INNOVATING NOISE MANAGEMENT: HOW CAN LOW-TECH THINKING IMPROVE THE YIELD FROM HIGH-TECH MANAGEMENT TOOLS?

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Abstract

While increasingly sophisticated methods have been developed to interpret remote and real-time monitoring of industrial noise levels, constraints around automation of these analytical methods remain. The optimisation of real-time noise management is constrained by differing stakeholder comprehensions of the role that technology plays in noise monitoring, and the role that noise monitoring plays in noise management.

A high level review of typical noise monitoring and management practices was undertaken to identify potential barriers to optimisation, and identify assumptions that may prevent the integration of emerging monitoring technologies and historical analysis methods.

Several case studies are presented to demonstrate how the design and implementation of hi-tech tools (remote, automated noise monitoring systems) can be enhanced through the integration of relatively simple (low-tech) logic, to leverage better outcomes for noise management.

It is hoped that assumptions pertaining to the deployment of conventional analysis methods into a technology and management environment that pursues autonomous manipulation of large datasets can be challenged, validated or better documented.

1. Introduction

The mining boom of the early 2000's established a development and regulatory environment that encouraged rapid change in the ways that industrial noise is monitored (and thus managed) in NSW. Improving communication technologies provided a foundation for remotely managed continuous noise monitoring programs, and increasingly robust computing and sensor hardware ensured that more data was available more quickly, to more stakeholders. Similarly, with increasing computational power and decreasing IT infrastructure costs, noise modelling software enables complex calculations to be completed in less time and at greater resolutions than previously available.

While increasingly sophisticated methods have been developed to interpret remote monitoring data – including the integration of predictive and measurement based approaches, constraints around automation of these analytical methods remains.

Most continuous or real-time monitoring technologies observe and report on a vast array of noise metrics, which provides end users with great flexibility in the data that can be obtained. However, the broad deployment capabilities and high quality of data returned by these systems means that they are often simply used as a hi-tech logging device, rather than being established in such a way to obtain feedback on a specific environmental management challenge.

On this basis, the optimisation of new monitoring technology is constrained by confusion about monitoring objectives, poorly understood trade-offs with regards to benefits and limitations, and undocumented assumptions about the transferability of methods.

Contemporary noise assessment increasingly takes the form of a hybrid implementation of well documented and proven analysis methods (old-tech) that simply utilize new (hi-tech) monitoring (or modeling) tools. The prevailing view (which is embedded in regulation), assumes that proven methods can be applied to the higher quality (or quantity) data acquisitions that new technologies provide, thus allowing the existing robust assessment processes to be applied to larger and larger data sets.

Challenges to this prevailing view occur when application of old-tech methods fail to yield outcomes that match the hi-tech hype. Given that existing methods have been well tested and proven, stakeholders often identify these challenges as deficiencies in the new technology, rather than the way in which it is used or the assumption that the full range of technological benefits can be realized with existing methodological approaches. While opportunities exist to explore gaps in methodological approaches, that the existing methods are embedded in regulation helps to maintain the inertia held by historical monitoring and management practices, and creates a barrier to innovation in this area.

In recognition that these challenges arise (in part) from limited technical documentation pertaining to the integration of available noise management tools, a program of works was commissioned to identify and address potential limitations of Integrated Noise Management (INM) practices. This program of works seeks to utilise measurement, modeling, data visualisation and mapping tools to undertake integrated assessment of the rural Soundscapes influenced by industrial and transportation noise. The intent of the program is to explore and document those factors that may discourage synthesis of information from all available management tools, and focus on those aspects that may yield practical findings that can be readily implemented by stakeholders.

For the purposes of this review, noise management stakeholders might include regulators (involved in compliance and enforcement, rather than strategy or policy development), individuals working in roles involving site based noise management, and acoustic scientists or engineers. The tools available to assist with noise management implementation may be either tangible (monitoring or modeling tools) or intangible (risk assessment methods and management systems).

2. Methodology

This paper focuses on reviewing some alternative ways in which tangible tools may be used to leverage better management outcomes. Specifically, the research considers the ways that low-tech thinking may be applied to hi-tech tools to understand why the benefits of technological advances are not being fully realized.

In this context, 'better' outcomes are considered in terms of being able to demonstrate congruence between the results of old-tech (e.g. attended noise monitoring) and hi-tech (e.g. noise modeling or real-time monitoring) assessment methods, or by contributing to better understanding of the reasons that results obtained via these different methods may diverge. To communicate some of the findings to date, several short case studies are presented, including:

- How can we exclude extraneous wind noise effects from unattended real-time monitoring data?
- How can noise levels vary when conditions are calm?
- Is the instrumentation broken? An exploration of differences in monitoring response.

