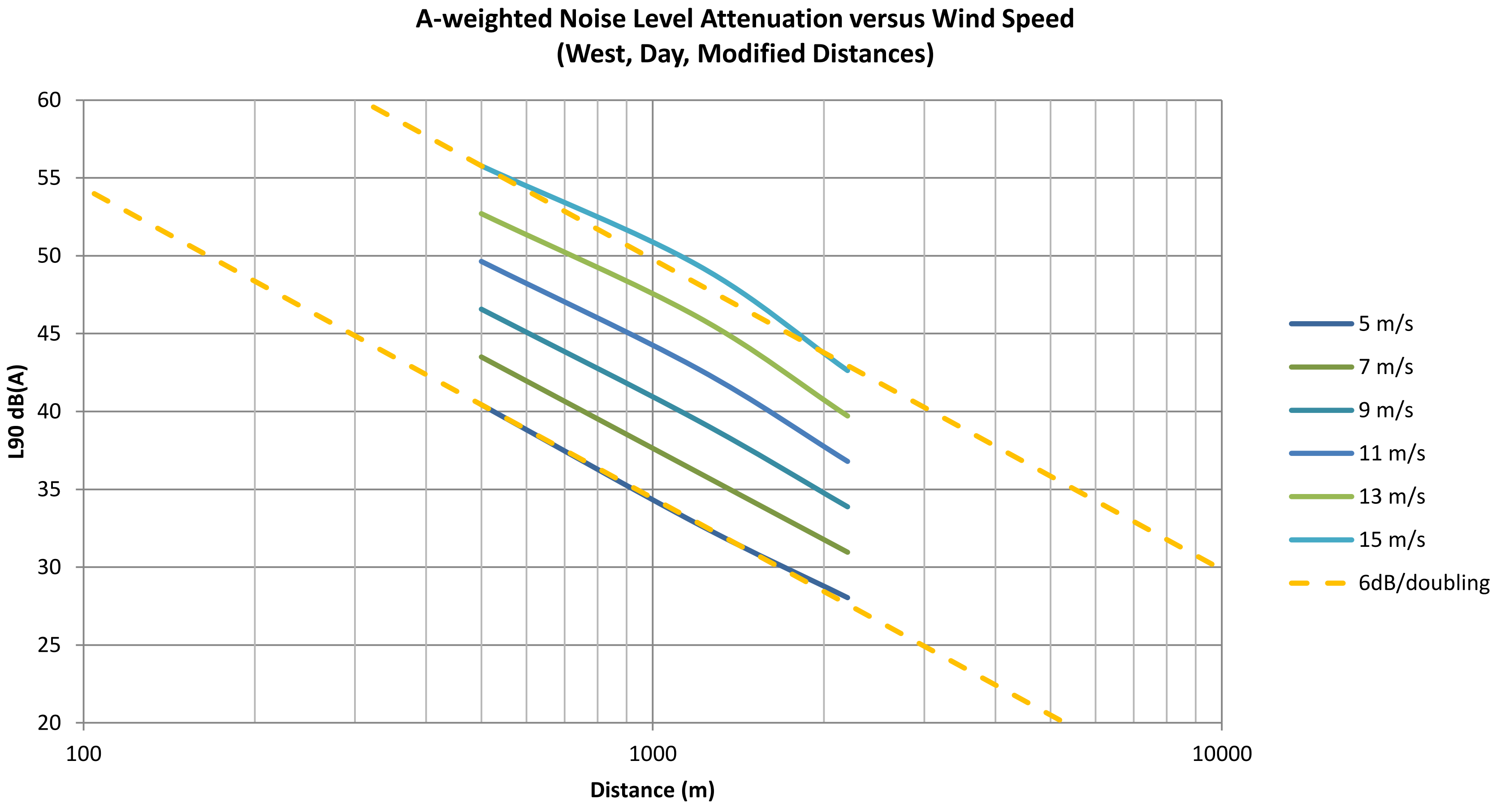
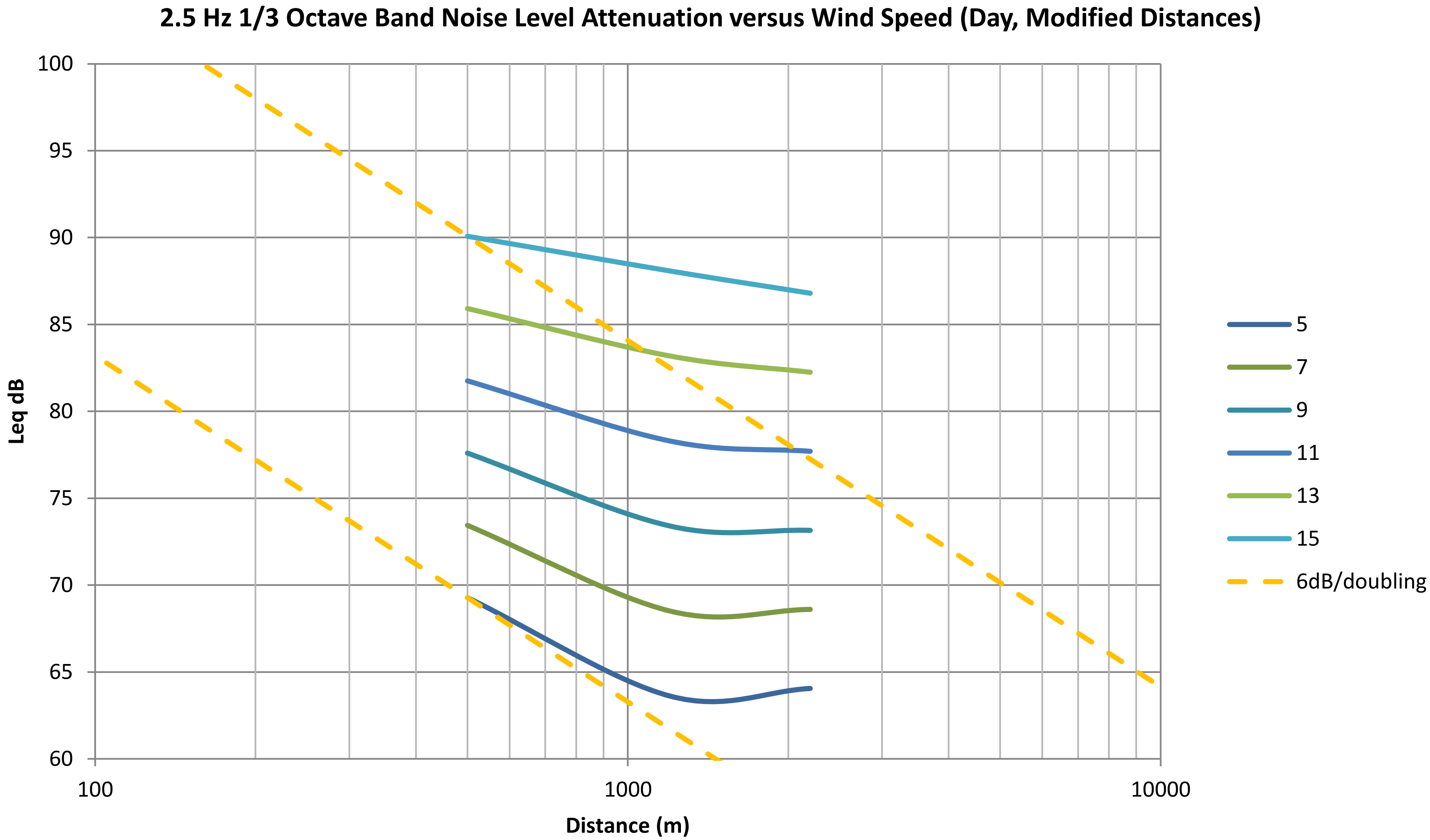
dB(A) Propagation

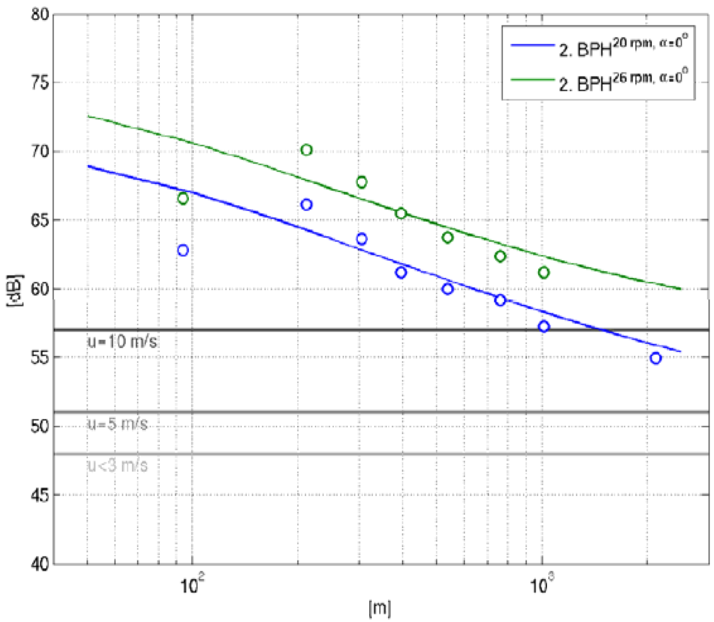


Infrasound Propagation

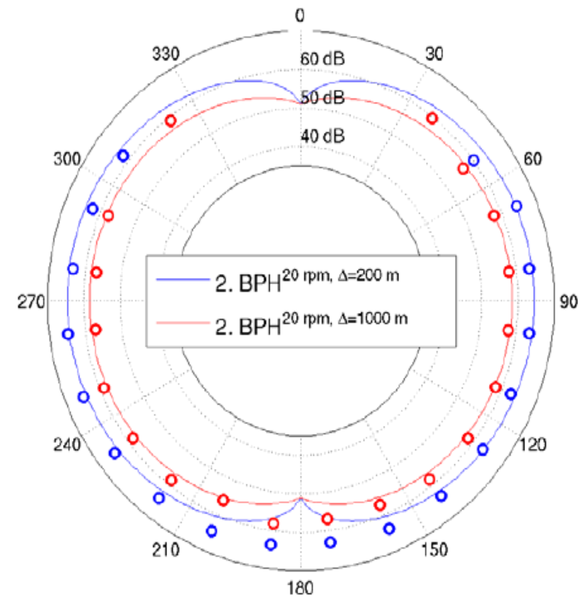


Comparison between measured and estimated SPL

SPL as a function of distance



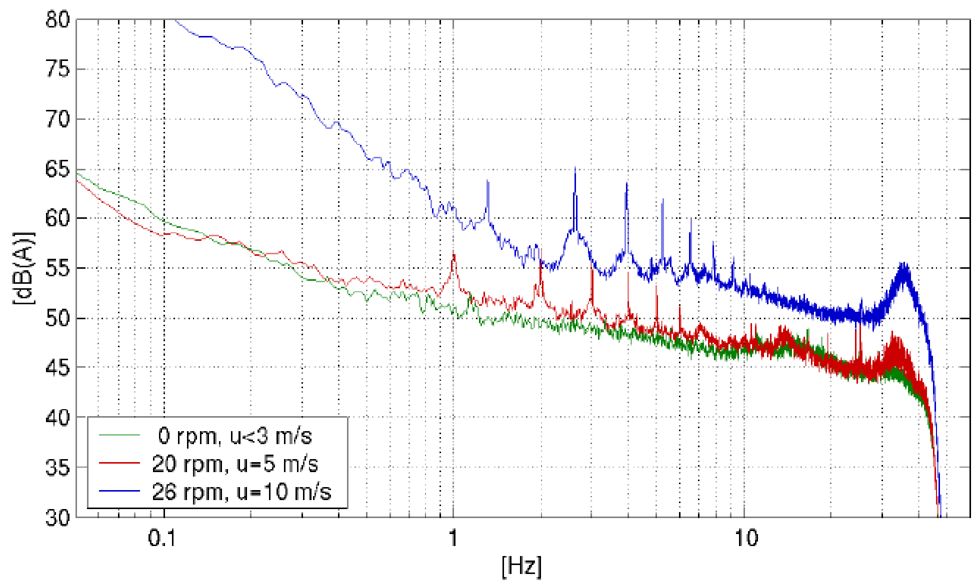
SPL as a function of azimuth



account for surface effects (e.g. reflections) by adding 3 dB to the estimated curves

Measured signals, Huf03, d=200 m

frequency domain



The inaudible noise of wind turbines, Ceranna, Hartmann and Henger, Federal Institute for Geosciences and Natural Resources (Hannover, Germany) Infrasound Workshop Nov 28 , 2005 Tahiti

Severity Ranking for the Observations

With the acknowledgement of the AECOM Wind Farm Noise Complaint Methodology (in NANR 277 Defra April 2011) the following severity rankings with respect to noise are set out below:

1. **No impact (No noise)**

2. **Slight impact (Non intrusive)** Noise can be heard, but does not cause any change in behaviour or attitude, e.g. turning up volume of television; speaking more loudly; closing windows. Can slightly effect character of the area but not such that there is a perceived change in the quality of life.

3. **Moderate Impact (Intrusive)** Noise can be heard and causes small changes in behaviour and/or attitude, e.g. turning up volume of television: speaking more loudly; closing windows. Potential for non-awakening sleep disturbance. Affects the character of the area such as there is a perceived change in the quality of life.

4. **Substantial Impact (Disruptive)** Causes a material change in behaviour and/or attitude, e.g. avoiding certain activities during periods of intrusion. Potential for sleep disturbance resulting in difficulty in getting to sleep, premature awakening and difficulty getting back to sleep. Quality of life diminished due to change in character of the area.

5. **Severe Impact (Physically Harmful)** Significant changes in behaviour and/or inability to mitigate effect of noise leading to psychological stress or physiological effects, e.g. regular sleep deprivation/awakening: loss of appetite, significant, medically definable harm, e.g. noise induced hearing loss.

