Leading Practice in Sustainable Development Handbook Series

AIR CONTAMINANTS, NOISE AND VIBRATION

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FOREWORD

1 INTRODUCTION

1.1 Scope

This handbook is the successor to two handbooks in the Best Practice Environmental Management in Mining Series, "Dust Control" and "Noise, Vibration and Airblast Control". The issues covered in this handbook have a number of things in common. Of all the topics covered in the Leading Practice handbook series, this topic is arguably the one that generates more complaints and more opposition from the local community than any others. The complaints are often immediate and are usually directed to the mine or in many cases to the regulator. Residents living near a mine site will not hesitate to phone the local EPA or mines inspector for action. This might be dust from a haul road or truck reversing alarms or a suspicious dust cloud. Blasting generates many complaints in all of the three areas covered by this new handbook. These complaints are not restricted to open cut mines as inefficient blasting practices in deep underground mines also give rise to community concerns, particularly when firings take place at night.

A recent newspaper article (Weekend Australian January 24-25 2009) highlighted the issue of noise and its impacts, both real and perceived on the local community. The article detailed the recent formation of an anti-noise lobby group– Noise Watch Australia. One featured case involved a retiree who moved to a heavily timbered block some distance from a capital city. A sawmill increased its production to 24 hours, 7 days a week. In his words, *"the noise drove us darn crazy"* and consequently he sold up. Another complainant stated *"the growth of noise in communities across Australia is still not recognized for what it is – another form of pollution that's having serious health impacts on many people"*. The World Health Organisation was quoted in the article as saying that up to three per cent of heart disease deaths, or more than 200,000 globally, are due to long time exposure to chronic traffic noise.

But are noise levels increasing? The EPA Victoria indicates that noise across Melbourne hasn't increased since the 1970s and yet community complaints have risen considerably. In Britain, noise complaints are five times higher than they were 20 years ago. It is clear therefore that the community is becoming less tolerant to noise than it once was.

The issue of dust emanating from a mine site has been the focus of intense media scrutiny in Western Australia recently. The issue surrounds the export of lead concentrate from Magellan Metals' Wiluna mine from the ports of Esperance and Fremantle. The extent of community dissatisfaction can be seen from newspaper headlines in November 2008 – *"Unions promise to fight Barnett over lead shipments"* and *"Port's mayor vows to fight risky lead exports"* and *"Lead leaches hope of Esperance future".*

These issues are important in all sectors of our industry – coal, metalliferous and the quarry sector. Indeed, the front cover of "Quarry", the official Journal of the Institute of Quarrying Australia in November 2007 headlined *"Ensuring your neighbours don't eat dust".* The issues are important whether the mine is situated in the Tanami Desert, the Hunter Valley or a more densely populated area. It is often in the latter situation where most problems arise. In Australia, these situations are typical of quarries for construction materials; mines with a residential workforce such as Kalgoorlie, Mt Isa or Broken Hill or mining fields in locations such as the Hunter Valley where mining is often not considered the most desirable land use. Of course many Australian mining companies operate internationally and it is in these countries, where far higher densities of populations exist in the vicinity of the mines, that the community impacts of airborne particulates, noise and vibration are exacerbated.

1.2 Leading Practice

Leading practice considers the latest and most appropriate technology applied to seeking better financial, social and environmental outcomes for present stakeholders and future generations. A long term time-frame is considered so that potential adverse outcomes are managed in both the short and long terms. Consideration of long term outcomes is particularly challenging as the predictive data sets may be incomplete. A number of variables may modify the expected from actual outcomes and these may not be fully understood or predicted. Never the less, leading practice demands that a best estimate of future impact is assessed and reasonable steps are taken in order to implement financially, socially and environmentally appropriate outcomes. The level of precision of such estimates also needs to be communicated.

Leading practice is about identifying, using and possibly developing appropriate technology in an enterprise to provide enhanced outcomes for all stakeholders. A key feature is the measurement of variables and performance outcomes to identify potential modifications to the processes for the mutual benefit of all stakeholders.

Leading practice includes a program to monitor inputs, processes and outputs. This information is incorporated in one or a number of managements systems. This may be incorporated in existing management systems such as safety management systems, environment systems and quality systems.

Leading practice includes being able to identify and manage competent technologists and communicators and ensure that they participate in programs to maintain their competence. A peer review process is important to ensure leading practice evolves with changing technology and social expectations and standards. While not essential, active participation in the application of teaching and research activities should be considered.

Useful information is available from professional bodies such as the Australasian Institute of Mining and Metallurgy, Engineers Australia, the Safety Institute of Australia, the Australian Institute of Occupational Hygienists and the Environmental Institute of Australia and New Zealand, as well as government authorities and industry representative bodies.

Airborne contaminants include dusts, gases, fumes, odours, and airborne biological material. They may produce some financial, social or environmental adverse outcomes. The emission may:

- be a one-off event due to some plant or system failure such as a major fire.
- be intermittent but regular such as blasting fumes.
- be continuous and considered acceptable in terms of the risk of adverse short term outcomes.

These all need to be fully investigated and appropriate measures taken. The outcomes need to be monitored and the process periodically reviewed.

Noise emissions may have a number of forms from single or intermittent events to continuous noise. Noise also has several dimensions including intensity and signal frequency. Vibration may or may not be connected to noise emissions in an indirect way. Leading practice also examines the varied nature of the impacts of airborne contaminants, noise and vibration. Impacts may affect workers, passing members of the community and local residents. The impacts may also have some environmental implications that need to be considered.