The case study titles are intentionally framed as questions, because this is often the way that monitoring and management queries are typically framed by stakeholders working at the implementation and innovation coalface. It also serves to demonstrate that an effective research program can be driven by simply asking questions about assumptions that have been adopted without significant challenge.

For the purposes of these case studies, the 'significance' of any findings is evaluated in the sense that the potential impact of the assessment practice is greater than the typical uncertainty envelope (+/-0.5dB) of environmental monitoring practices undertaken using instrumentation that is compliant with accepted international standards [1].

3. Results

3.1 How can we exclude extraneous wind noise effects from real-time monitoring data?

One of the most significant benefits of improved communication and computing technologies to noise management is the potential to measure and report noise levels in near-real time, thus enabling operations to adaptively manage their activities based on prevailing conditions and a real-time feedback. Despite the significant gains that this technological innovation has provided to the management of mining noise in NSW and Queensland, systems remain subject to significant constraint where contributions from target sources cannot be effectively filtered from ambient environmental noise.

In environmental noise measurement, extraneous noise may take the form of transportation (road, rail or air), natural (birds, insects, barking dogs), meteorological (gusting wind or thunder) or domestic (localized vehicle movements) sources. Previous review suggests that the inability to exclude extraneous noise represents the single greatest constraint to real-time management of industrial noise impacts [1]. It is accepted that further innovation in monitoring and measurement technologies will undoubtedly yield some gains; however, significant potential for immediate improvement may be derived from relatively low-tech efforts that seek to exclude extraneous noise from entering the measurement chain, rather than through development of increasingly high-tech methods for removing it after it has already been embedded in the measurement data.

In currently unpublished assessment [2], a simple field monitoring experiment was established to compare the range of Sound Pressure Level (SPL) results from side-by-side microphones (equipped with 4” and 7” windshields) over the course of several days. Simultaneous wind speed monitoring was undertaken at microphone height, and analysis of resulting SPLs under different wind conditions provided some insight into the effect that windshield diameter may have on the exclusion of extraneous wind noise. A schematic of the monitoring arrangement is provided in Figure 1, while a sample of results is provided in Figure 2.

Analysis of measured SPLs suggested that there was a statistically significant ($p<0.05$) difference in measured noise levels at wind speeds greater than 0.4m/s, indicating the 7” windshield returns measurement results approximately 0.5 to 1.0B(A) lower than the standard 4” windshield. Analysis of C-wt SPLs suggested that reduction of 0.5to 5.5 dB(C) may be returned.

In this sense the impact of this low-tech practice may be significant, as it has potential to effect changes of more than 0.5dB in monitoring results, and hence would decrease measurement uncertainty by a factor greater than the typical uncertainty envelope (+/-0.5dB) for environmental noise assessment.

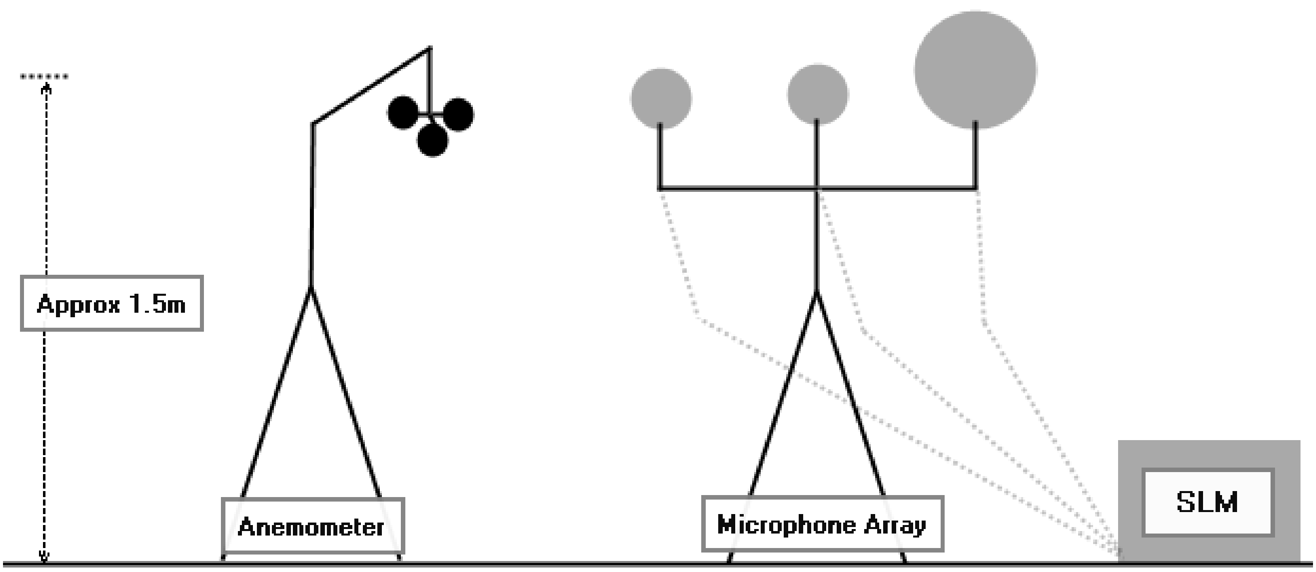


Figure 1: Monitoring arrangement schematic (SLM is Sound Level Meter)