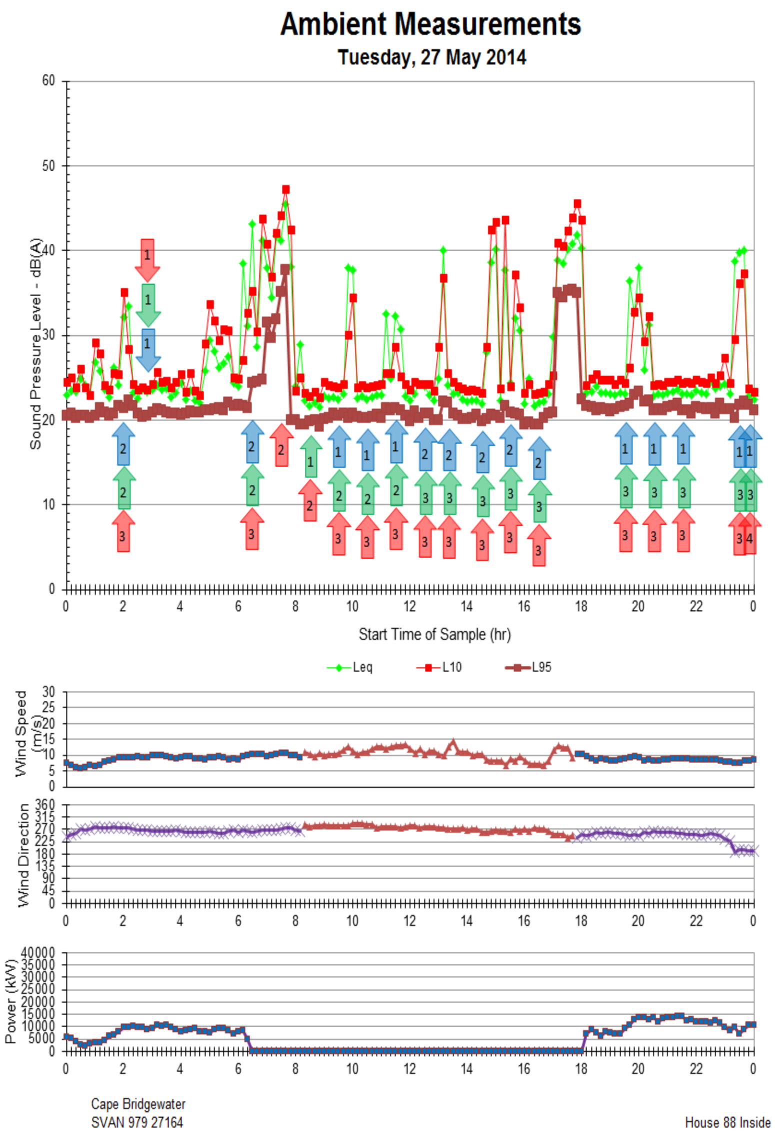
   NB In some case residents relate severity 5 to be equivalent to having to leave their premises and go somewhere else because of the noise.

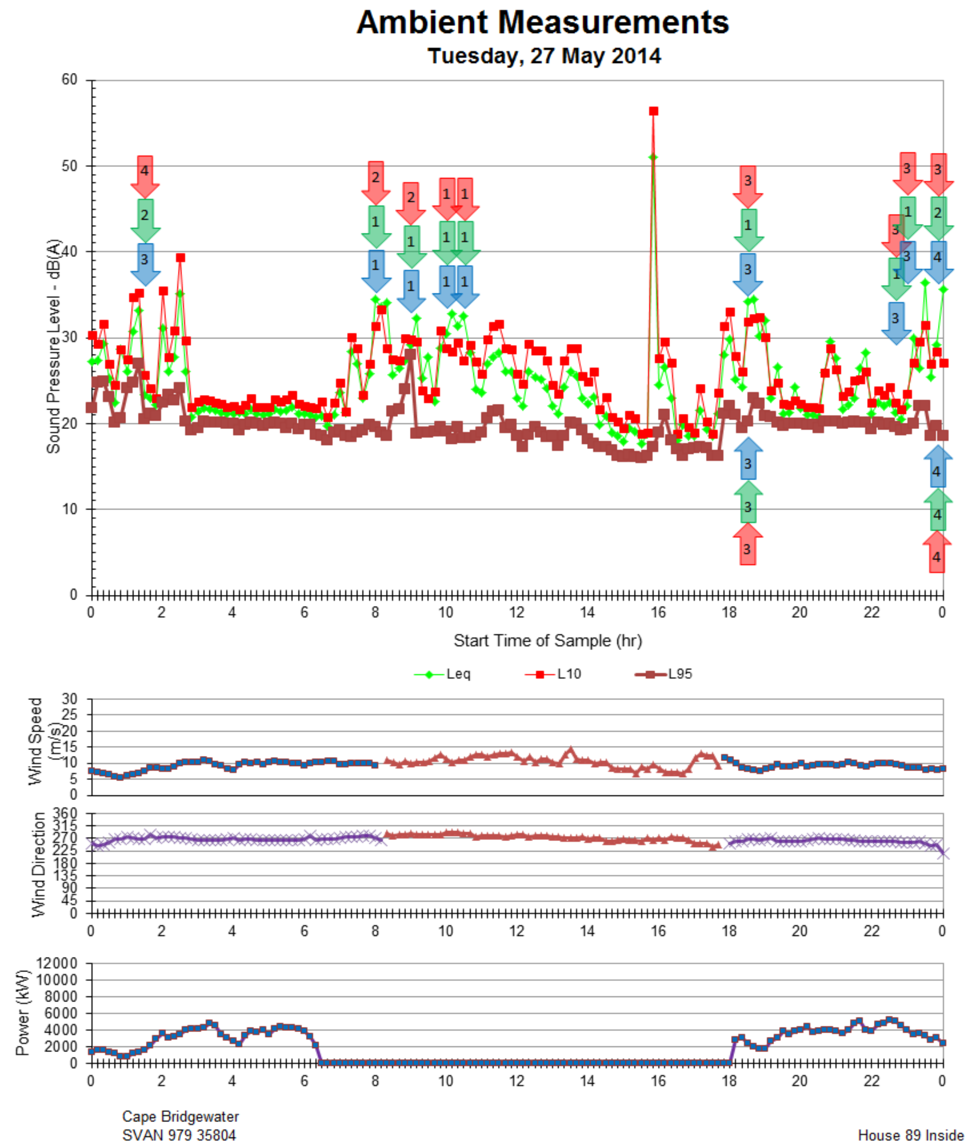
OBSERVATION CLASSIFICATIONS

Following consultation with residents, residents were asked to record (using severity rankings) perceived noise impacts, vibration impacts and other disturbances which, for the purposes of this study, have been labelled “sensation.”

“Sensation” includes headache, pressure in the head, ears or chest, ringing in the ears, heart racing, or a sensation of heaviness.

Displaying Observations





Different Parameters Considered

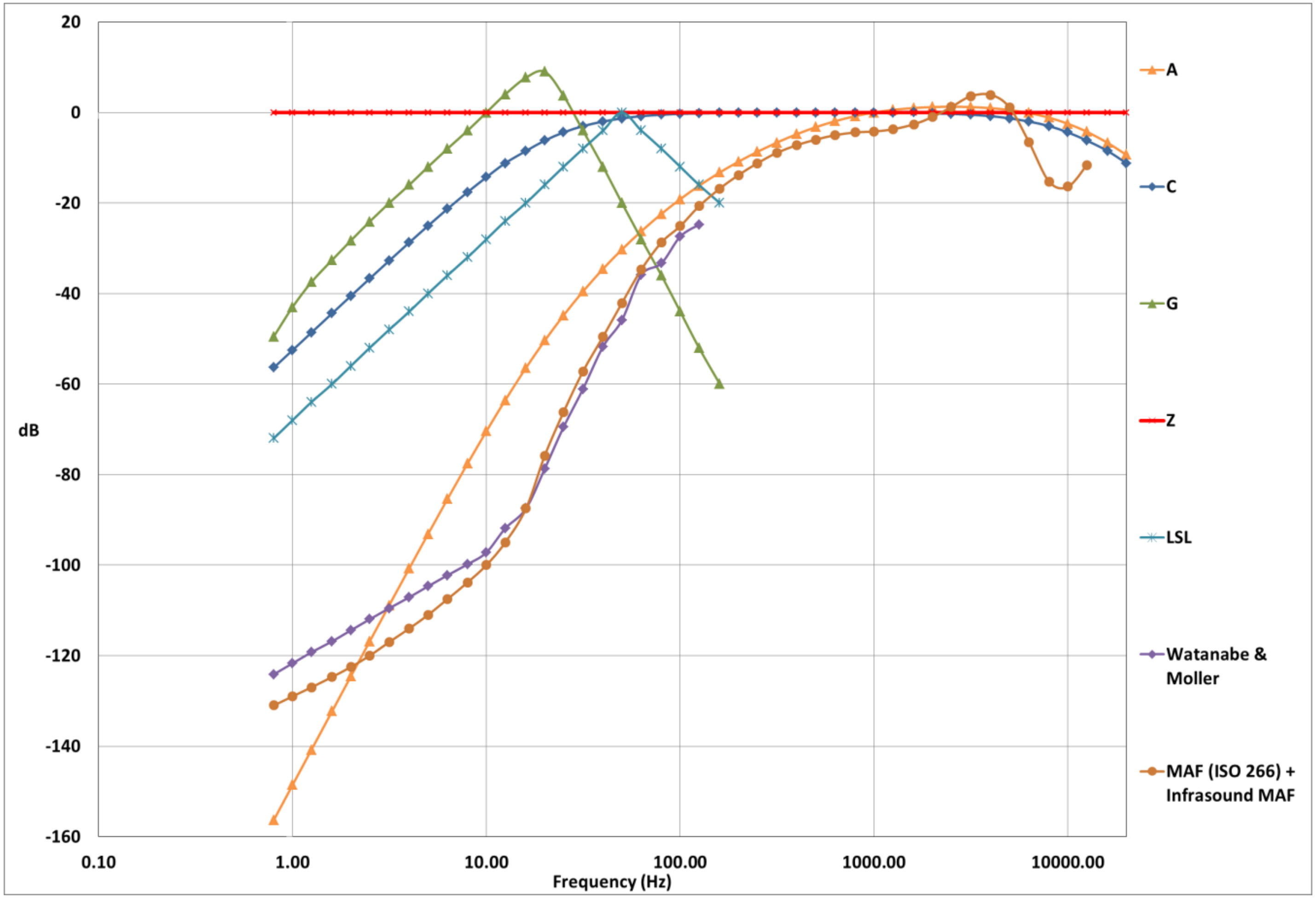


FIGURE 20: Weighting Curves

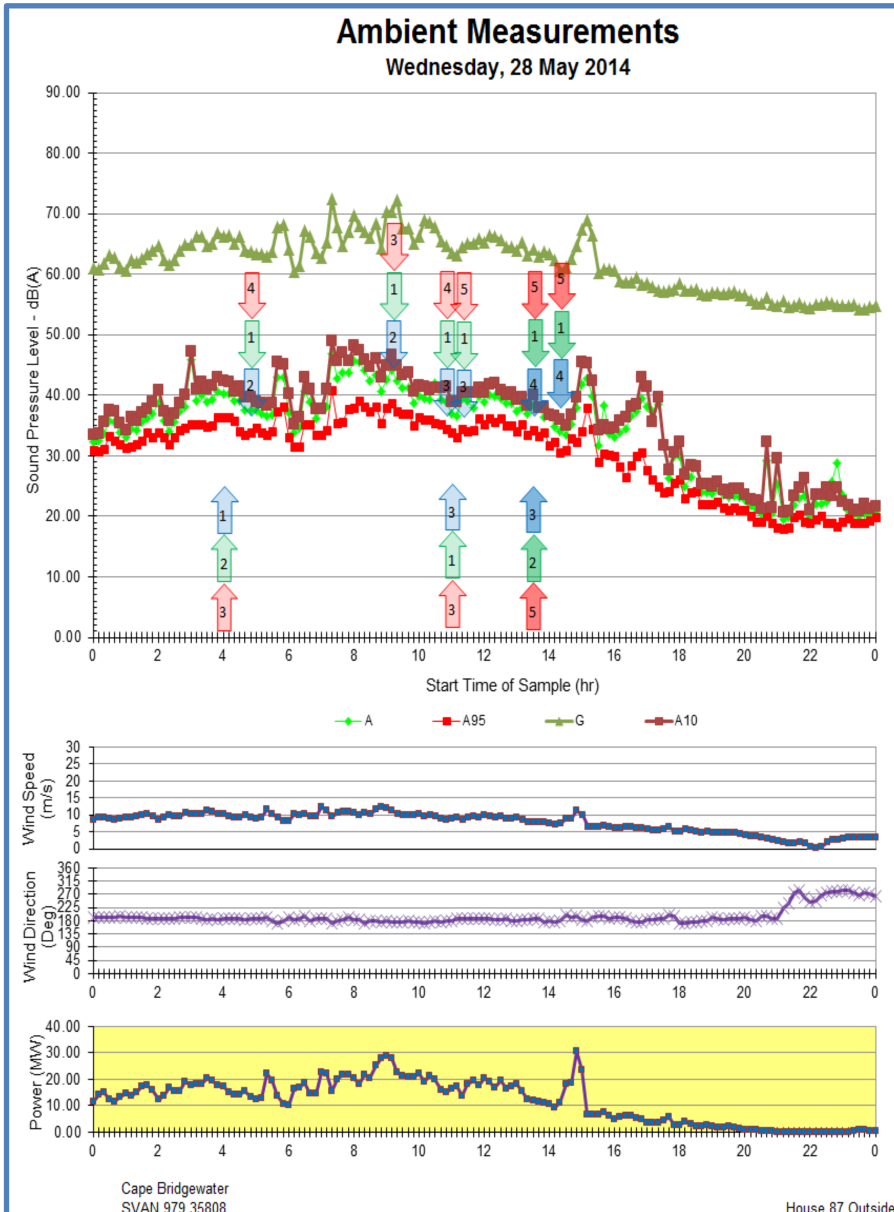


FIGURE 15: House 87 External Measurements: blue – noise, green – vibration and red - sensation

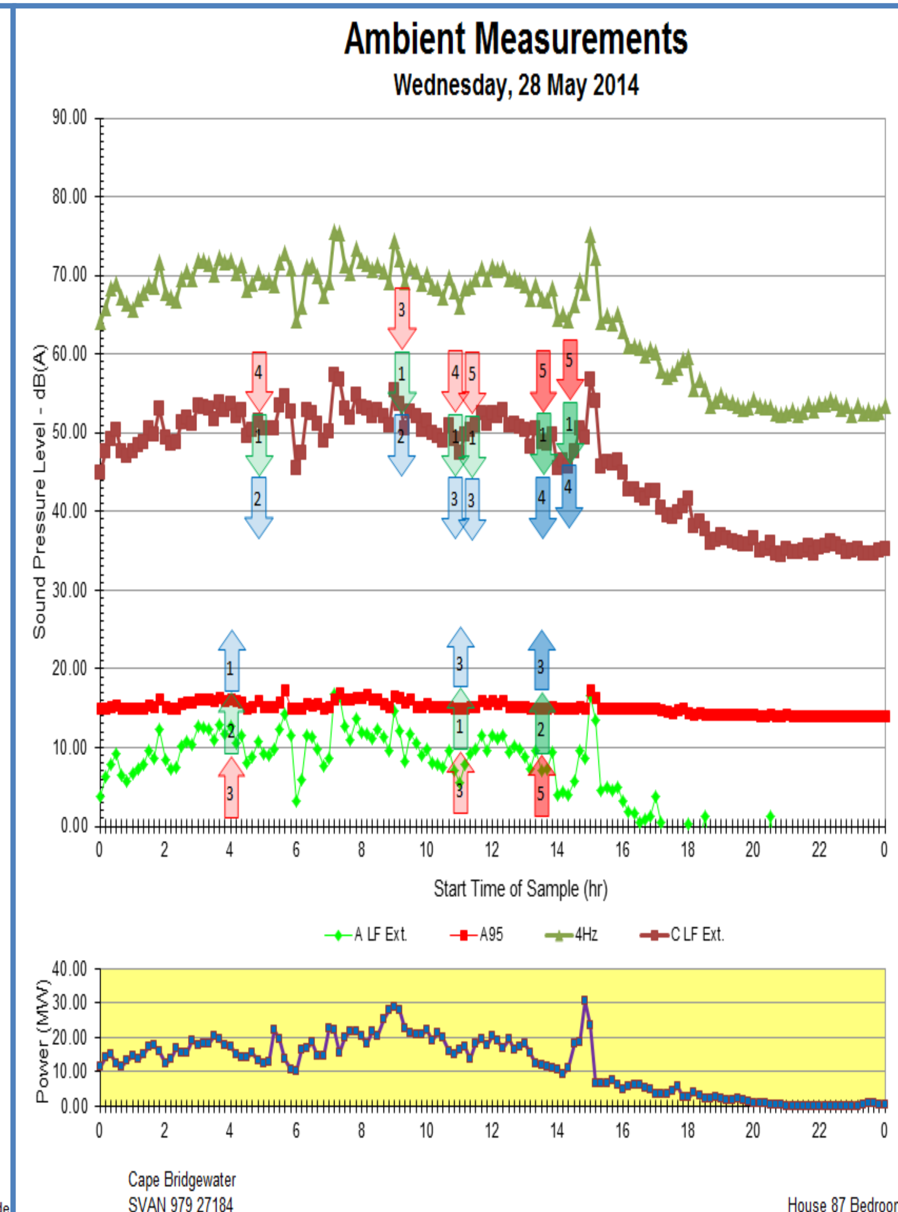


FIGURE 16: House 87 Internal Measurements: blue – noise, green – vibration and red - sensation