Particular consideration is given to the sources and impacts as they relate to mining operations and quarries. To investigate the sources and impacts, a detailed analysis of the inputs, outputs and the mining processes is required. This extends from exploration, project design and evaluation, construction, commissioning, operations, to decommissioning and mine closure. The process of assessment also requires a characterisation of the materials extracted and consumed in the mining and processing activities. The potential and unintended interaction of these materials also needs to be considered.

Before embarking on leading practice systems, it is important to ensure there is a level of agreement between stake-holders on what are the broader objectives of the enterprise. From the perspective of shareholders or investors, there is a clear need to ensure that an acceptable financial return is obtained. Leading practice systems seek to manage financial and sovereign risk by ensuring all the stakeholders are engaged and considered so that outcomes are not just expressed as the financial bottom line but rather a triple bottom line that includes financial, social and environmental positive outcomes for all stakeholders.

Social outcomes include a broad range of issues including worker safety, long-term worker health, community health, and freedom from community annoyance or outrage. The community may extend beyond near-by residents and include state and national authorities and pressure groups. A part of the process of ensuring broad community support is the need to establish and promote the concept of the value chain in which the full range of stakeholders gain a reasonable level of benefit from the mining operations. Any groups that can demonstrate that they have been disaffected have the potential to apply political or other pressure on operations that may adversely affect the other stakeholders.

With most management systems, it is important to identify and characterise the various stakeholders who participate or have potential to disrupt the project under consideration. The different stakeholders need to be identified as do their values and objectives. In leading practice, some strategy as to how to communicate with different stakeholders needs to be developed. It is important to identify their networks and explore how effective different approaches might be. Consultative groups with local representation should be formed as a conduit to communicate with the community. Local and regional interest groups should be consulted.

In leading practice, stakeholders need to be engaged so they have some sense of control, responsibility and ownership. The success of the project then becomes a benefit to each stakeholder. This creates an environment where potential problems and conflicts are identified at early stages and their management can be incorporated into the project systems

Dialog needs to be established with a range of regulators who have obligations to ensure that there is compliance with community expectations as set out in legislation and standards. It is beyond the scope of the current text to deal in any details with the management of Greenhouse gas emissions, due to the complexity of the issues involved including the variety of stakeholder groups and the extension beyond local boundaries.

1.3 Hazard Identification and Risk Management

The nature of hazards in the areas of airborne contaminants, dust, noise and vibration may be complex and may have long latency periods, therefore appropriate health and safety professionals should be consulted. The generic risk assessment processes are covered extensively in the Risk Assessment and Management handbook (Department of Resources, Energy and Tourism (DRET), 2008). In the context of air contaminants, noise and vibration there are a few issues that need to be reinforced. These specifically relate to the complex issues of management of the risk of chronic and potentially fatal disease from cumulative exposures.

In Australia, the proponents of major projects are required to submit and have approved Environmental Impact Statements (EIS) and environmental management plans that identify environmental hazards, assess the risk, identify the measures by which their performance should be judged, implement monitoring and engage third party auditors to confirm the effectiveness of the program. The flexibility of such programs facilitates continuing improvement of industry environmental standards, but is costly and discourages smaller operators and projects.

1.4 Planning and Life Cycle Approach

In the subsequent chapters, airborne contaminants, dust, noise and vibration are each discussed in detail as separate issues but with a common life cycle approach of exploration, design, evaluation, construction, operations, rehabilitation and closure.

1.4.1 Exploration

There are a range of airborne contaminants, dust, noise and vibration that are associated with exploration. The transient and often isolated nature of exploration creates an environment for potential clashes with local inhabitants unless the operation is carefully monitored and considerable effort has been made to keep the community informed of activities.

1.4.2 Design and Approvals

The hazard identification, risk assessment and risk control planning as discussed above should be incorporated into the project design and communicated to stakeholders for comment and review. Having completed the design and environmental impact assessment phases, a vast array of approvals for a wide range of commercial activities is required. While the scope of this discussion prevents detailed analysis of the approval processes, it is sufficient to identify that considerable resources need to be devoted to identifying all the approval processes and ensuring that they are tracking effectively.

The hazards and risk management associated with exploration and small mines in relation to air contaminants, noise and vibration are generally limited as are the sites' ability to identify hazards and manage risk. The format of material to address these problems should focus on the development of simple check-lists that address specific issues at the site. The site operators need some limited assistance to develop the check lists and identify appropriate responses when a significant issue is identified. Assistance from corporate centres, consultants or government officials should be sought as appropriate.

1.4.3 Monitoring plans

While all management systems need some form of planned monitoring, the strategy in developing the nature and frequency may be quite complex. Variables to consider include the nature of the hazard and the potential rate at which the risks in relation to the hazard may change. The cost of monitoring needs to be balanced by the potential cost of an adverse incident. Changes in monitoring technology need to be regularly reviewed as effective new systems emerge on a regular basis.

Monitoring for potential long term impacts of occupational exposures (and the risk of such) is another area where new science and practice is slowly emerging. Interventions have traditionally been based on a level of harm, but there is legislative pressure on developing systems that trigger interventions based on elevated risk of harm

1.4.4 Audit and review

While a health and safety or environmental management system may be leading practice at the time of its development, elements within the mine site or aspects relating to the community and technology may change. There is a need for regular audits of the system to ensue practices are being followed. At less regular intervals, comprehensive reviews are necessary to re-assess the objectives and examine how the current systems is meeting the objectives, and what modifications are necessary to improve performance.