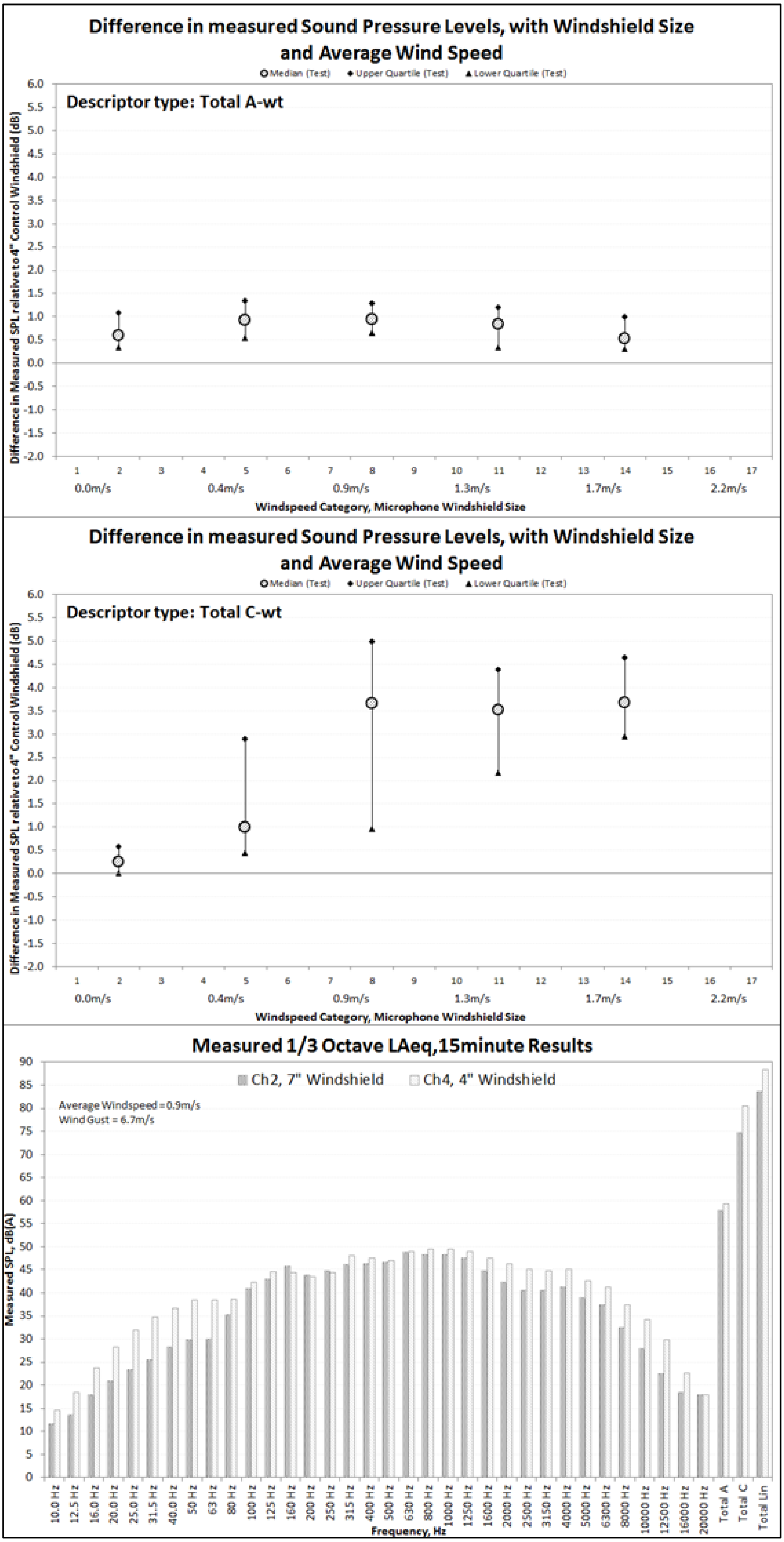


Figure 2: Analysis of SPL variability for various windshield configurations and wind conditions

The results also suggest that use of the larger windshield may yield a more accurate representation of the spectral characteristics of the industrial noise contribution, which may improve the performance of any narrow-band metrics that are used to evaluate specific source contributions.