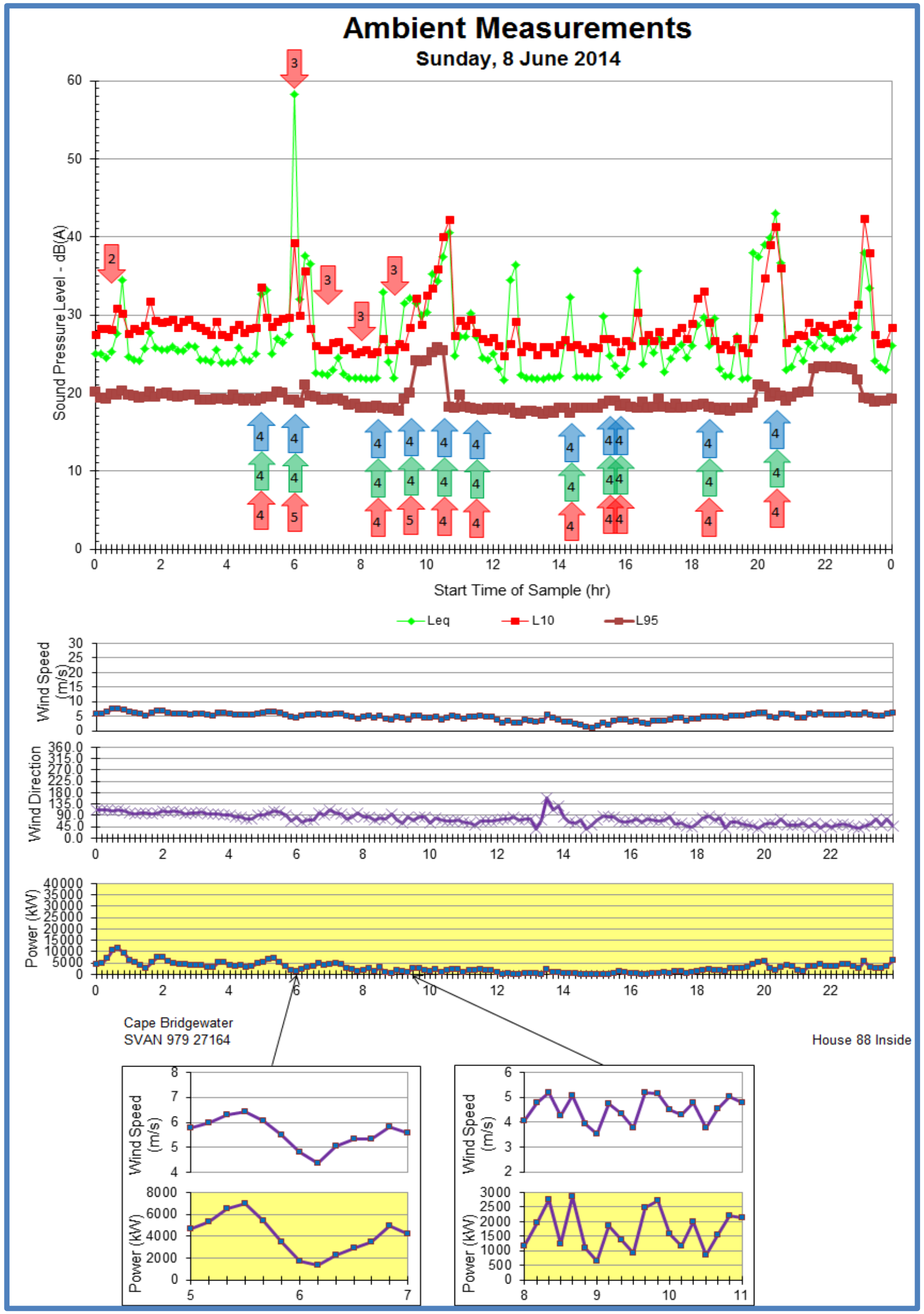


FIGURE 19: Internal Measurements (House 88): blue – noise, green – vibration and red - sensation

Different Operations for Individual Turbines

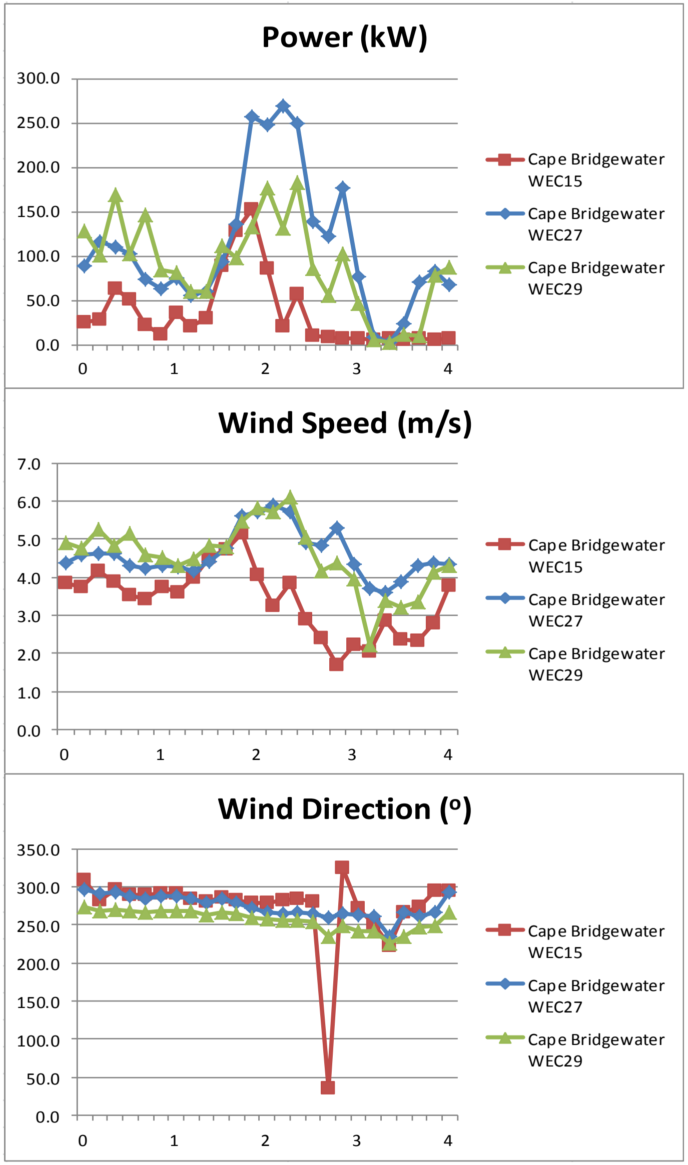


FIGURE 27: Operation of three nearest turbines to house 87 (midnight to 4AM)

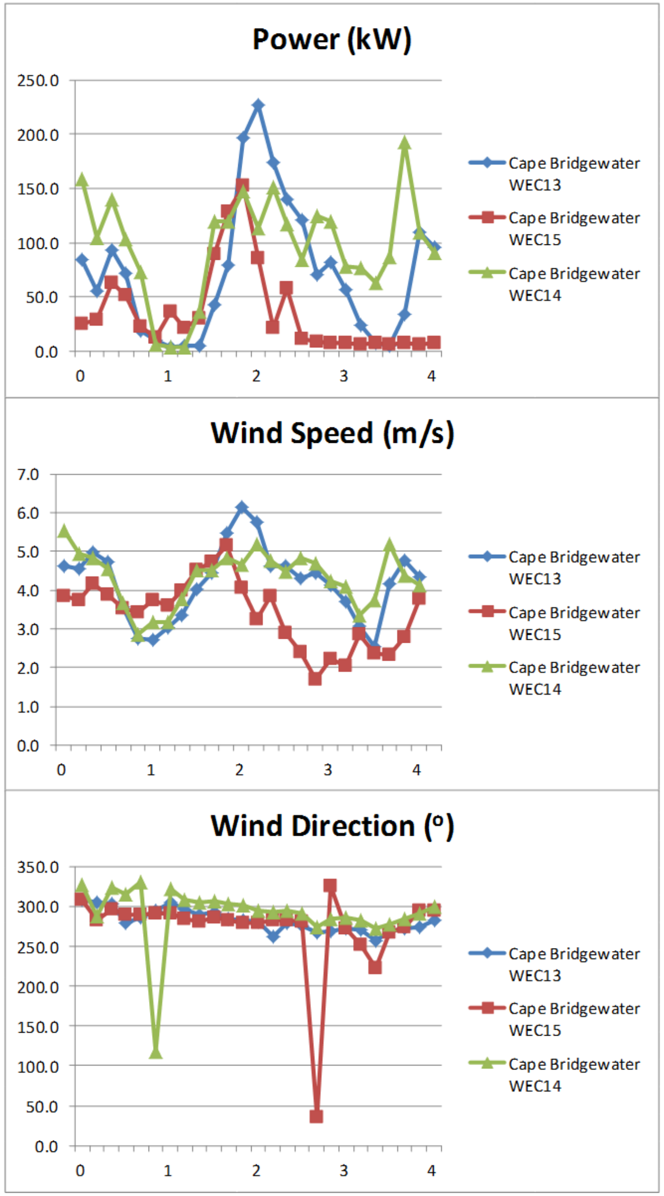


FIGURE 28: Operation of three nearest turbines to house 88 (midnight to 4AM)

FIGURE 34: Average wind direction 9.00 AM - 9.10AM on 10th June 2014

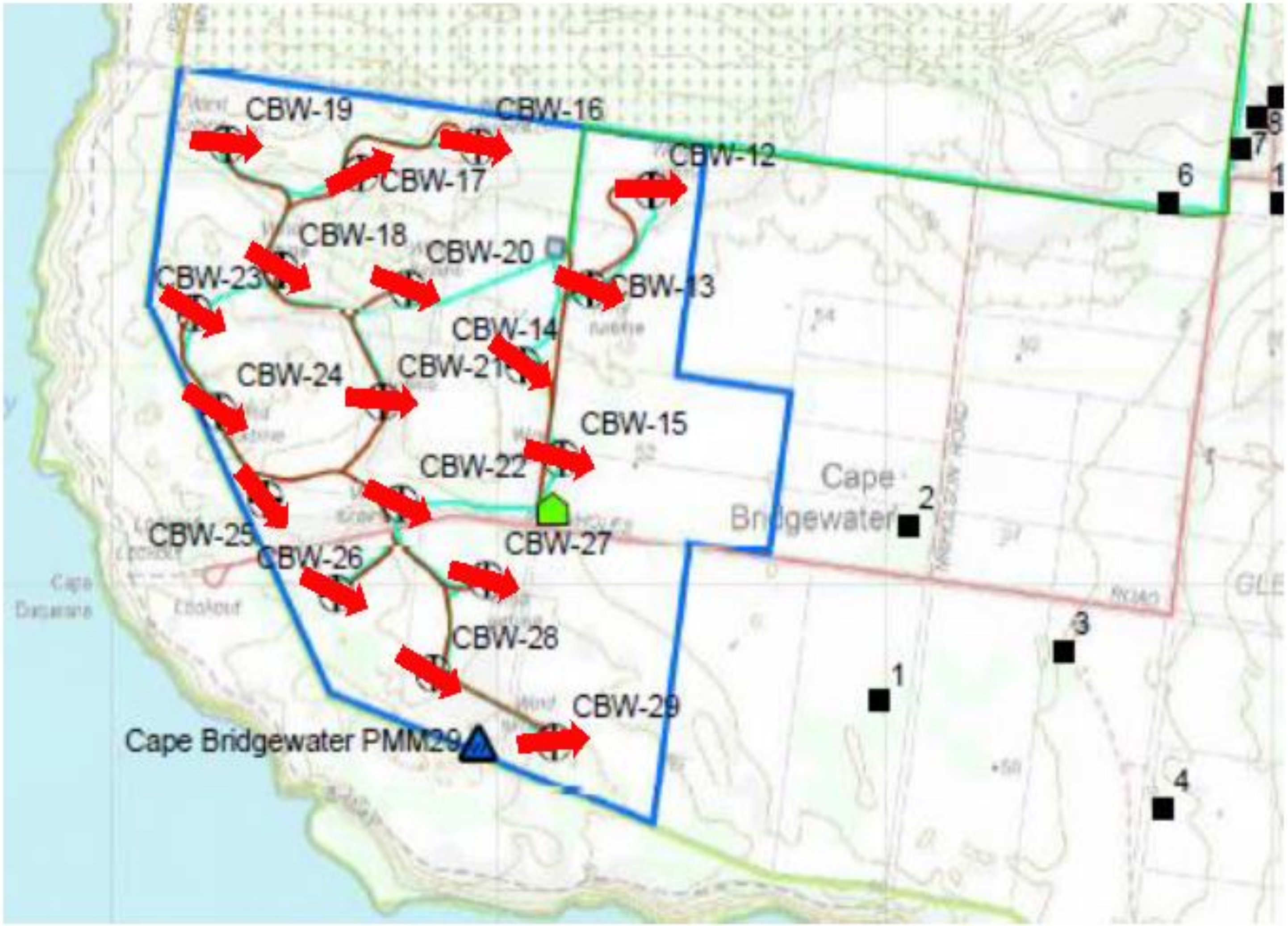
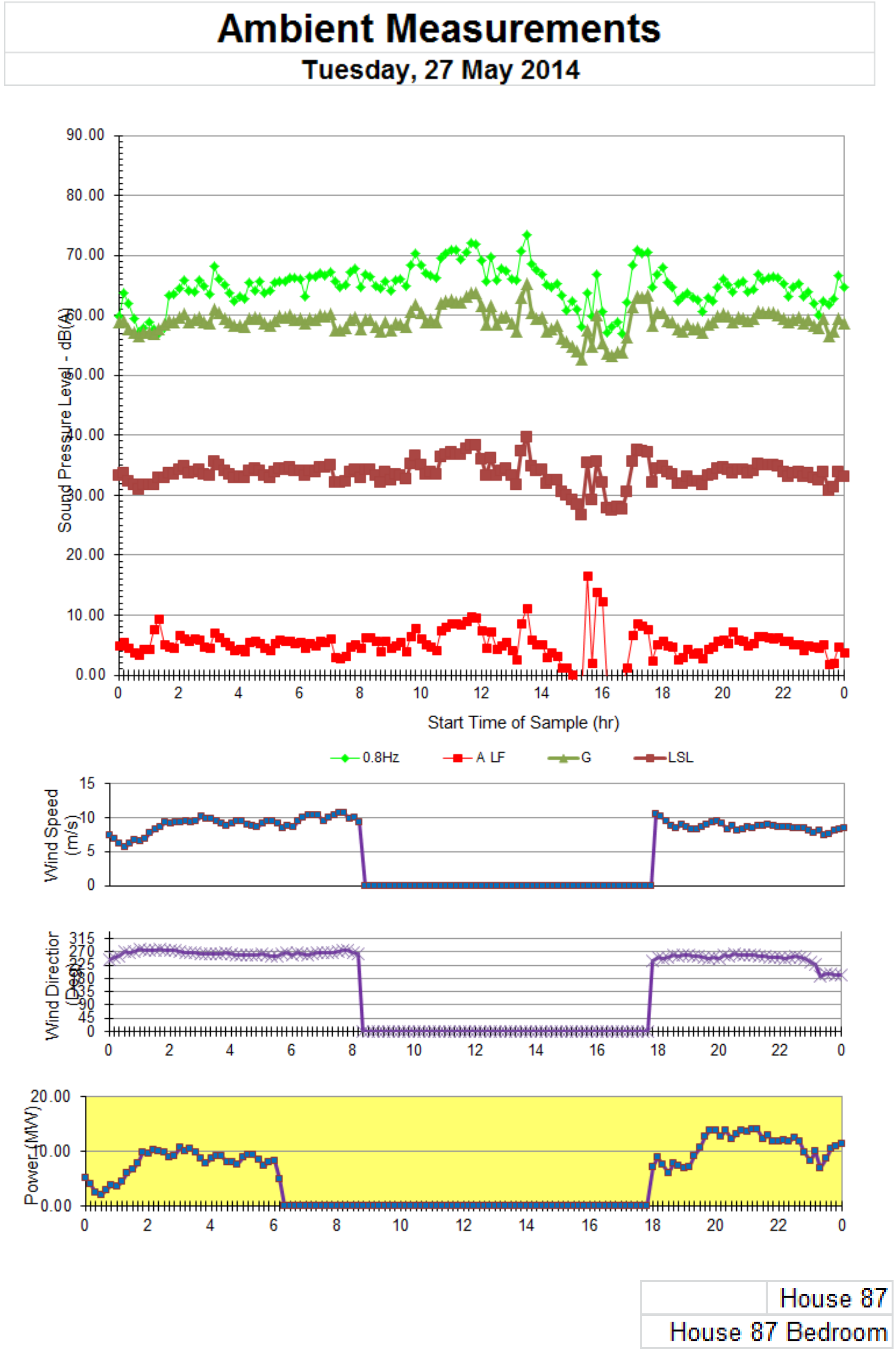