1.4.5 Mine Rehabilitation and Closure

The long-term objectives of rehabilitation can vary from simply converting an area to a safe and stable condition, to restoring the pre-mining conditions as closely as possible to support the future sustainability of the site. Rehabilitation normally comprises the following:

- developing designs for appropriate landforms for the mine site;
- creating landforms that will behave and evolve in a predictable manner, according to the design principles established; and
- establishing appropriate sustainable ecosystems.

It is in this second process where the potential for dust and noise in particular will become a problem. Creating sustainable landforms from spoil piles in strip (coal) mines; from waste dumps in open cut (metal) mines; and from tailings disposal sites as well as all associated infrastructure including roads, hard stand areas etc will require extensive earthmoving. These earthworks will require large machinery and will usually result in dust and noise hazards that need to be controlled. In most cases, the rehabilitation works will be carried out by contractors who may not have been involved in the mining process. Thus they may not be sensitized to the noise and dust management strategies employed when the mine was operating. It is important therefore that an appropriate induction program takes place to ensure they are aware of the potential hazards and can mitigate the risk arising from them.

Mine closure is a process. It refers to the period of time when the operational stage of a mine is ending or has ended, and the final decommissioning and mine rehabilitation is being undertaken. Closure may be only temporary in some cases, or may lead into a program of care and maintenance. The overall objective is to prevent or minimise adverse long-term environmental, physical, social and economic impacts, and to create a stable landform suitable for some agreed subsequent use.

Once the earthworks stage of the rehabilitation/closure process has been completed, and all infrastructure removed from the mine, the noise hazard should be eliminated. However a dust hazard may remain. A mine operator will have on-going responsibilities at the site until it is able to obtain a clearance certificate or relinquishment “sign off” from the appropriate regulatory body. Governments are reluctant to absolve companies of their responsibilities so they will be careful to ensure that there is low or no risk of dust emanating from the site. If the site is affected by drought and the replanting program fails, the mine operator will need to carry out revegetation maintenance, particularly over waste dumps and tailings storage facilities. It may be necessary in high wind areas to use additional surface capping such as a rock mulch rather than rely on the success of the revegetation program. The impacts of fires on revegetation and thus reducing rehabilitated surfaces to bare areas once again, should not be underestimated. This is particularly important in the Top End of Australia where the prevalence of fire in the dry season is widespread.

Further information on mine rehabilitation can be obtained from the Mine Rehabilitation Handbook in this series available at http://www.ret.gov.au/resources/Documents/LPSDP/LPSDP-MineRehabilitationHandbook.pdf

Further information on mine closure can be obtained from the Mine Closure and Completion Handbook in this series available at http://www.ret.gov.au/resources/Documents/LPSDP/LPSDP-MineClosureCompletionHandbook.pdf

The contributors to this handbook have a wide range of experience in their respective fields. We trust the information provided, including the numerous case studies, to be of considerable practical use in helping the reader integrate leading practice into his/her mining operation, thereby maintaining the social licence to operate mines and quarries in Australia and beyond.

2 AIR CONTAMINANTS

2.1 OVERVIEW

Air emissions from mining and related activities can have potential impacts on the environment on a local, regional and global scale. Despite the remoteness of most mines in Australia, many are located near settlements where management of emissions is a vital concern for the miners, their neighbours and regulatory authorities. Although dust is the predominant emission associated with mines, there is a range of gaseous and particle emissions associated with mining and other on-site processing activities. This chapter identifies the main emissions issues and their management.

2.1.1 Sources of Air Emissions

The principal activities associated with a typical mine site over its life cycle leading to air emissions are summarised in Table 1.

Table 1: Summary of Major Mining Activities Associated with Air Emissions[1]

Activity/Source	Coal Mining		Metalliferous Mining	
	Open cut	Under-ground	Open cut	Under-ground
Earthmoving associated with construction and development of surface facilities	P	P	P	P
Shaft/drift access and ventilation development		P		P
Removing vegetation and topsoil for mine preparation	P		P	
Drilling and blasting overburden	P,G[2]		P,G[2]	
Removing and placing overburden	P		P	
Drilling and blasting of ore			P,G[2]	
Extracting, transporting and dumping coal or ore	P	P	P	P
Crushing coal	P	P		
Washery operations	P	P		
Ore beneficiation			P,G[3]	P,G[3]
Transporting and placing washery rejects	P	P		
Workshop and/or power plant operations	P,G[4]	P,G[4]	P,G[4]	P,G[4]
Rehabilitation	P	P	P	P
Wind erosion from open pit, stockpiles, and exposed areas	P	P	P	P

NOTE:

1. The cells are denoted as ‘P’ if dust or primary particle emissions occur and ‘G’ if significant gaseous emissions occur and ‘O’ if significant odorous emissions are possible. Note that in some cases, individual source activities may not apply: for example, ore beneficiation does not occur at all metalliferous mine sites. Note also that exhaust emissions from vehicles and machinery have not been included in the tabulation, as generally these emissions are relatively minor in quantity and impact compared to other emissions. In some cases, specific particle hazards such as Respirable Crystalline Silica (RCS) or asbestos fibres may be emitted.
2. The gaseous pollutant of most concern is nitrogen dioxide (NO_2)
3. The gaseous pollutant typically of most concern is sulphur dioxide (SO_2). For gold ore processing, hydrogen cyanide can be emitted.
4. Gaseous emissions can include SO_2, NO_x and various VOCs

In addition to the emissions noted in Table 1 are exhaust emissions from mining equipment and motor vehicles, emissions from spontaneous combustion (especially in coal), emissions of volatile organic compounds (VOCs) from fuels and solvents, and emissions of carbon disulphide and hydrogen cyanide from some flotation processes. Transport of coal and ores from mines to export terminals or customers can lead to significant emissions, predominantly dust.