This may be of particular significance to the real-time identification of a specific source contribution, where the source is identified not from the overall noise level, but on the basis of the relationship between multiple measurement results.

3.2 How can noise levels vary when conditions are calm?

Decades of research has established a significant body of literature describing the factors that induce variation into the way that sound propagates in the environment. In the applied domain of environmental noise assessment, this body of knowledge is typically utilised in the sense that it assists stakeholders to explore those factors with potential to *most significantly* influence noise propagation.

Regulatory driven environmental noise assessment typically mandates that the influence of several key variables such as topography, wind conditions, temperature gradients and plant Sound Power Levels (SWL) be considered when evaluating the propagation of potential noise pollution. Where emerging technology makes it more practical to explore the sensitivities of noise levels to these variables, an understanding of the uncertainty envelope under real world conditions can be built.

While new technologies and assessment methods will undoubtedly improve the way in which environmental noise assessment is carried out, implementing these methods only with regards to historical practices or the prevailing regulatory framework should be cautioned against. A new generation of technology provides not only an opportunity for iterative improvements, but may also allow us to challenge the assumptions that have historically defined best practice.

Changes in monitoring technology mean that SPL observations can be obtained over longer time domains, and under a greater variety of conditions than historical monitoring methods. This means that stakeholders are required to interpret monitoring results obtained under a wider variety of environmental and operational conditions. This will require a broader understanding of all of those variables that may influence noise propagation in order to effectively validate or contextualise monitoring data.

For the purposes of demonstrating the scope and potential opportunities in this applied area, we look beyond those factors that are known to *most significantly* affect noise propagation, and explore the uncertainty envelope of some of the factors known to be of less significance; the impact of changes in atmospheric absorption associated with changes in Temperature and Relative Humidity (RH). The intent of this research is not to challenge the assertion that temperature and RH are less significant factors than (for example) wind conditions, but to understand whether they may be of *sufficient significance* to warrant consideration in the context of contemporary noise assessment, and specifically in the context of the technologies that are now available.

To facilitate this exploration, a simple model was constructed within Microsoft Excel to calculate the range of received SPLs associated with the operation of a typical item of mining plant (Haul Truck), at a distant receiver location (4,000m from the point of emission). The simple model was constructed to account for losses over this distance that may be attributed to geometric spreading and atmospheric absorption as defined in ISO9613 [4].

Several sets of 15 minute average meteorological observations (temperature and RH) from monitoring locations within NSW and Queensland were loaded into the model. The assumed SWL and separation distance between source and receiver were established as constants in the calculation, and the only factors subject to variation were the temperature and RH input data. These calculations were used to evaluate the variation in attenuation due to atmospheric absorption (and hence the variation in resultant SPLs at the receiver location) over time (Figure 3).

From the set of modelled 15 minute average SPL data, analysis was undertaken to explore the potential variation in received noise levels over the course of a night period (from 18:00 to 07:00) that may be reasonably attributed to only changes in temperature and humidity. The range of SPL values (max SPL - minimum SPL) was then calculated for each night in a 3 month assessment period (Autumn, 2014), and further analysis of aggregated data was then undertaken to document the distribution of results (Figure 3).

It is considered that review of this aggregated data may contribute to the potential definition of an uncertainty envelope for temperature and RH effects, and hence contribute to understanding of the significance of this as a variable in validating environmental noise monitoring data, or resolving differences between measurement and modelling data.