FIGURE 34: Average wind direction 9.00 AM - 9.10AM on 10th June 2014



On off testing

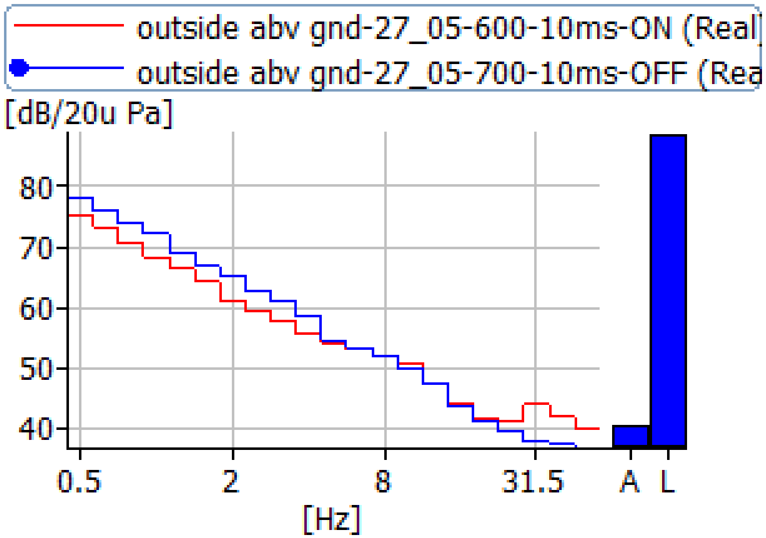


Figure 84: 1.5m above ground house 87 10m/s wind

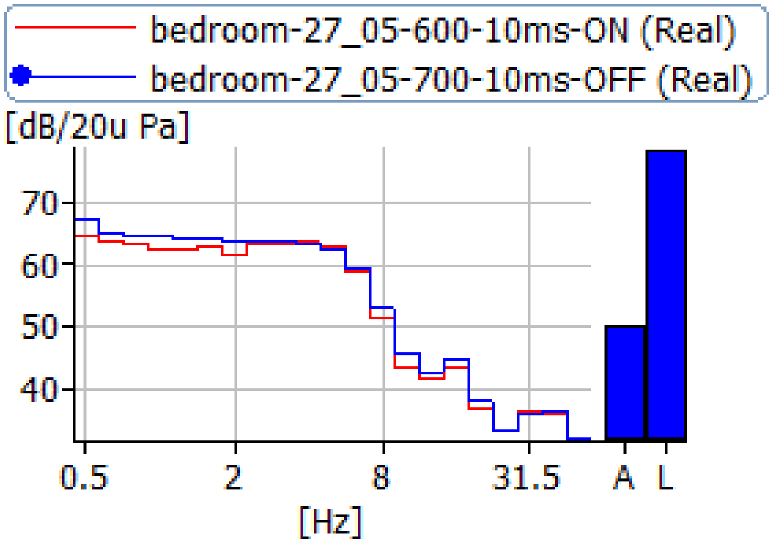


Figure 86: Bedroom house 87 10m/s wind

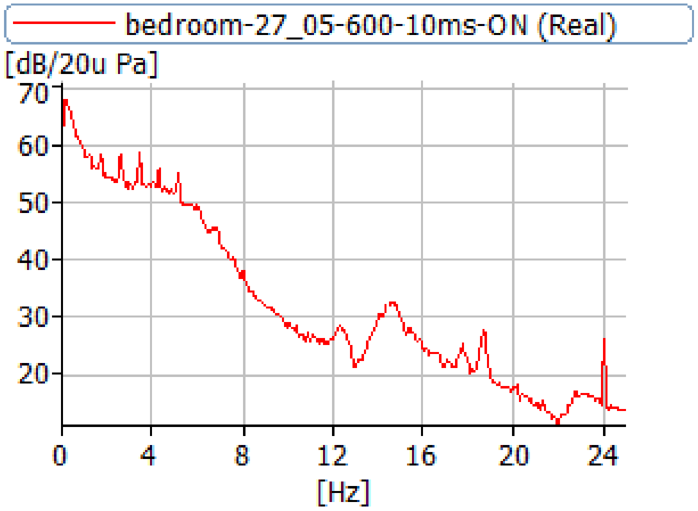


Figure 92: 6am turbines on (0 – 25Hz)

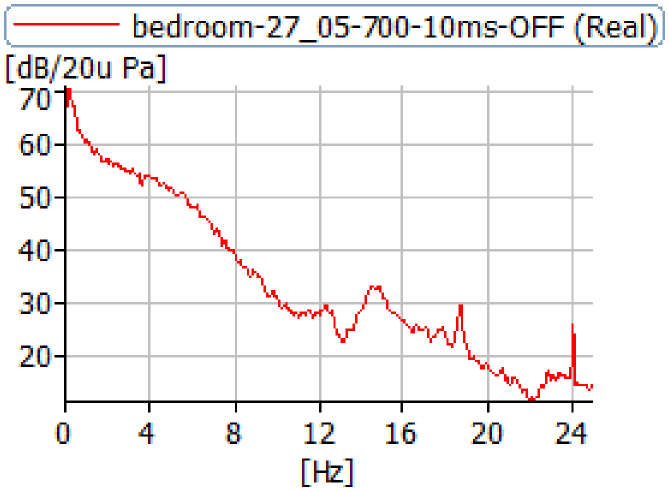


Figure 93: 7am turbines off (0 – 25Hz)

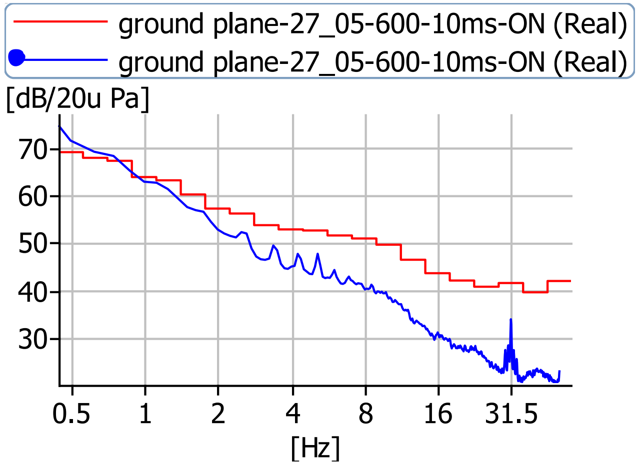


Figure 94: Ground plane house 87, turbines ON - 10m/s wind

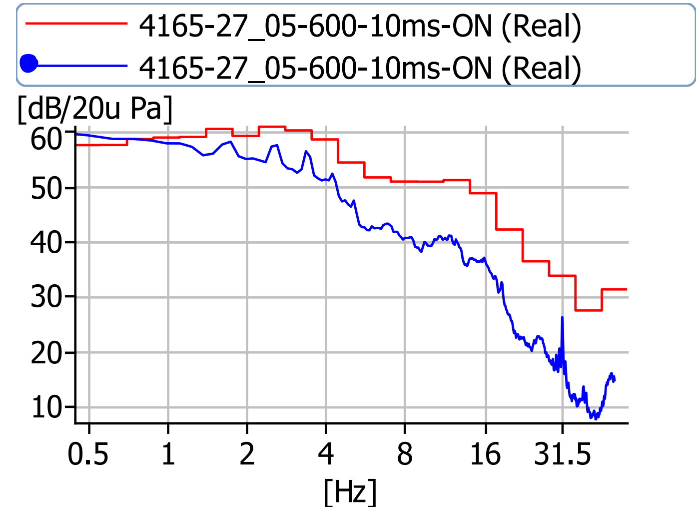


Figure 96: Living room house 87, turbines ON -10 m/s wind

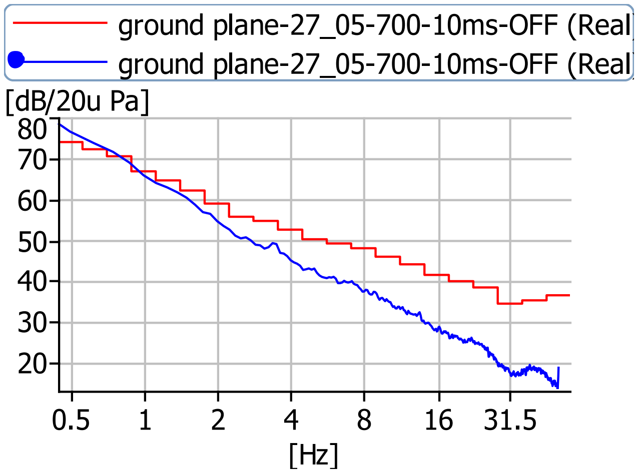


Figure 95: Ground plane house 87, turbines OFF - 10m/s wind

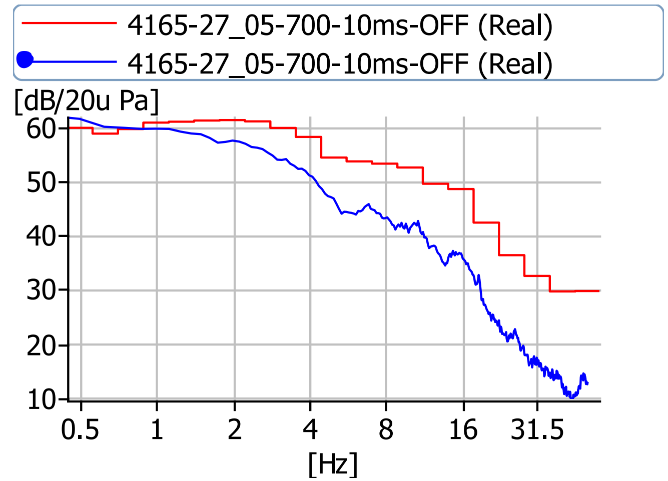


Figure 97: Living room house 87, turbines OFF - 10m/s wind

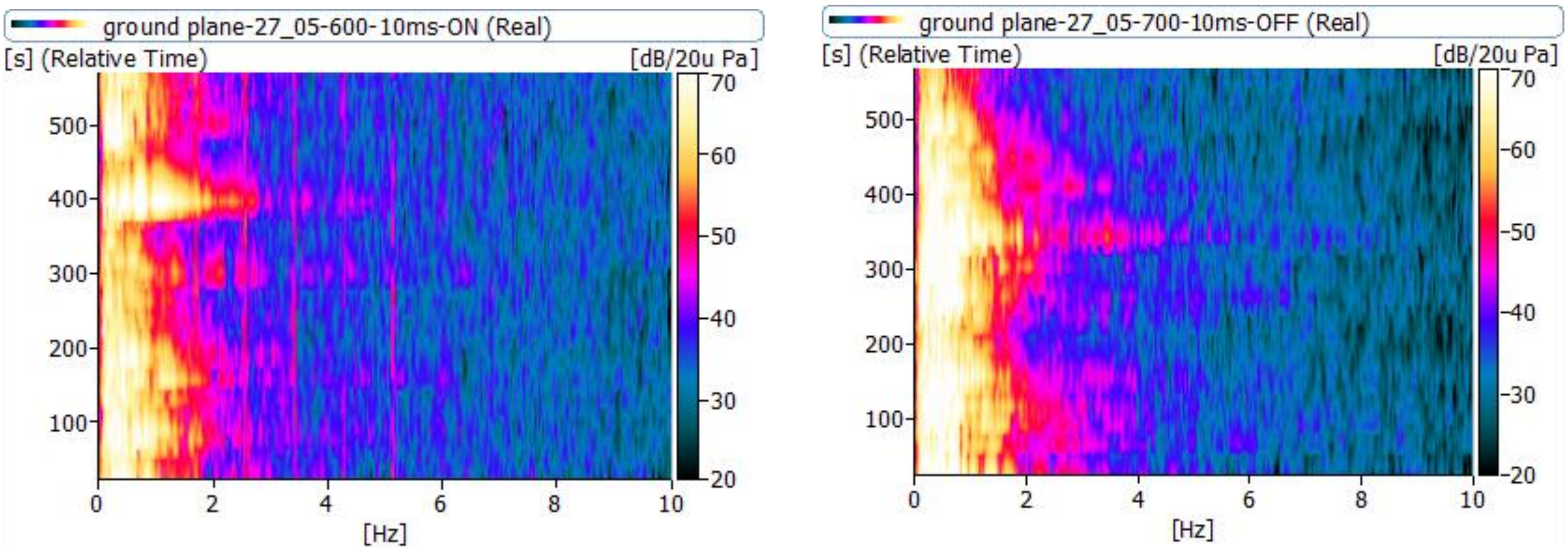


FIGURE 43: House 87 Results Wind Farm ON and OFF – MODERATE WIND

MG Acoustics

Analysis, Modeling, and Prediction of Infrasound and Low Frequency Noise from Wind Turbine Installation

Phase 1: PEI Site

Final Report

Please note that, in accordance with the provisions of the *Access to Information and Privacy Act* these documents have been redacted to protect confidential business information and the identity of study participants.