An example of blasting fume.

2.1.2 Why Control Emissions?

The impacts of air emissions depend on the type of pollutants, their release characteristics and the nature of the receiving environment. The intrinsic hazards associated with each pollutant, such as particulate matter, lead or sulphur dioxide are well documented (substance fact sheets are available at www.npi.gov.au).

We need to control particulate and various gaseous emissions because they may be harmful to our personal health, the fauna and flora in the environment, cause concern for local communities, can become a hazard to safe operations and, in the case of dust, cause increased wear to moving machinery. Dust and odour can cause annoyance and lead to complaints.

Air quality is influenced by the concentrations of a vast number of substances, some naturally present and others due to human activity, that may be present in the air. Pollutants emitted from mining and related activities constitute both gases and primary particles[1] (e.g., dust).
Dust derived from the mechanical breakdown of rocks and soil is the most widespread and abundant emission from mines, and occurs across a wide range of particle sizes. Total Suspended Particulate matter (TSP) refers to the full size spectrum of suspended dust particles. Of more direct relevance to health are the finer fractions; PM_{10} (particles less than 10 μm in diameter) and especially $PM_{2.5}$ (less than 2.5 μm). Finer particles are more readily transported into the lungs where they can become lodged and cause irritation and disease.

Depending on the rocks being mined and handled, dust may also contain significant amounts of hazardous substances such as lead and other heavy metals, crystalline silica, asbestos or radio nuclides, which adversely affect health at very low exposure levels. Hence, it is important to understand the characteristics of emitted particles to ensure that especially hazardous components are properly controlled.

In general smaller particles are carried further by the wind than larger particles. There is a rule of thumb that states no dust is carried more than four kilometres away from the source but the reality is that particles that are finer than 10 μm can easily be carried around the world and they provide the hazy mornings and evenings that we often see when there has been wind. Also, hail stones as large as tennis balls are created within clouds by very strong updraughts so if this is possible then large particles can be carried much further than four kilometres.

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[1] Secondary particles are formed in the atmosphere due to reactions involving non-particle primary pollutants: the in-plume formation of sulphate particles from emissions of SO_2 is an example. In the context of this Manual, these particles are not of significant concern.

Wind strength, particle size, moisture, porosity and density all play a role in the distance that a particle will be carried from the source. Local communities can be affected by the nuisance effect of particulate emissions through dust deposition on sensitive surfaces such as washing, table surfaces, cars and the like. Safety on and off site can be adversely affected by dust clouds that limit visibility, increasing the risk of motor vehicle accidents.

Dust increases maintenance costs as it gets in between moving parts of machinery. For example dust ingress into bearings causes the oil and dust to mix to form a highly efficient grinding paste which can quickly destroy the usefulness of that bearing. Fan impellers are impacted and worn away at the tips by larger (>30 μm) particles of dust. In order to manage dustiness, the material characteristics must be analysed to be understood and to provide the information that leads to a solution. The particle characteristics that must be understood include the mineralogy, particle size distribution, moisture, porosity, density and in some cases the particle charge.

Gaseous emissions arising from fuel combustion (e.g., power generation) or mineral processing (e.g., ore roasting or smelting) include pollutants like sulphur dioxide and nitrogen dioxide which have well-defined human health effects and are tightly regulated in the ambient environment and workplace.

Odour emissions can arise from some mining and related processes, such as oil shale processing, and gold ore roasting or leaching. The occurrence of annoying odours, especially on a regular basis, can cause annoyance in a community. Complaints are normally a symptom of severe annoyance, but an absence of complaints does not necessarily mean the absence of an odour problem: there can be complex drivers behind the decision to lodge a complaint, or not. Complaints can lead to regulatory intervention and potentially expensive programs to deal with complaints management and process rectification. If odour problems do occur, it is important that each complaint is properly investigated and followed up with the complainant and regulator, and is fully documented. A pattern of complaints may point to specific process or weather conditions that can then form the basis of a reactive management program, which avoids certain activities during those identified adverse conditions.

Dust from an ore train.

2.1.3 Regulation & Standards

Controlling dust and other emissions is a legal obligation, set out through laws on environmental protection, workplace health and safety, and common nuisance. Regulatory authorities in the various Australian jurisdictions have developed specific criteria for the control of emissions and ambient air quality.

2.1.3.1 Responsible Authorities

The regulation of ambient air quality (i.e., outside the workplace) is the responsibility of government agencies in the various Australian jurisdictions, primarily the state government departments responsible for mining activities and environmental protection. Broad national policy direction on protecting air quality is provided by the Environment Protection and Heritage Council of Australia and New Zealand (EPHC) (http://www.ephc.gov.au/), which incorporates the National Environment Protection Council (NEPC).

In all jurisdictions, regardless of the administrative arrangements for approving and managing mining activities, the environmental performance criteria that have to be met by mining and industrial activities are established by the relevant environmental protection agencies.

2.1.3.2 Standards, Policies and Guidelines

Air quality regulation is achieved by a range of measures under the umbrella of environmental protection laws. Generally, Environmental Protection Acts or similar legislation in each State set out general principles and administrative structures. Details of air quality regulation tend to be contained in a hierarchy of separate policies, standards, objectives and guidelines.

Federal programs

At the federal level, National Environment Protection Measures (NEPMs) are the key instruments affecting the mining industry. The most relevant of these are the National Pollutant Inventory (NPI) (http://npi.gov.au/index.html) and the NEPM for Ambient Air (www.ephc.gov.au).