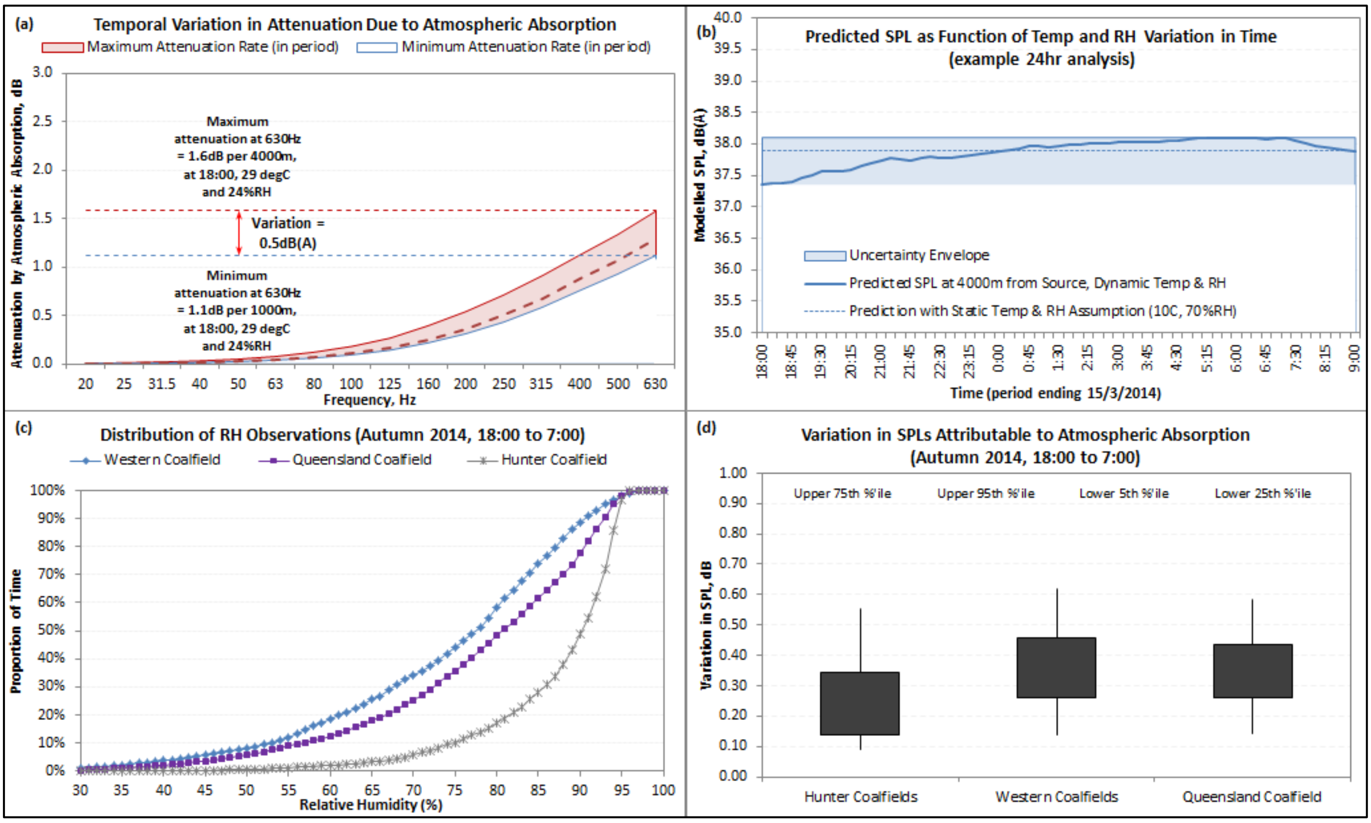


Figure 3: Modelled impact of Temperature and RH on sound propagation. Upper left (a) shows the calculated variation in 1/3 octave attenuation rates (dB/km) that may be experienced due to changes in temperature and RH over the course of a typical night (18:00 to 7:00); upper right (b) shows the resulting impact on variation in SPLs (uncertainty envelope) at a receiver located 4,000m from a typical mining source (Haul Truck). Lower left (c) plots the ranges and distribution of RH over the course of 3months at monitoring locations in the Hunter, Western and Queensland coalfields. Finally, lower right (d) aggregates the analysis (92 days) of diurnal differentials in SPLs, as a means of documenting the variation in sound levels that may be attributed to changes in temperature and RH.

Results of the analysis (Figure 3b) indicate that there is likely to be regular variation in SPLs over the course of a night (or at any other time when temperature and RH vary over time), at distances representative of typical separations between mining operations and adjacent sensitive receiving environments. While there is variation (Figure 3d), it does not appear to be 'significant' in the sense that the variation is greater than the uncertainty envelope (+/-0.5dB) of typical environmental monitoring practices.

While the aggregate analyses suggests that the temperature and RH uncertainty envelope may not exceed the existing uncertainty envelope for typical environmental noise monitoring methods, this information remains of interest as it may contribute to improvements in the contextualization of monitoring data where the cumulative impacts of multiple excess attenuation factors or sources of temporal variation are observed.