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Ottawa, Ontario
K1A 0R6

Provided by Canada Health

February 2014

One of the main challenges found in this study related to measurement of wind turbine noise below 100 Hz was separating the wind turbine noise from the ambient background noise. The ambient background noise is comprised of noise generated by man-made sources, such as highway traffic, trains, aircraft, and industry, and by naturally-occurring sources including surf-generated infrasound noise. The separation was only possible when the measured spectra showed the characteristic peaks related to the blade passage frequency as discussed above.

Figure 3 shows noise generated by a wind turbine clearly evident above the ambient background. The red peaks are the infrasonic frequencies between 0.8 Hz and 8.0 Hz produced by the [redacted] wind turbines. They are an example measured by the microbarometer at a distance of 2.5 km during one night. The blue line is the ambient background noise. Observe that the blade passage frequency of 0.8 Hz is just evident above the ambient background noise around this frequency.

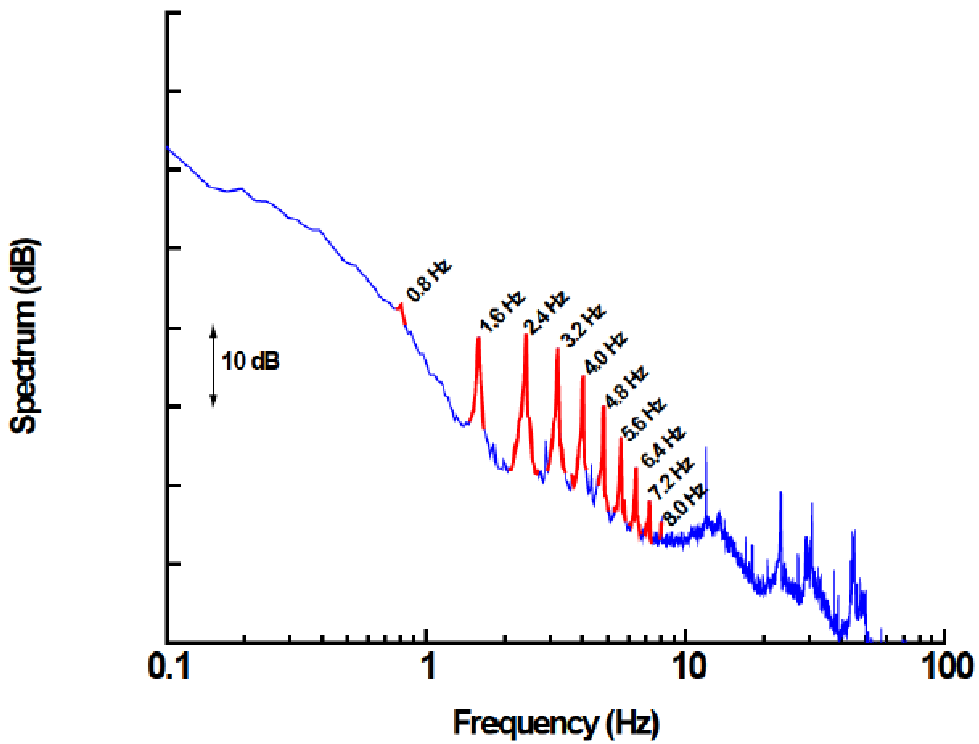


Figure 3. Spectrum measured by the microbarometer at 2.5 km during one night from the [redacted] PEI wind turbines. The red peaks are the infrasonic frequencies generated by the turbines. The blue line is the ambient background noise.

Sensation 5 – worst case scenario

From the resident's diaries there are 441 Sensations classified as severity ranking 4, and 81 as severity ranking 5. A total of 323 Sensation 4 and 5 observations were examined in terms of the wind farm power output to find 194 of the observations fell into the wind farm operation sensation hypothesis proposed in this report (turbine start up, increase in power output of 20%, decrease in power output of 20% and maximum power output). The remainder of the Sensation 4 & 5 events would be either steady moderate winds or changes less than 20%.

Whilst sensations 4 & 5 would normally be grouped for analysis, as sensation 5 is of a level that would make the specific residents in the study want to leave their premises to obtain respite, the following analysis is based on sensation severity 5 and being the absolute worst case scenario. Noting that the degree of time involved in analysing the data for sensation 4 would be significant.

Of the 81 Sensation 5 observations the noise data is missing data for 30 of those results.

In considering the WTS material in relation to Sensation 5, of the 51 remaining wave files, 7 results were not used because when the hub height wind speed was in the order of 18 m/s (or more) the ambient Leq as a result of the wind masked the WTS thereby leading to those samples removed from the analysis.

Similarly for the start/low power sensation 5 the analysis found the blade pass frequency to be much lower than 0.85 Hz and as such did not give the same harmonic frequencies as for higher wind speeds. For the analysis 13 (all) start up sensation 5 results were excluded.

Figure 49 provides a plot of the WTS and 31.5 Hz RMS components from a 400 line analysis for 0 – 50 Hz range for the sampled sensation 5 and a similar sample for sensation 2. Figure 50 are the same results but using PSD as the amplitude of the measured values.

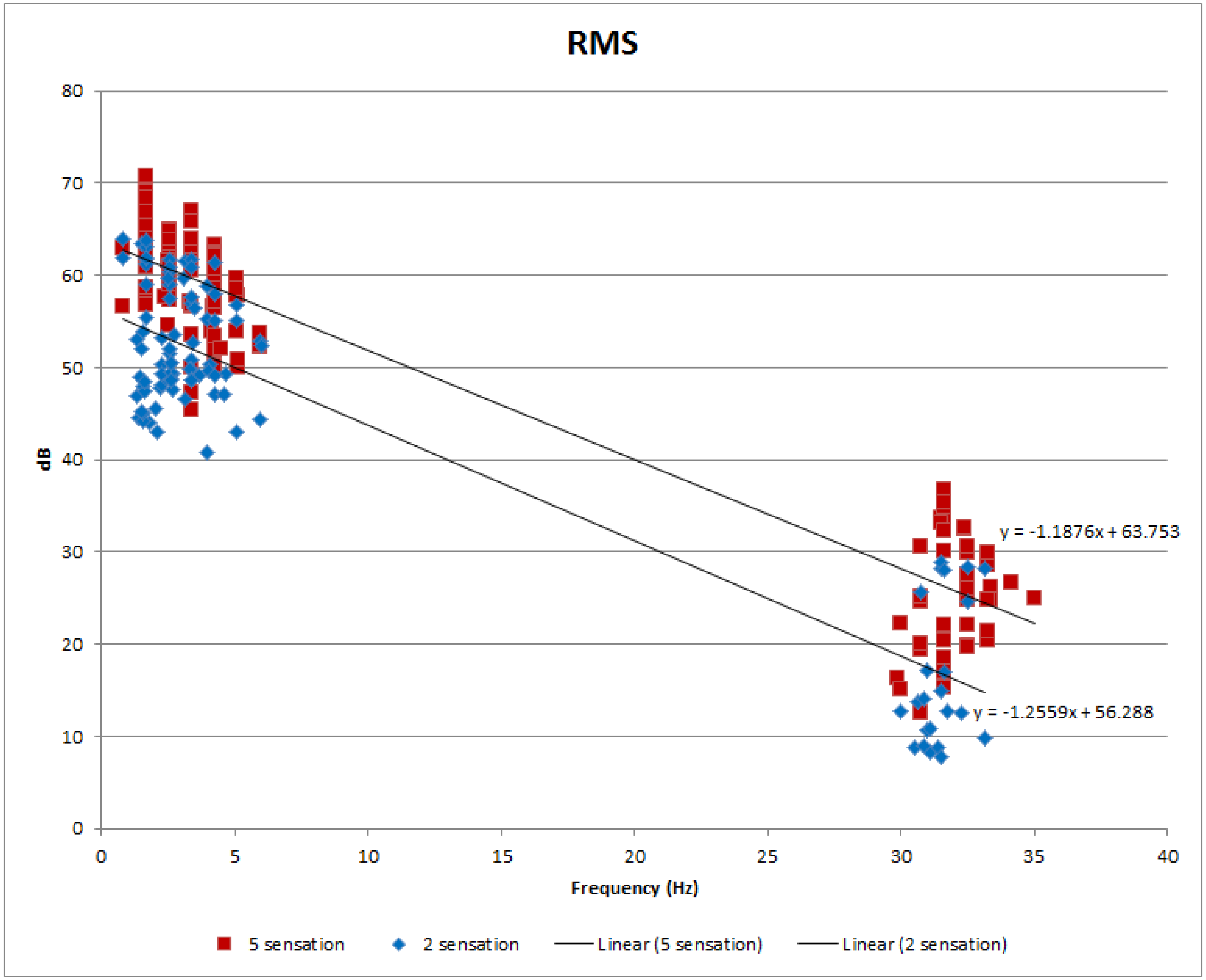


FIGURE 49: WTS and 31.5 Hz RMS components

dB(WTS)

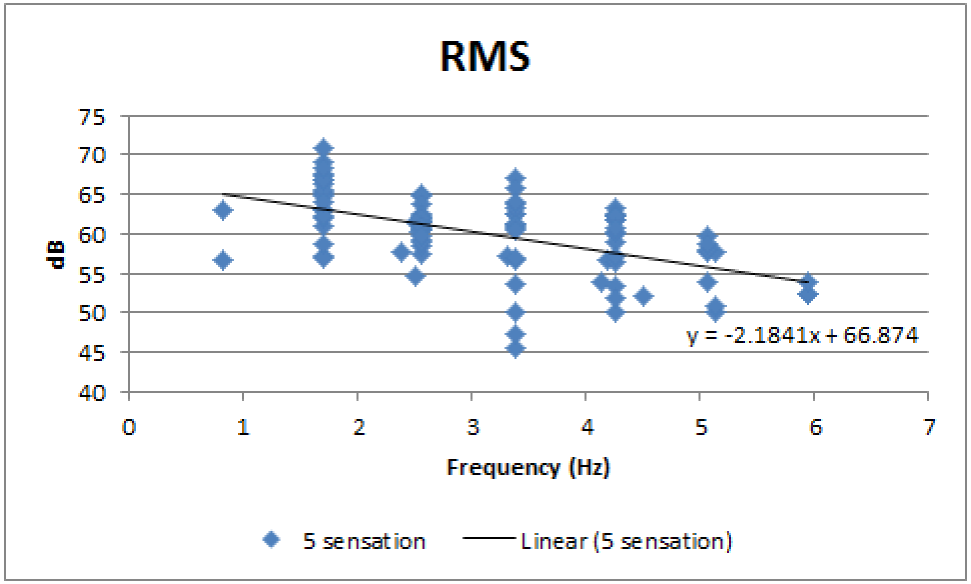


FIGURE 51: WTS RMS components

Harmonic	Blade pass frequency	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
Frequency Hz	0.855	1.71	2.57	3.42	4.28	5.13	5.99	6.84	7.70	8.55	9.41
weighting	-19.97	-18.11	-16.23	-14.37	-12.49	-10.64	-8.76	-6.90	-5.02	-3.17	-1.29