The NPI is a national web-based annual inventory of emissions of 93 hazardous substances that pose potential risks to environmental quality. Mining and related activities contribute very significantly to national emissions of particulate matter (PM_{10} and $PM_{2.5}$). By virtue of the quantities of dust emitted, most mines are required to report to the NPI.

The Ambient Air NEPM sets out objectives, goals, protocols and guidelines[2] for ambient air quality, specifically for six pollutants. The standards and goals of the Ambient Air NEPM, as of mid 2009[3], are listed in Table 2.

Table 2: Ambient Air NEPM Standards and Goals

Pollutant	Averaging period	Maximum concentration	Goal within 10 years maximum allowable exceedences
Carbon monoxide	8 hours	9.0 ppm	1 day a year
Nitrogen dioxide	1 hour 1 year	0.12 ppm 0.03 ppm	1 day a year none
Photochemical oxidants (as ozone)	1 hour 4 hours	0.10 ppm 0.08 ppm	1 day a year 1 day a year
Sulfur dioxide	1 hour 1 day 1 year	0.20 ppm 0.08 ppm 0.02 ppm	1 day a year 1 day a year none
Lead	1 year	0.50 $\mu g/m^3$	none
Particles as PM_{10}	1 day	50 $\mu g/m^3$	5 days a year

The NEPM ambient air standards were not designed specifically to regulate ambient air quality at and beyond the boundaries of individual industrial and mining facilities. However, they are the same as, or similar to, the criteria used by various state and territory regulations.

The 50 $\mu g/m^3$ PM_{10} criterion in particular has led to problems of interpretation and compliance for the mining industry, for example, in the Hunter Valley where multiple mines can affect the air quality in nearby communities. Invariably, other (background) sources can be significant. For mining projects committed to the application of best practice controls, the 50 $\mu g/m^3$ criterion is

[2] These terms are explained in detail at http://www.ephc.gov.au/nepms

[3] The NEPM was under review at this time

often applied as an incremental goal, i.e., the concentration above background from other sources. In Victoria, for example, a total concentration of 60µg/m^3 applies to mines and quarries.

In many parts of the country the 50 µg/m^3 24-hour standard can be breached by the effects of bushfires, deliberate burning-off or dust storms on some days in a typical year.
In relation to the more hazardous finer particles, an Advisory NEPM for $PM_{2.5}$ (NEPC, 2002) has set numerical values for $PM_{2.5}$:

- 8 µg/m^3 – annual average; and
- 25 µg/m^3 – maximum 1-day average.

At this stage, the advisory $PM_{2.5}$ standard is not formally part of the assessment criteria used in regulation by all States but in Victoria. For example, the 2008 PEM[4] for Mining and Extractive Industry sets out an assessment criterion of 36 µg/m^3 (24-hour average).

State and Territory programs

The State and Territory authorities responsible for air quality have implemented ambient air quality policies and guidelines specific to their legislative frameworks. In general, though, the ambient air concentration goals for controlling dust and other emissions from mines and related industries are similar across the jurisdictions, and closely reflect the standards set out in Table 2. Nevertheless, in each jurisdiction it is necessary to know the actual limits and how they are applied: for example, are they absolute limits or can they be exceeded on a small number of occasions per year?

In addition to airborne particles, deposited dust is a major amenity issue associated with mining. In some states there is no formal guideline for dust deposition, mainly because the relationship between deposition rate and the likelihood of annoyance or complaint is not straightforward. In NSW the dust deposition guideline in residential areas is a maximum of 4 g/m^2/month in total, while the deposition due to any new activity must not exceed 2 g/m^2/month. This guideline, or similar, is often applied in other states. All states have policies and guidelines pertaining to odour management, aimed at avoiding nuisance in potentially affected communities.

2.1.4 Monitoring

Monitoring of air quality is commonly required to establish baseline conditions to use in an air quality assessment before a mining proposal is decided on. It may also be required after operations start, either for model validation or as part of an ongoing air quality management plan.

[4] Protocol for Environmental Management: http://www.epa.vic.gov.au/air/epa/default.asp

2.1.4.1 Monitoring Design & Logistics

The sensible design and operation of a monitoring program involves some strategic and logistic considerations. Many a monitoring program has failed to yield its potential value through inadequate planning and poor quality control.

What is the Purpose?

The purpose of monitoring influences its design. If it is required as part of a baseline study, the authorities will require a certain period of data to be gathered (usually at least a year) to capture seasonal variations. Adherence to accepted standards for instrument choice, siting, calibration and data management, etc., will be necessary. Similar requirements will apply if the monitoring is required for compliance and model validation as part of a licence condition. However, if dust monitoring is instigated for real-time management, where responsiveness and flexibility is more important than data precision, then instruments complying with Australian Standards or other references are not as critical.

What to Measure?

If a monitoring program is required as part of a baseline air quality study, it is important to check with the relevant agency overseeing the approval process on what specific monitoring is expected. For mines, the relevant aspect is usually dust, typically represented by PM_{10}. A monitoring program may require simultaneous measurement of TSP or PM_{10} or $PM_{2.5}$, or a combination of these[5]. Various types of instrumentation can achieve this, but the choice of instrument will determine whether it is possible to gather continuous data averaged over 10 minute periods, or 24 hours, for example.

Measurements over short intervals (e.g., 10 minutes) provide a better basis for understanding the sources of emissions. However, this requires meteorological data as well: the simultaneous monitoring of wind speed and wind direction, as a minimum. A well-configured weather station forming part of an air quality monitoring program will also measure fluctuations in wind speed and direction (measures of turbulence), solar or net radiation, temperature, rainfall, air pressure and humidity. It may also have wind and temperature sensors at two or more levels above the ground.