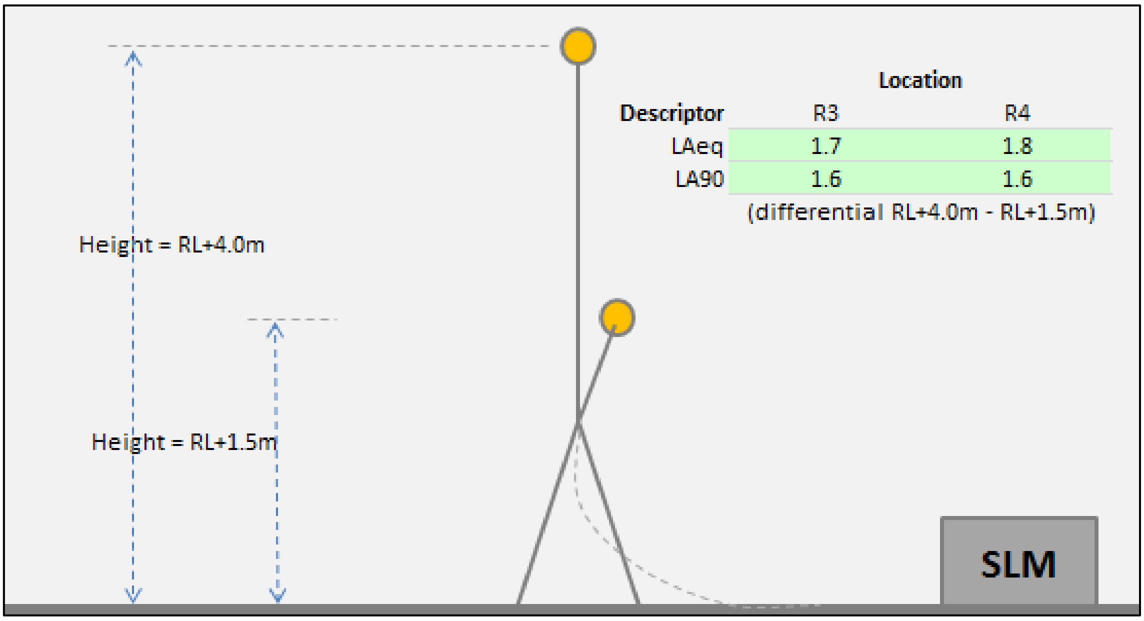
3.3 Is the instrumentation broken? An exploration of differences in monitoring response

A series of project was undertaken throughout 2014 and 2015 to confirm that remote monitoring systems throughout the Hunter and Western Coalfields were performing to the intended specification. This was commissioned following reports of divergence between compliance monitoring results and real-time data, and sought to confirm that remote monitoring systems were not malfunctioning.

Through this process of data collection and assessment, key insights were obtained into some of the factors that may be driving the divergence in measurement results. While contributing to this divergence with varying levels of significance, these factors were found to include: poor synchronisation of sample intervals, application of different sampling rates, use of different descriptors, and differences in measurement height.

Following this, a case study was developed to demonstrate the ways in which one of these factors – a difference in measurement height – may challenge the validation of continuous noise monitoring systems response. The Case Study presents assessment of the noise environment within Camberwell Village in the NSW Hunter Valley. Camberwell Village is located in a complex noise environment, subject to potentially cumulative impacts of multiple open cut mining and coal processing operations, plus major road and rail corridors. These factors have contributed to challenge the effective use of remote management technologies.

Continuous and remote monitoring systems typically utilise an elevated microphone position in order to return measurements representative of the broader environment in which the system is established. Conversely, standard methods dictate that operator attended noise monitoring (particularly where undertaken for compliance assessment) should observe noise levels at the point most representative of exposure at the location under assessment. This means that continuous monitoring systems may typically observe SPLs in the range +3.0m to +5.0m above ground level, while attended monitoring results may return measurement data for the noise environment only +1.5m above ground level (as the schematic in Figure 4 denotes). Under certain circumstances, this means that the two measurement methods may actually be observing very different noise environments.



	Location	
Descriptor	R3	R4
LAeq	1.7	1.8
LA90	1.6	1.6

(differential RL+4.0m - RL+1.5m)

Figure 4: Results of noise monitoring indicating that differences in measured SPLs may be returned when measurements are obtained at different heights (image not to scale)(SLM: Sound Level Meter).

To understand how this may challenge validation efforts (or more broadly, general noise assessment) in a location such as Camberwell Village, short term operator attended noise monitoring was undertaken between approximately 19:00 and 21:00 on the evening of 13 March, 2015. Monitoring was undertaken using 2 channels of a Svantek958 (S/N:20777) multi-channel analyser; one microphone was mounted on a tripod approximately 1.5m above the ground, while the second was mounted on a pole approximately 4.0m above ground (and 2.5m directly above the lower microphone).

The response of the instrumentation was monitored using a SvantekSV30A field calibrator (S/N:7906), and drifts of less than 0.1dB were observed during the experiment. At the time of the assessment the noise environment was dominated by road traffic noise, and monitoring was undertaken at two locations (R3 and R4) with different exposures to the New England Highway. A summary of monitoring results are presented in Figure 4. The assessment locations (R3 and R4), along with the results of some supplementary noise modelling are shown in Figure 5.

Analysis of measurement data (n=6 x 15 minute results) indicates that (on average) noise levels at the upper measurement location (representative of the noise environment observed by continuous monitoring) may be on the order of 1.5dB to 2.0dB higher than the noise environment typically observed by compliance monitoring. While this assessment is based only on short term monitoring and has a limited sample size, it suggests that significant difference in the monitoring response may be observed if different measurement heights are used to evaluate SPLs at the same monitoring location.