Vibration – outside house 88

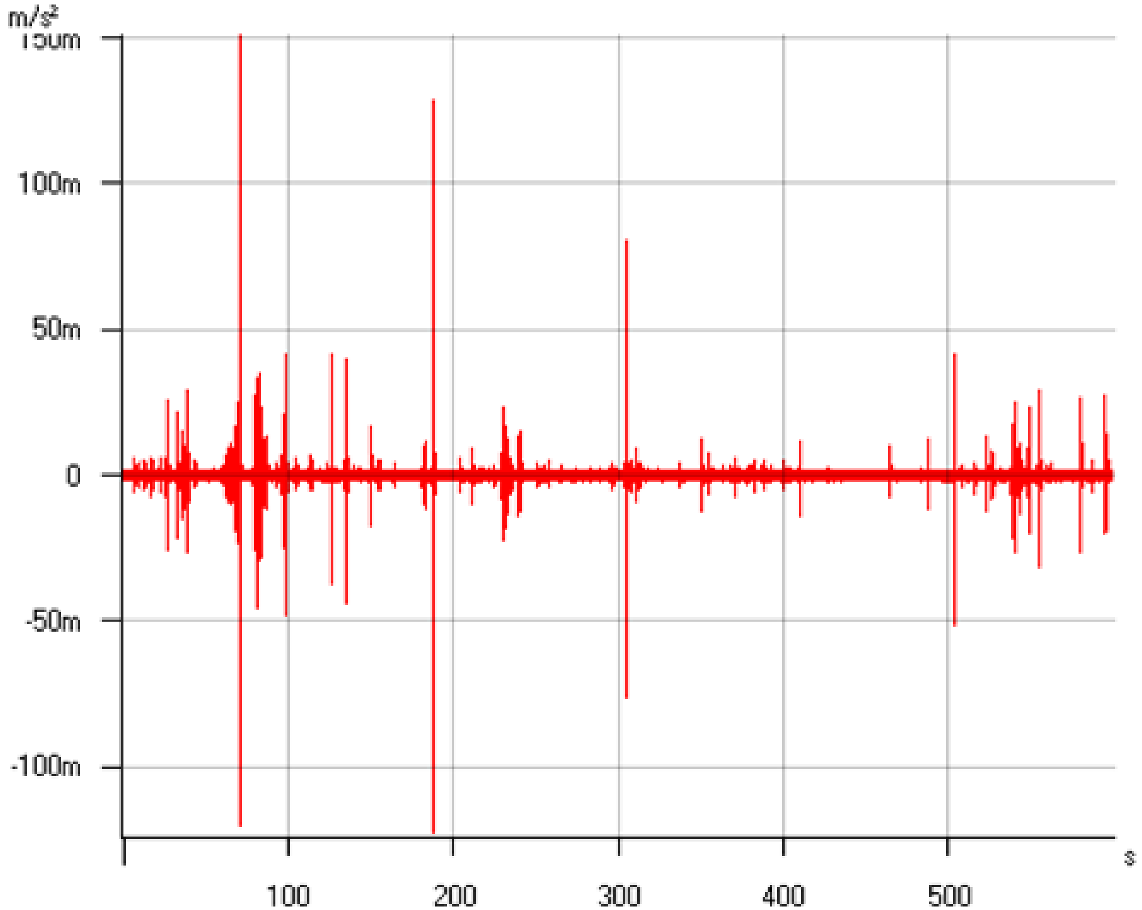


FIGURE 69: Time pulses external to house 8

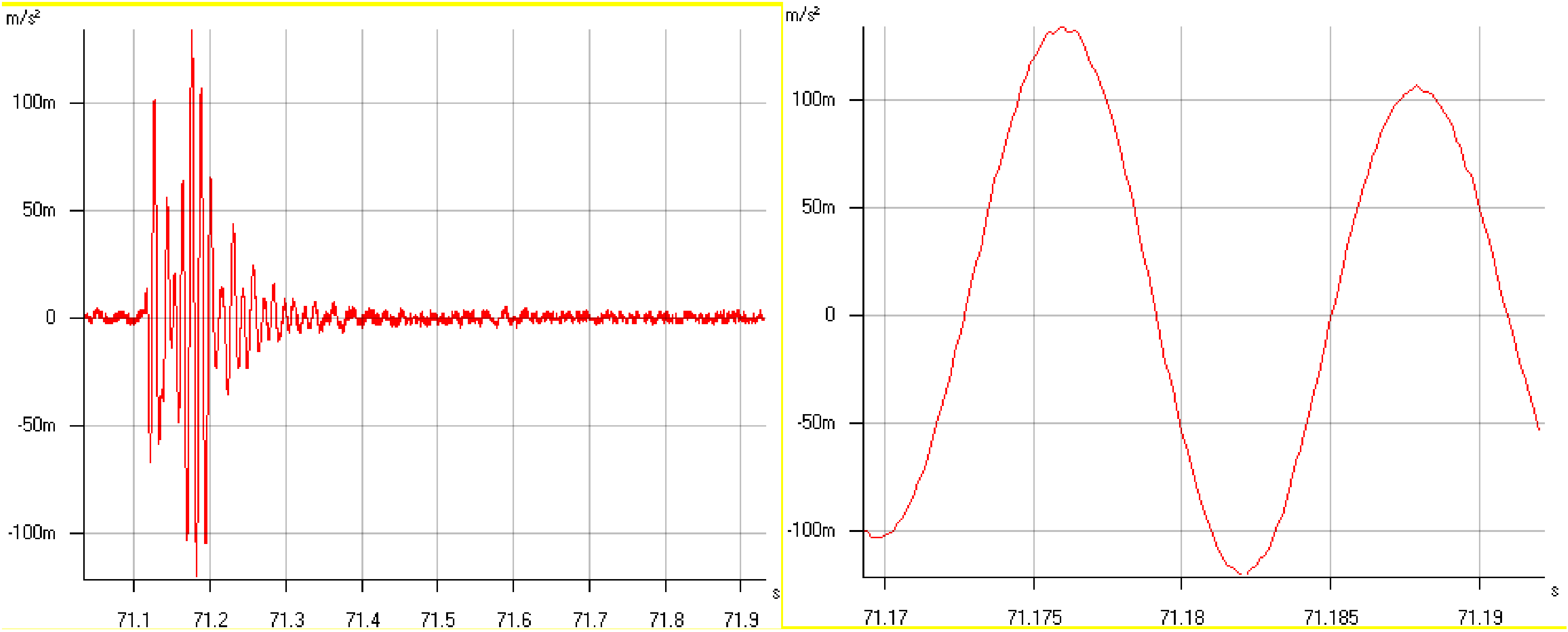
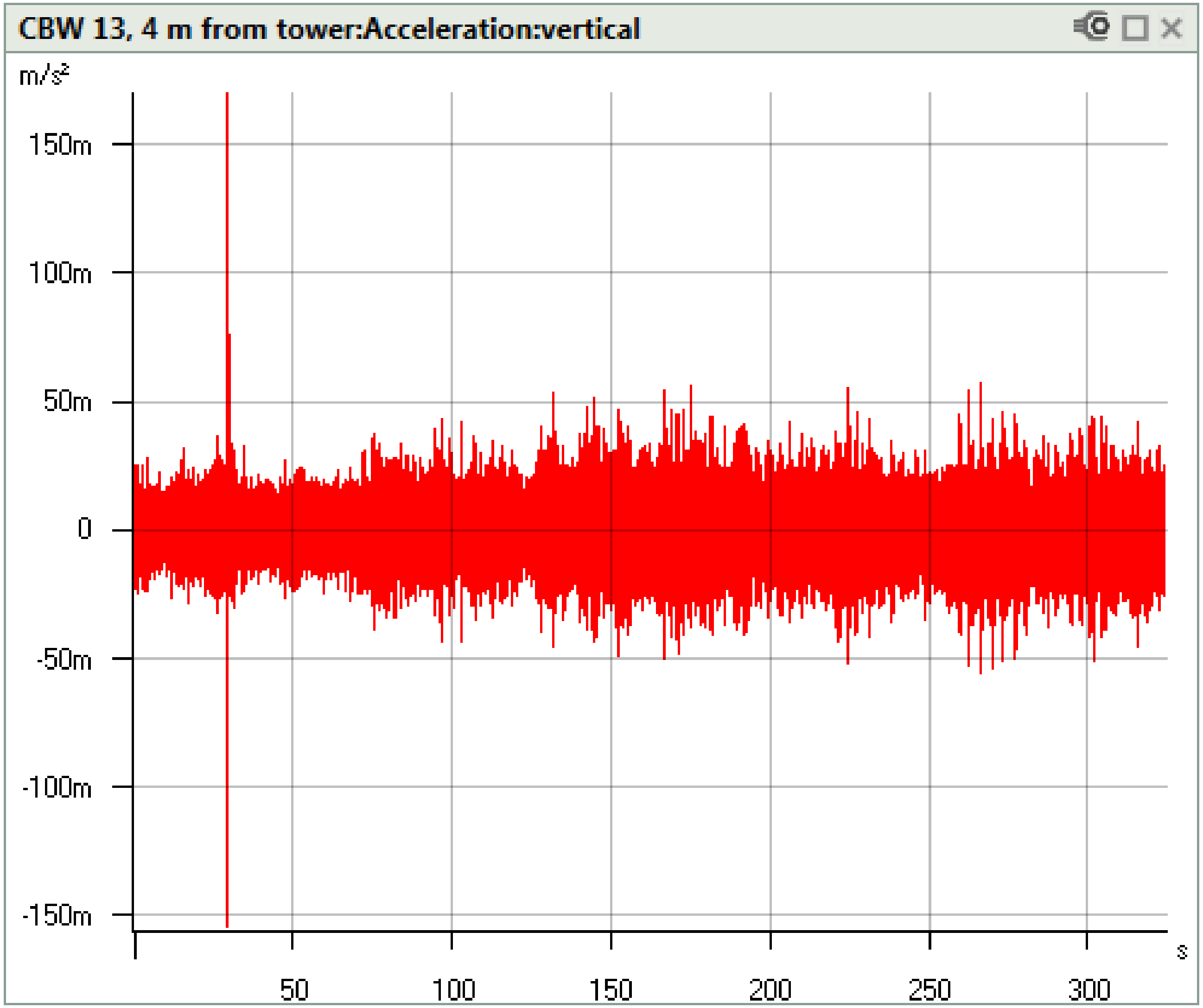
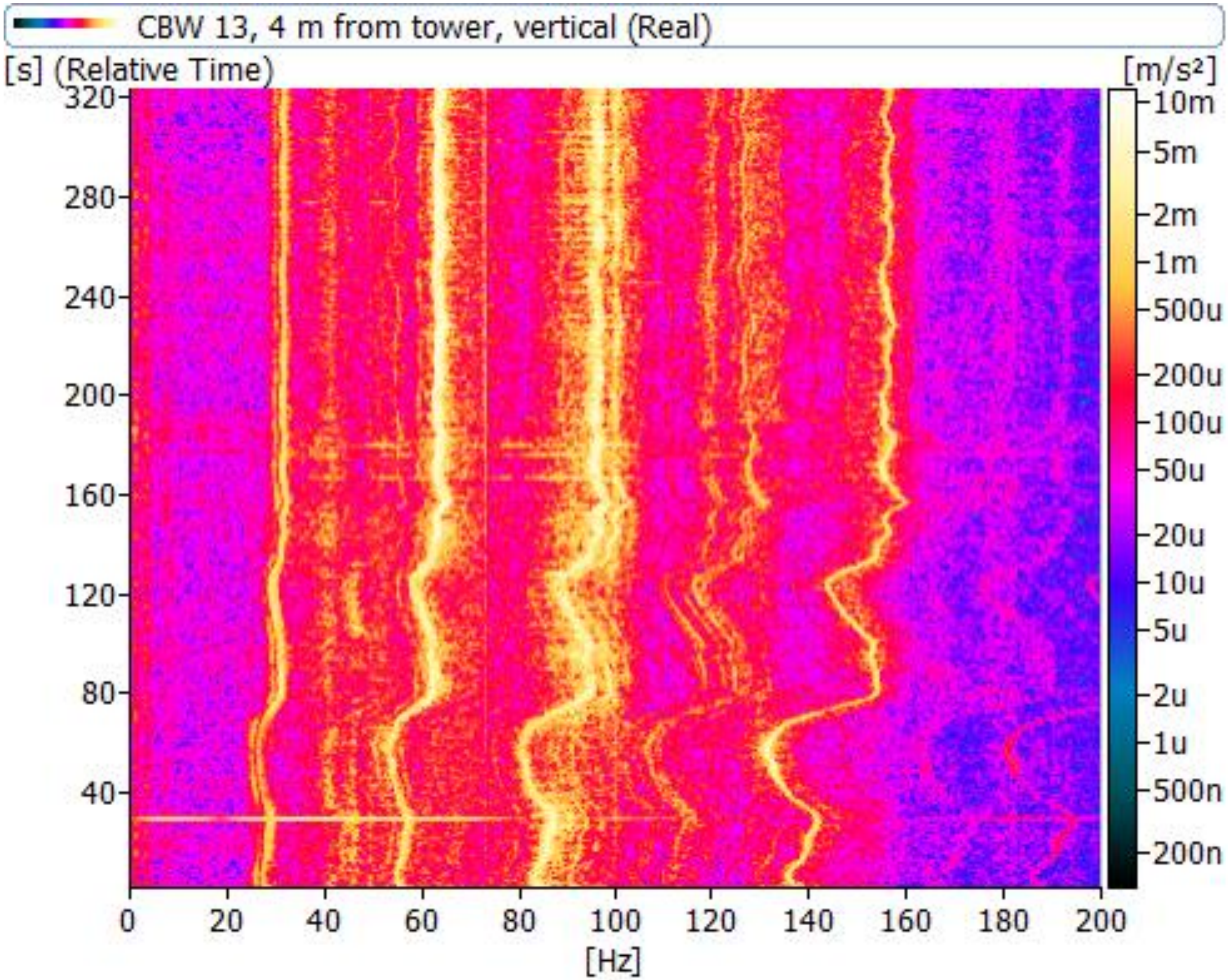