An aspect of dust that most directly affects neighbours of mining operations is fallout or deposition. The accumulation of dust deposits causes annoyance because of its aesthetic impact and the need for frequent cleaning. Dust deposition monitoring using dust gauges is a simple method and more directly measures the cause of complaint than methods that measure

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[5] PM_{10} is most widely used indicator, while $PM_{2.5}$ is as yet routinely considered in only some jurisdictions. TSP is not

suspended dust concentrations (PM_{10}, $PM_{2.5}$, TSP). However, the standard dust deposition measurement involves passive collection of the sample over a 30-day period. On the other hand, most dust deposition problems are caused by short events, typically over some hours. The standard 30-day sample tells nothing of the timing of the fallout, and may not be a very good quantitative indicator of the level of annoyance caused.

Nevertheless, deposition monitoring remains common because of its relative simplicity.
In some cases, there may be site-specific issues that require more targeted monitoring. For example, if rocks contain significant silica content then the respirable crystalline silica concentration should be measured. If there is a radioactive component, then monitoring of radio nuclides and/or radon may be important.

For most mining proposals and operations, there is no need to be concerned with monitoring of gaseous pollutants such as SO_2 for environmental baseline or compliance purposes.

For operational mines, it is possible that the threshold for annual reporting to the NPI or National Greenhouse Gas & Energy Reporting scheme will be triggered. Reporting for these programs involves various methods, typically 'default', simple methods that use emission factor calculations that require the input of data on characteristics of materials, rates of activity and throughputs: for example, the estimation of PM_{10} emissions from haul roads requires input of data on vehicle mass, distances travelled, road silt content and daily rainfall. However, emission factors are relatively crude, especially when used with default, rather than site-specific, values for various inputs. Hence, it may be decided to gather more site-specific data (e.g., on road silt content). Depending on the specific emission source and pollutant under consideration, there will be one or more parameters to be measured on site in order to obtain more reliable emissions data. Such monitoring programs are voluntary, and usually require some specialist input or advice.

<u>Instrument Selection</u>
The selection of instruments for monitoring is an important step, and needs to take into account any necessary standards (Australian Standards, USEPA standards, methods approved by state regulatory authorities, etc.), particularly if monitoring is for compliance or statutory purposes. The selection also needs to consider cost, maintenance needs, power requirements, siting (e.g., exposure to wind), security and site accessibility.

2.1.4.2 Quality Issues

Many monitoring programs suffer from insufficient attention to maximising both data quantity and quality. Data loss is minimised by regular checking and maintenance of equipment. The more quickly sensor or logging problems can be identified, the better the chances of quickly rectifying the problem and reducing data loss. The best results are achieved by having data available real-time or downloaded frequently and checked at least daily.

Data quality is highly important, but can often be taken for granted. Regular maintenance and calibration assist, but data needs to be regularly screened and checked: real-time data checking software with alarms communicated to the user provides the best results, but regular 'reality checking' of data is also very useful. Checks should be made to test if data are within expected ranges for the season and time of day, or if expected relationships between measured parameters exist (e.g., do wind speed and temperature increase during the day?). If data outliers are identified and checked routinely, then instrumental errors can be quickly dealt with.

Ultimately, a monitoring program should aim to consistently achieve at least 90-95% valid data return. Specific performance level requirements may be specified by regulators and this should be checked. Monitoring in remote locations without power poses particular logistic problems, so low-power samplers with solar recharge might be necessary instead of more standard instruments like high volume samplers which require 240V power. There is a greater risk of data loss from remote monitoring sites.

2.1.5 Modelling

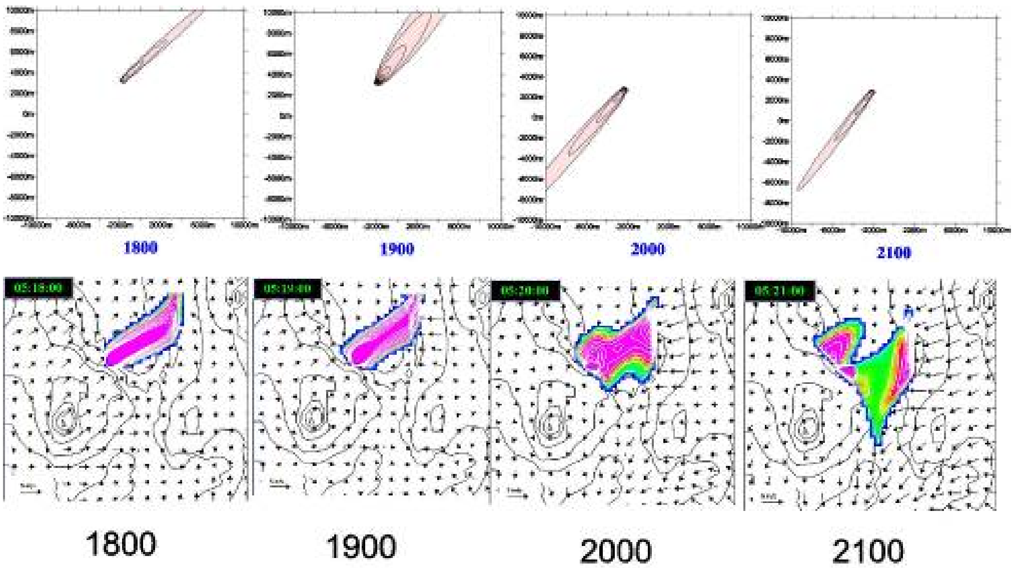
Plume dispersion models are routinely used to inform assessments of air quality impacts, either for prediction or to analyse past events. They can also be used in real-time air quality management. The needs for real-time models are different in some respects from those typically used for compliance assessments.