Despite the potential significance of this finding, the constraints of small samples sizes and effort demanded by operator attended monitoring are recognised as challenges to the widespread implementation of these types of site specific validation activities. On this basis, further assessment presented in Figure 5 explores how other high-tech tools in the noise management kit might be leveraged to extrapolate findings such as these to larger study areas.

A simple model was constructed using the Predictor-Lima (Type7810) software to evaluate the spatial distribution of noise levels in Camberwell Village, and was subsequently used to explore the difference in noise levels that might be expected based on different receiver heights. To enable assessment in the context of measurement results, the model was constructed in such a way as to account for topographic influences, and model the contributions from road traffic noise at heights of 1.5m and 4.0m above ground level.

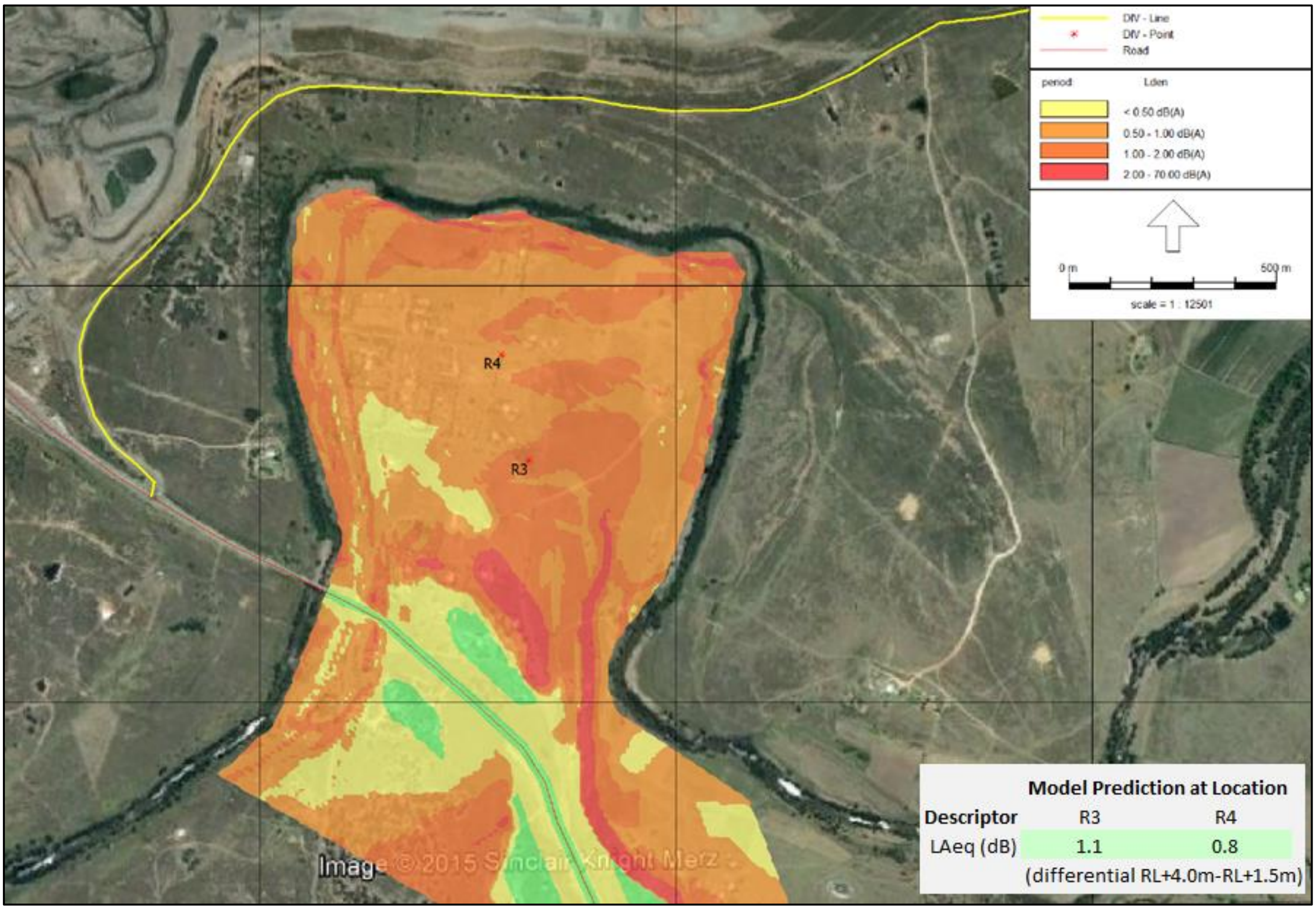


Figure 5: Image of Camberwell Village environs showing the location of road traffic noise sources, results of modelled road noise contributions, and locations (R3 and R4) subject to assessment. Noise level contours denote the difference between predicted road traffic noise levels at 2 measurement heights: RL+1.5m and RL+4.0m.