FIGURE 70: Time pulses external to house 88

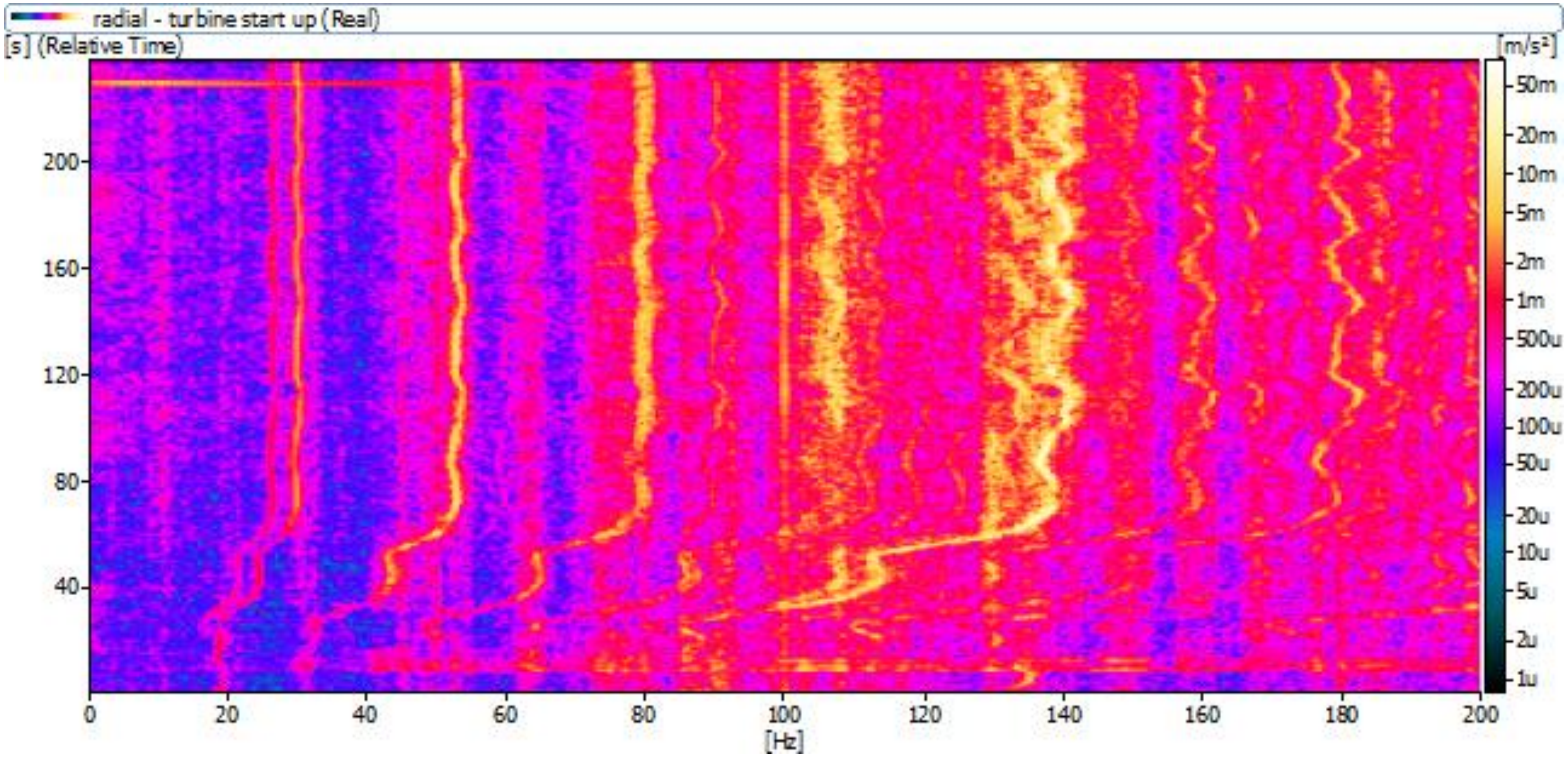


APPENDIX Q68

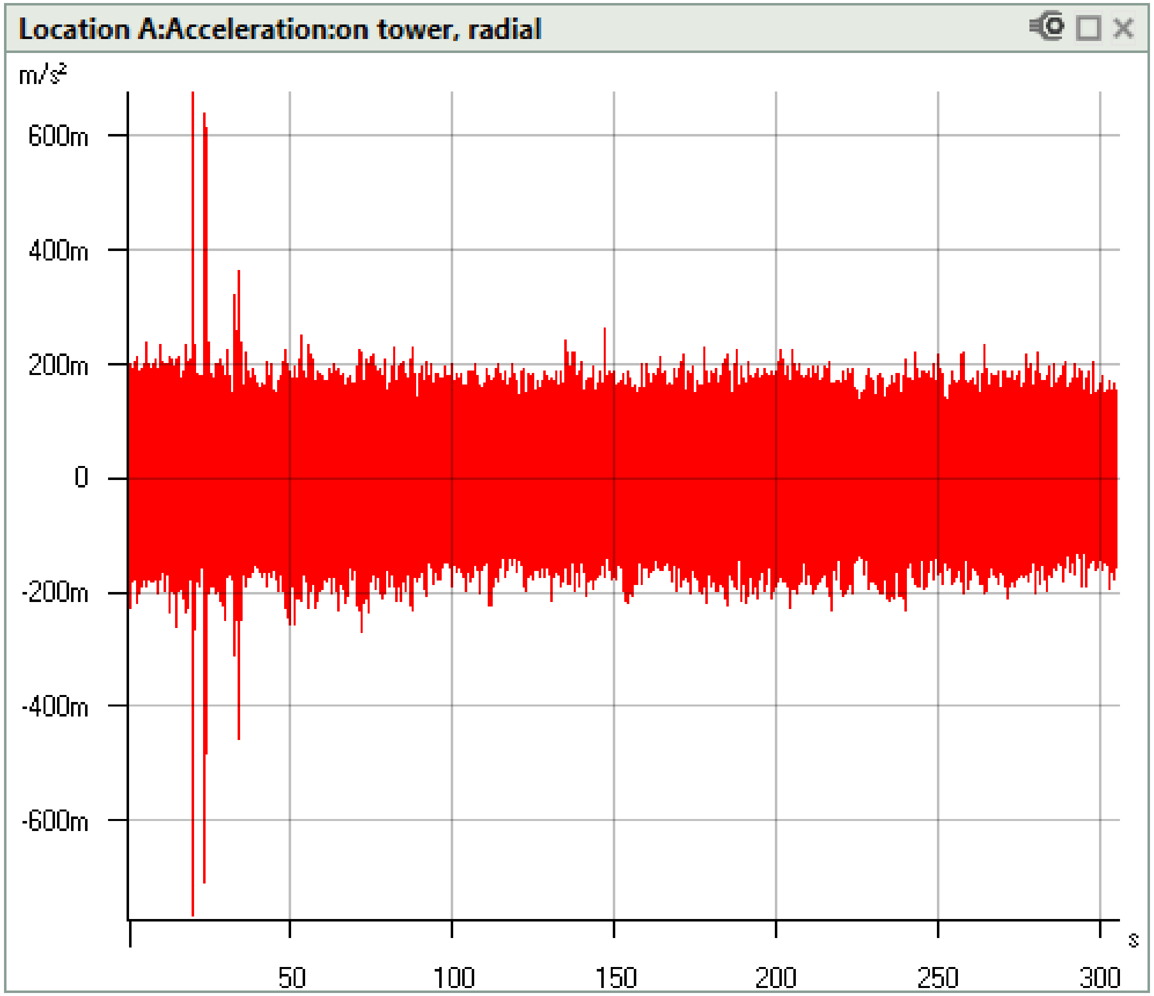


APPENDIX Q70

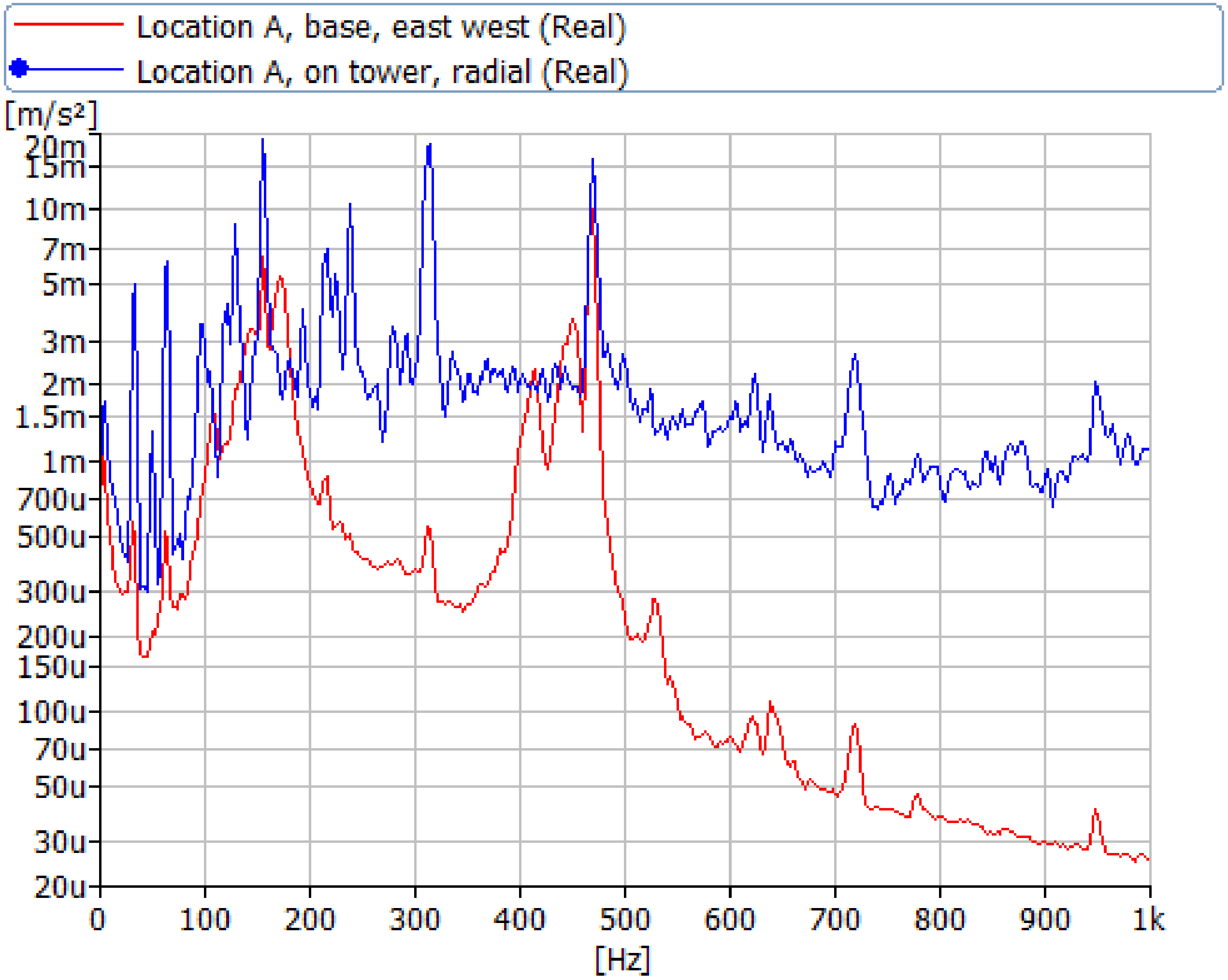
Vibration on tower – turbine start up



Appendix O12


Location A:Acceleration:on tower, radial
m/s²
600m
400m
200m
0
-200m
-400m
-600m
s
50
100
150
200
250
300

APPENDIX R4



Location A, base, east west (Real)
Location A, on tower, radial (Real)
[m/s²]
20m
15m
10m
7m
5m
3m
2m
1.5m
1m
700u
500u
300u
200u
150u
100u
70u
50u
30u
20u
0
100
200
300
400
500
600
700
800
900
1k
[Hz]

APPENDIX R5

Instrumentation Issues

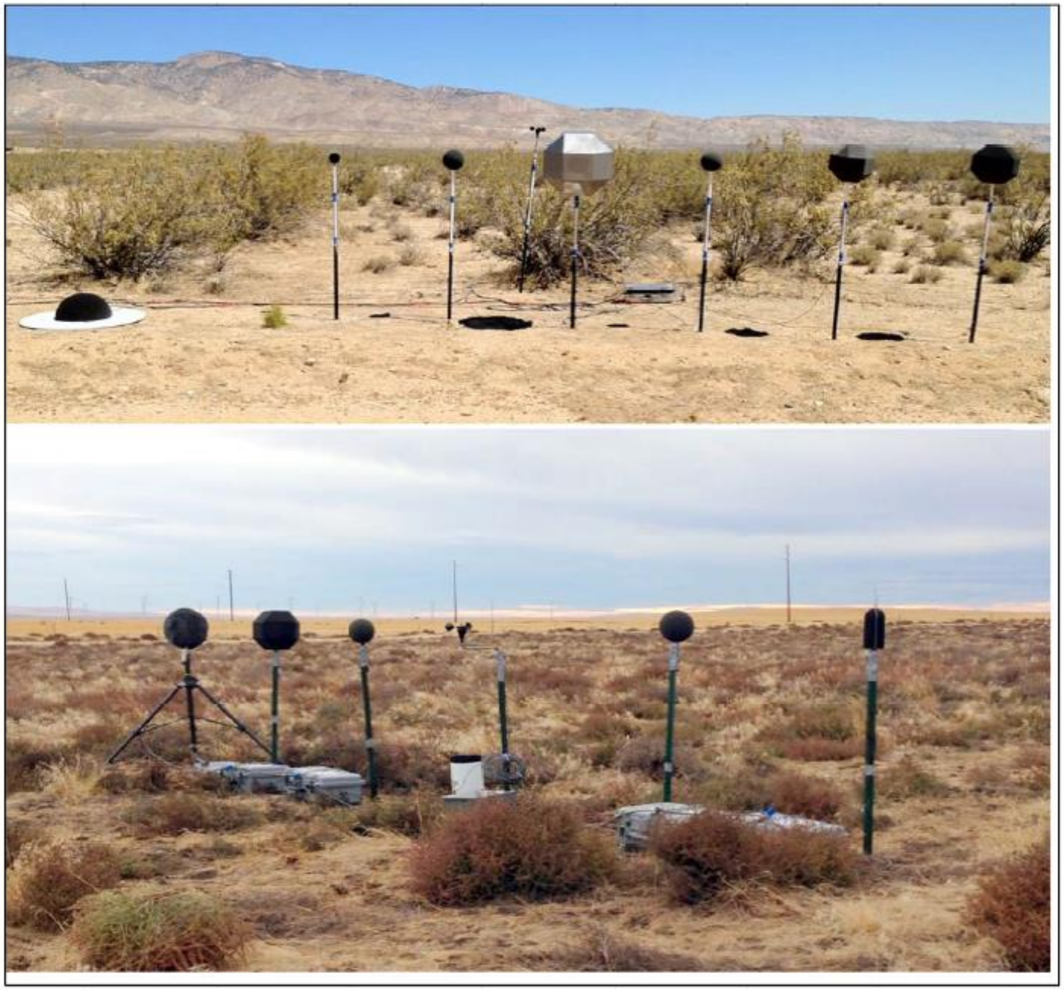


Figure 2 – Wind-induced noise (WIN) measurement set-up; in the Mojave desert (upper image) in California and western Oregon (lower image)