2.1.5.1 Basic Description of Models

Plume dispersion models mathematically simulate the dispersion (and deposition) of pollutants in the atmosphere after they are emitted from specific, defined emission sources. In common usage today there are two main types of dispersion model: steady-state and non-steady state.

Steady-state models assume that for each calculation of the plume, typically an hourly average, the meteorological conditions for that hour are in steady-state, i.e., they have always been and will always be the same. An example is the Australian regulatory model AUSPLUME, which is a steady-state Gaussian plume model, so named because it assumes that plume material, when averaged over time, has a Gaussian or normal distribution around the centreline of the plume. In performing its calculations, AUSPLUME steps from one hour to the next using the meteorological data for that hour to calculate the distribution of plume material downwind from the source(s). The steady-state assumption means that each hour is independent of other hours.

A non-steady-state model, on the other hand, tracks the location of plume segments through time and this means that variations in wind and other meteorological parameters that affect ground level concentrations can exert an influence on the predicted plume patterns. An example of how the two model types can result in quite different results is provided in the figure below, which shows the same 4-hour sequence of a plume in which the wind changes direction between the second and third hours. Unlike the steady-state model, the non-steady-state version treats the variations in wind conditions in space as well as time.



Example of Differences between Steady-State and Non-Steady-State Dispersion Models

2.1.5.2 Applications of Modelling

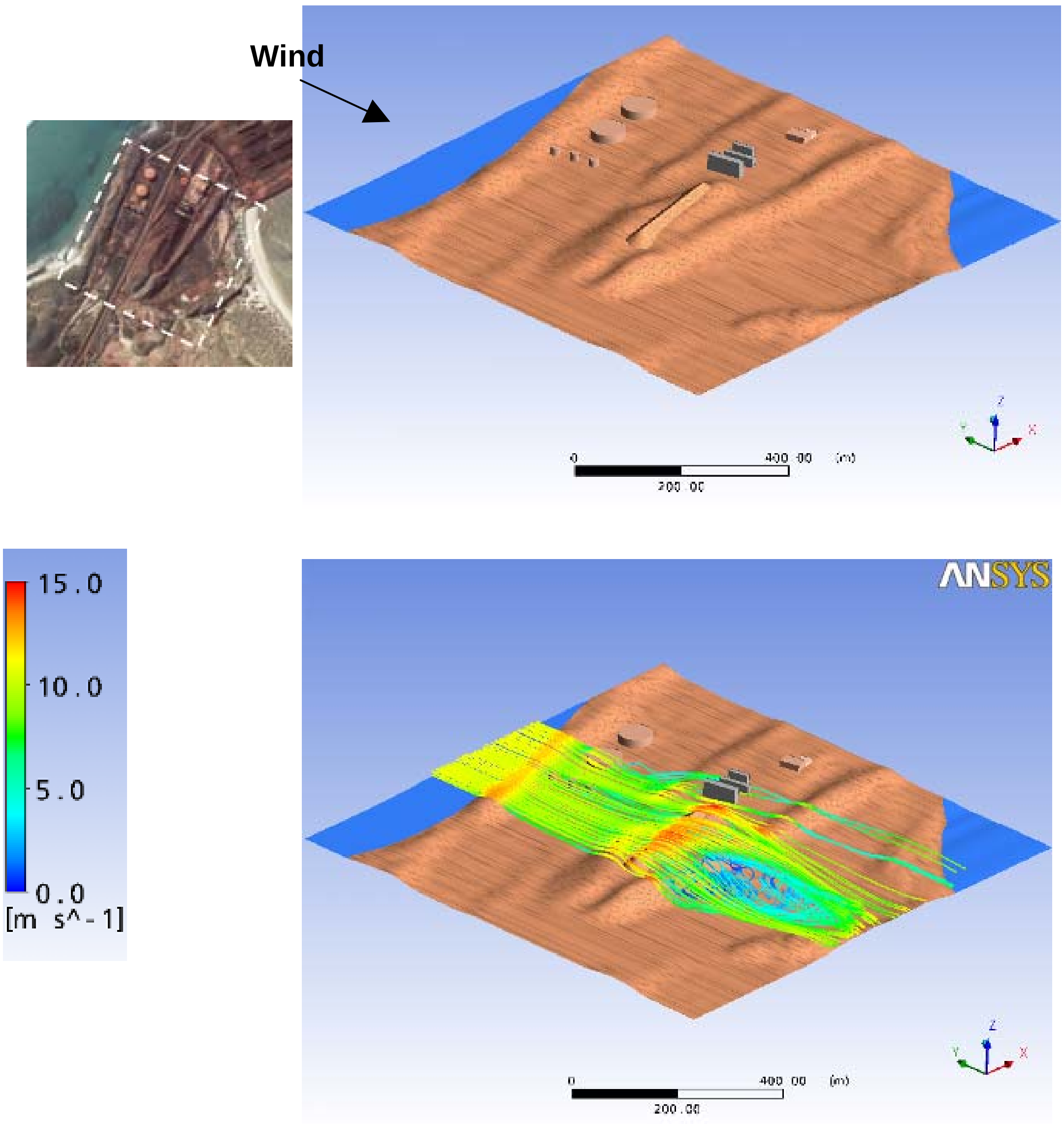
Despite the sometimes large differences in model results for specific situations, the simpler steady-state models such as AUSPLUME are widely used for regulatory purposes. However, more advanced, non-steady-state models such as TAPM and CALPUFF are now increasingly used as their costs and accessibility improve. The main applications of dispersion models are:

- Predicting the impact of a proposed activity such as a mine or smelter;
- Designing chimney heights or emission control systems;
- Apportioning ambient impacts of emissions to specific sources;
- Ranking emission sources in terms of priority for applying controls;
- Analysing past air quality events; and

- Estimating emission rates (by back-calculation modelling: this can be particularly useful for estimating dust emissions from area sources).