While modelling results indicate that noise level differentials (based on receiver height at R3 and R4) are slightly lower than those observed via measurement, a differential of greater than 0.5dB was returned. The convergence of modelling and modelling results provides some validation for the assertion that assessment height may have a material impact on observed SPLs in this environment.

These analyses raise questions about the simple application of ground level (RL+1.5m) compliance monitoring results for real-time system response validation, and may challenge historical assumptions about the spatial heterogeneity of noise levels. It is considered that while the analysis demonstrates the potential challenges to recently mandated requirements to ‘validate’ the response of real-time management tools, it also provides guidance on how to address these challenges.

Predictions returned for both (RL+1.5m and RL+4.0m) surfaces on a 10m x 10m grid enabled the preparation of a contour plot of the surface differentials. This type of spatial analysis may be used to document variations in the noise environment, and understand those locations where greater divergence between ground level and elevated measurements may be expected.

This type of extrapolative assessment may then be used assist practitioners understand why divergence in attended and continuous monitoring results is observed, or even help improve the design of monitoring programs by identifying locations that may be unsuitable for real-time monitoring on the basis that they may not be representative of ground level impacts.

4. Discussion

The case studies demonstrate the ways in which experience derived from the traditional environmental acoustics knowledge base may be applied to leverage better outcomes from the adoption of new management technologies. While dealing with relatively simple challenges, the case studies seek to demonstrate the benefits that may be realised where traditional knowledge and emerging technologies can be effectively synthesised. The examples are also provided to demonstrate that ‘technology’ may not be an intrinsically effective solution to noise management challenges, where it is implemented with neglect to a large pool of comparatively ‘low-tech’ knowledge.

Case study 1 (excluding the effects of wind noise) demonstrates that the quality of real-time data from continuous monitoring technologies may be significantly improved by simply reviewing the choice of windshield, or otherwise reducing microphone exposure to strong winds. In addition to increasing the quantity of the data yield (more data becomes available as less data is excluded), the yield quality can also be improved through reduced masking and better spectral resolution of those noise sources that are actually under investigation.

Case study 2 (review of uncertainty envelopes associated with variations in temperature and relative humidity) indicates that a small amount of variation in received noise levels may be driven by changes in rates of atmospheric absorption. While the assessment indicates that these environmental variables may not be driving *significant* variation, it does provide a framework to explore monitoring data under a broad range of propagation conditions. It may also help in defining the uncertainty envelopes and practical limits to the precision of real-time management systems.

Case study 3 (Is the Instrumentation Broken?) raises questions about the use of compliance monitoring results for real-time system response validation, and challenges historical assumptions about the spatial heterogeneity of noise levels. While the analysis demonstrates potential constraints to ‘validation’ of real-time management tools, it also provides useful guidance on how to address these challenges.

The common theme across these case studies is one of the contributions that knowledge of ‘traditional’ (low-tech) environmental noise assessment methods can make to understanding and shaping the hi-tech management environment that now exists. The three examples demonstrate that, rather than investing in more technology to solve the perceived deficiencies of contemporary technologies, these challenges may be resolved by simply reviewing the assumptions that have been adopted (without significant challenge) to assist with implementation of these approaches.

The inertia that sustains existing assessment methods (such as operator attended monitoring and ‘worst-case’ assessment) was established on the back of a significant body of research, which provided evidence that the methods were justifiable and fit for use. In asserting this, it is acknowledged that it takes time to develop such a body of literature, and that adoption of these assumptions is not an unreasonable starting point to aid in our navigation of the new high-tech management environment.

Notwithstanding this, caution should be applied where assessment seeks only to ‘validate’ new methods in terms of the old, and efforts that seek to build a new body of research around innovative management environments should be encouraged. While it is reasonable to expect that building such a body of research will take some time, the process may be expedited by integrating ‘low-tech’ methods (such as sensitivity analysis) with ‘high-tech’ tools (such as continuous monitoring and modelling) to increase the rate of research.

References

[1] IEC 61672.1-2004 Electroacoustic – Sound level meters – Specifications, *International Organization for Standardization*, Geneva, Switzerland, 2004

[2] Sparke, C.J. “Continuous noise monitoring network design: An end user perspective”, *Proceedings of Internoise*, Melbourne, Australia, 16-19 November 2014, pp. 2880-2889.

[3] Sparke, C.J. *Continuous noise management systems design: effects of windshield diameter on extraneous noise*, available at www.integratednoisemanagement.com.au

[4] ISO 9613-1:1993 Acoustics -- Attenuation of sound during propagation outdoors -- Part 1: Calculation of the absorption of sound by the atmosphere, *International Organization for Standardization*, Geneva, Switzerland, 1993.