BSR/ASA S12.##-201x

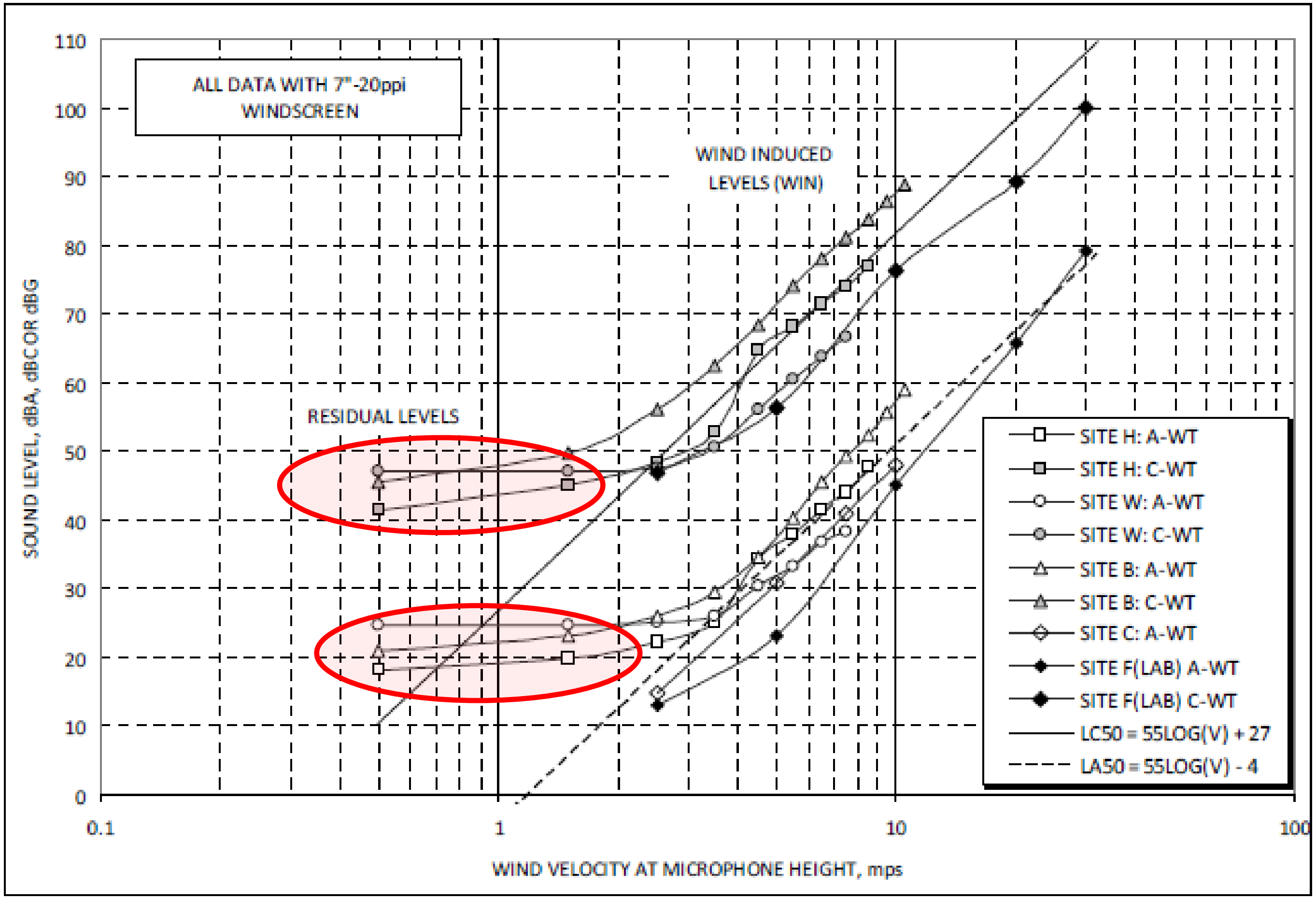


Figure 3 – Measured wind-induced noise levels for a 175mm-20ppi windscreen

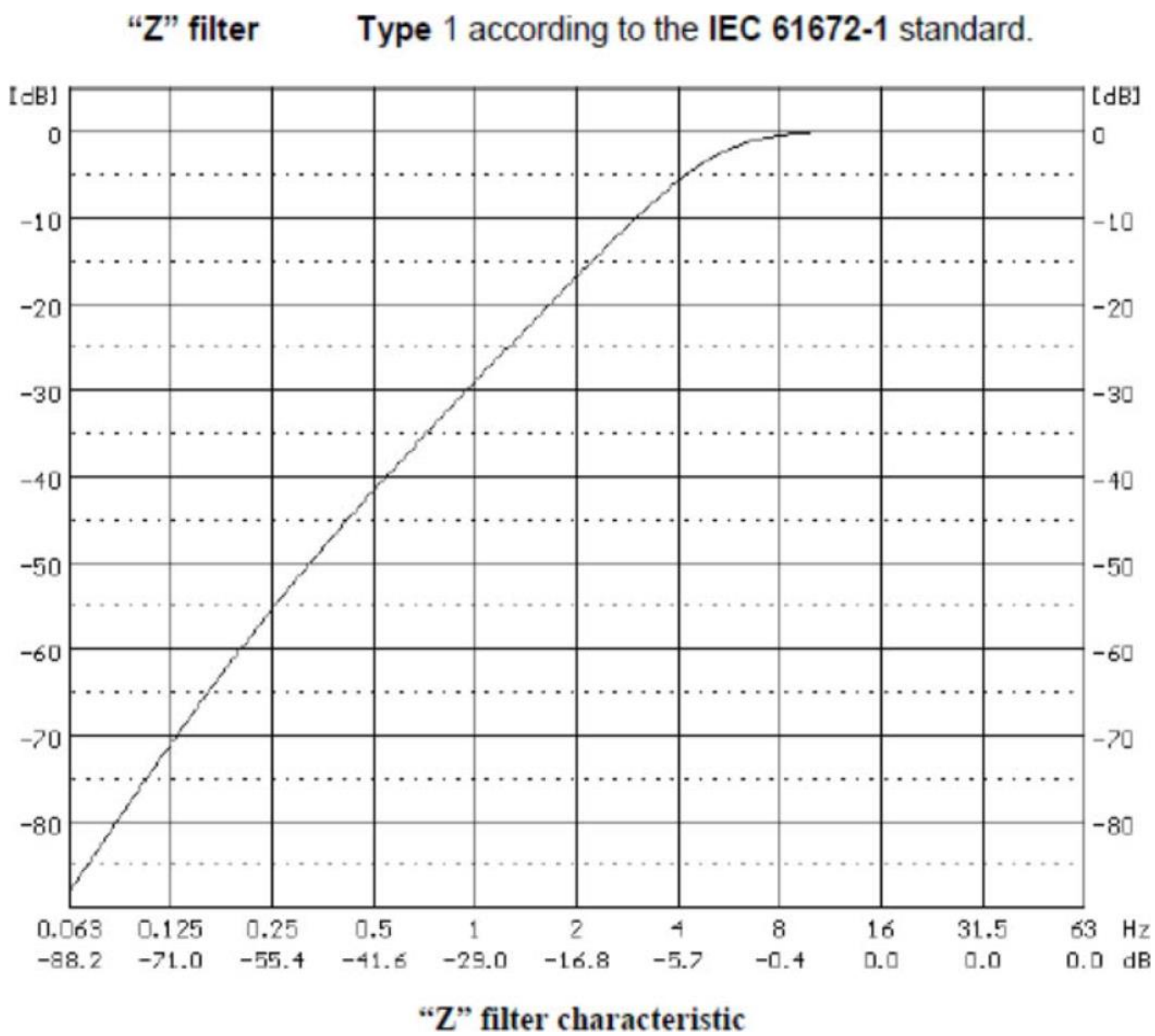
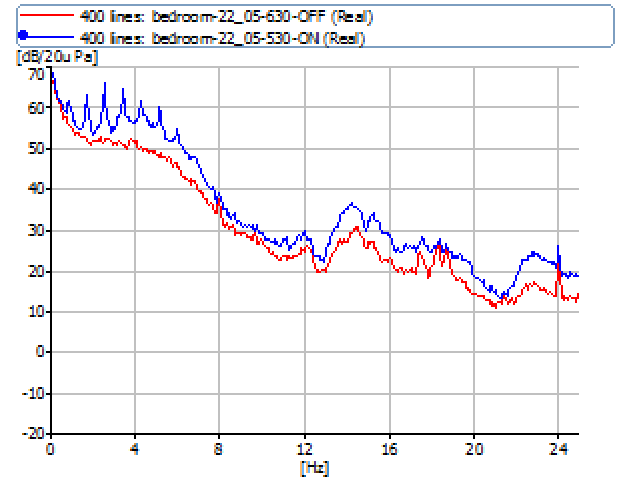
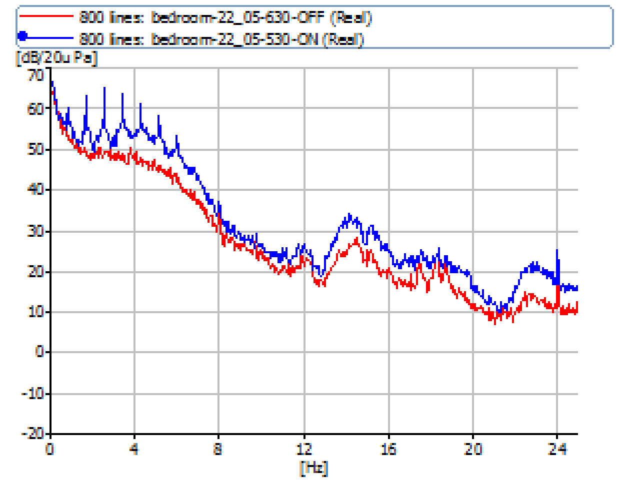
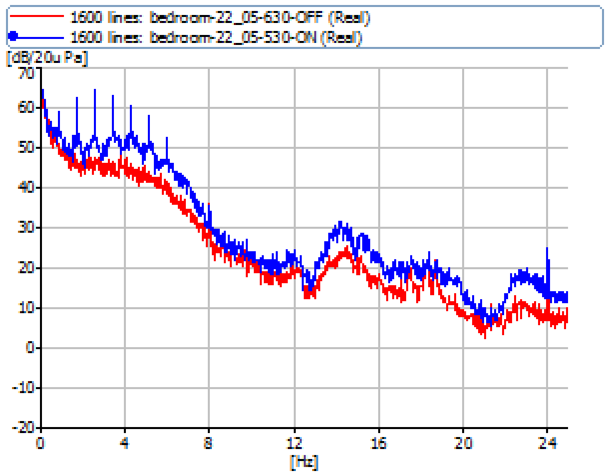


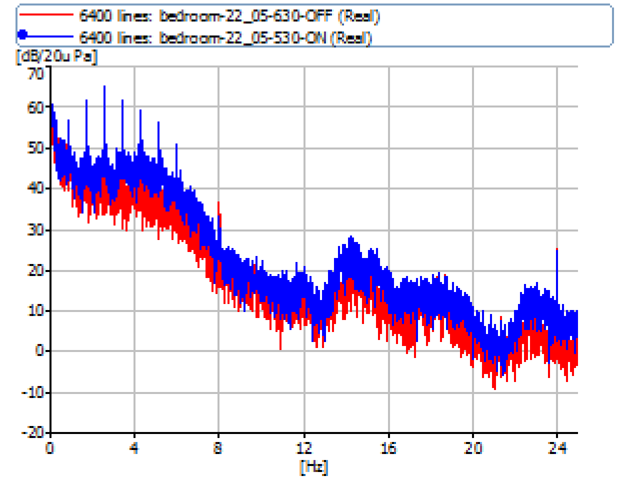
Figure 98: Z filter extracted from the SVAN 979 manual

Narrow band results – number of lines









APPENDIX N41

Viewing Infrasound Data

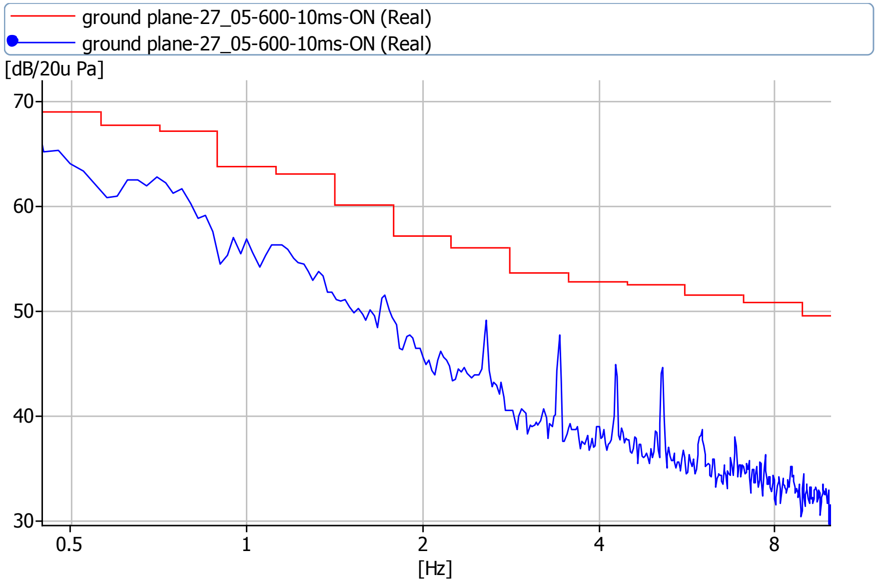


FIGURE 102: 1/3 octave and narrowband RMS levels in constant percentage bandwidths

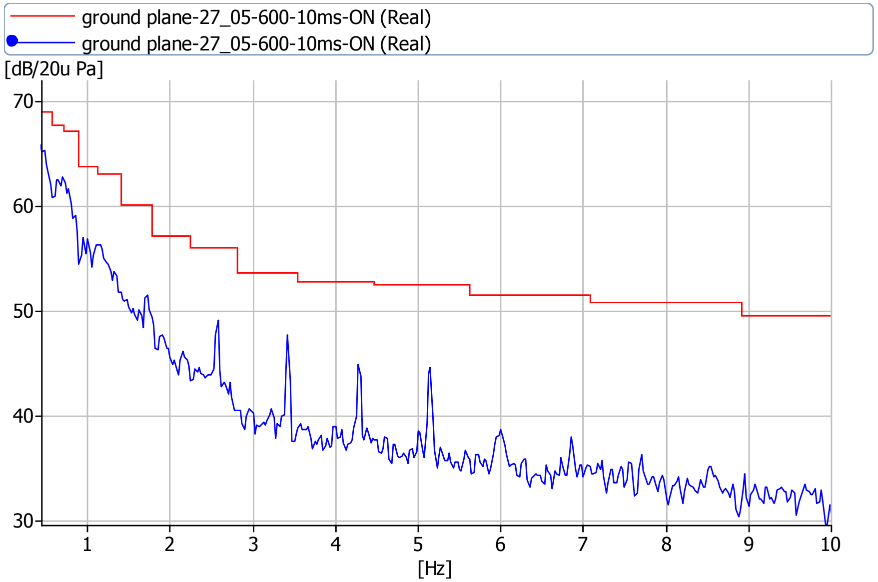


Figure 103: 1/3 octave and narrowband RMS levels in linear frequency domain

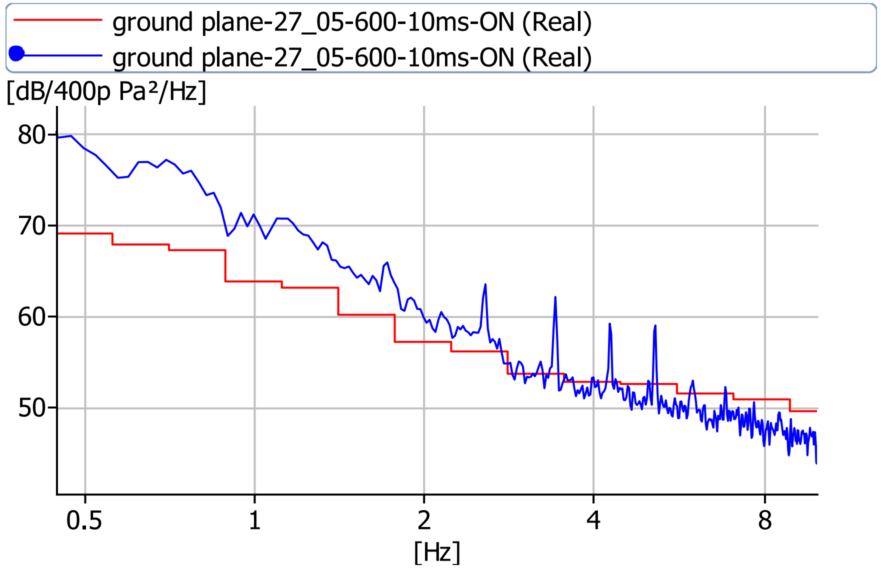


Figure 104: 1/3 octaves in RMS levels and narrowband in PSD levels

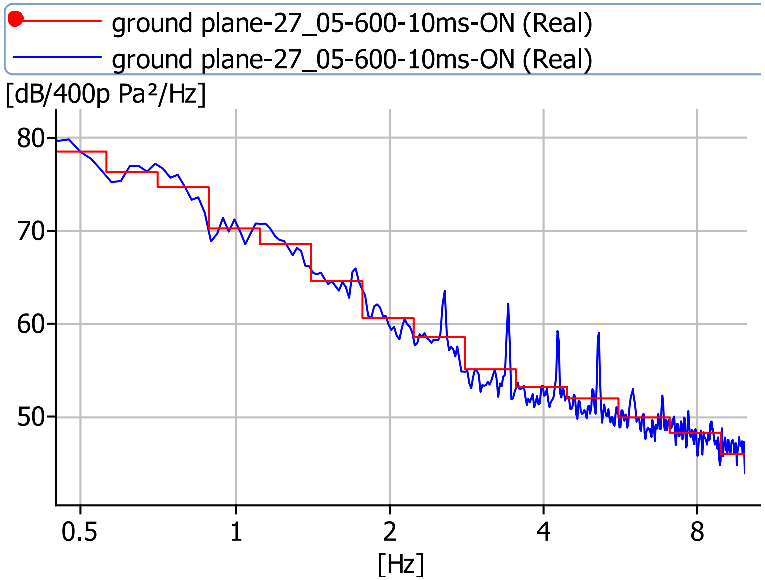


Figure 105: 1/3 octaves and narrowband in PSD levels