2.1.5.3 Computational fluid dynamics (CFD) models

This kind of software produces dynamic models that simulate the air flow over and around objects and barriers, or within enclosed and semi-enclosed spaces. CFD models have a multitude of applications, ranging from assisting in the design of combustion chambers and ventilation systems, to designing barriers to prevent dust liftoff. With respect to dust, they are particularly useful in understanding how far dust will be carried, where it will land and how effective the wind barrier will be.



2.1.5.4 Modelling Cumulative Impacts

For the assessment of a new mine or emission source, the existing levels of dust (or other pollutants as relevant) need to be taken into account. For some pollutants such as SO2, which have well-defined sources it is possible to include the new sources as well as existing or background sources in the model and yield acceptable results. However, for particles the complete definition of background sources is not possible: the background of airborne particles comes from a variety of local and distant sources such as natural wind erosion, marine salt, agricultural activities, vegetation, industry and transport.

In the case of PM10, for example, the best approach is to conduct monitoring and to apply the results as a background to which the new sources are added. Depending on the sensitivity of the activity and regulatory needs, the background can be included either as a fixed value, such as the 70th percentile of the daily values, or as daily or hourly-varying background. However, particularly where there are multiple mines or other sources nearby, such as in the Hunter Valley, cumulative impact modelling is not straightforward and there are multiple sources of uncertainty.

2.1.5.5 Model Validation and Uncertainty

All models are simplifications of the real world and carry with them inherent uncertainty, as well as uncertainty associated with inaccuracies in the input data such as meteorology and emissions. Data on emissions used in an impact assessment may turn out to be significantly in error, and particularly if the assessment shows a small difference between predicted impacts and the acceptable limits, an approval may include a requirement to validate the model.

Once the operation is underway, this involves monitoring ambient PM_{10} (or other critical air quality indicator) and meteorology for a year or two, and compiling a more accurate emissions inventory. Once the necessary data have been gathered, the model is re-run and the results compared to the measured PM_{10}. Once a validated model exists, then any future expansion or changes to emissions can be predicted with greater confidence.

2.1.6 Air Quality Management Plans

A dust or air quality management program is a way of systematically dealing with or avoiding problem issues, and may be required as part of an environmental approval to operate a mine.

Identifying rational and effective solutions to air quality problems requires a sound understanding of the nature, causes and effects of the problems. For example, if there is a risk of dust nuisance impacts in a neighbouring community during dry northerly winds, the plan would need to identify the main contributing dust sources (e.g., haul roads, topsoil dumps) and prepare mitigation actions for times those conditions occur, such as increased watering, reduced haulage activity, alternative activity locations, and the like. Some prior knowledge of dust events will assist in preparation, and advising the community of the risks and actions taken is also important. If complaints occur, they need to be handled systematically and documented from time of receipt, through the consultation and investigation stages, to remedy.

In other words, a plan needs to be more than just a list of isolated actions. Important elements for a management program include:

- well defined objectives;
- appropriate methods of implementation;
- effective monitoring and assessment of performance against compliance targets;
- well-defined lines of responsibility;
- auditability;
- communication of essential information to stakeholders; and
- periodic program review based on measured performance.

2.1.7 Controls

TO BE COMPLETED

2.1.7.1 Hierarchy of Controls

Efforts at controlling emissions of any type should follow the engineering hierarchy for control: source, then dispersion pathway, then receiver. The most beneficial controls are usually at source, so that emissions are minimized or even eliminated. This is most effective for sources that have a small size and can be enclosed to enable filtration or other forms of capture and removal. Source control is not as straightforward for area sources or roads, where application of water or chemicals is typically the most effective option.

Where emissions are unavoidable, there may be opportunities for reducing the downwind impact by installing windbreak systems, either in the form of vegetation or engineered structures. Such methods are most effective when they are close to the source, when the plume still has relatively small dimensions and thus can be more readily intercepted. The least effective and least acceptable option is to mitigate effects at the receiver. This is rarely done, but can take the form of fully air-conditioning the premises or paying for regular cleaning.

2.1.7.2 Dust

The focus of this section is dust, given that it is by far the most prevalent problem air emission associated with mining and quarrying.

Main sources

The following mining or quarrying activities can lead to particulate emissions.

- The movement of top soil, the ore or product and waste or overburden.
- Blasting, mining, hauling, conveying, stacking, loading trains and/or ships, reclaiming of material can all lead to dusty conditions.
- Clearing of open areas that are cleared for any reason can be a source of particulate emissions if a strong wind blows or if any vehicular activity occurs on the open area when a light wind is blowing.
- Unsealed roads that carry medium to heavy traffic are a significant source of particulate emissions.

Material characteristics

Some soil, waste and ore types tend to be dustier than others. If clay minerals are present then not only will particulate dustiness be more prevalent but particulate emissions will be higher. The size distribution also plays a role in the severity of the particulate dustiness of the ore, waste and/or soil as does the porosity, density and hydrophobic nature of the material. It is important therefore to determine what is known about the dust characteristics of the ore, waste and soil types that will be disturbed. Once this is done the task of preventing dusty operations is simplified and made possible.

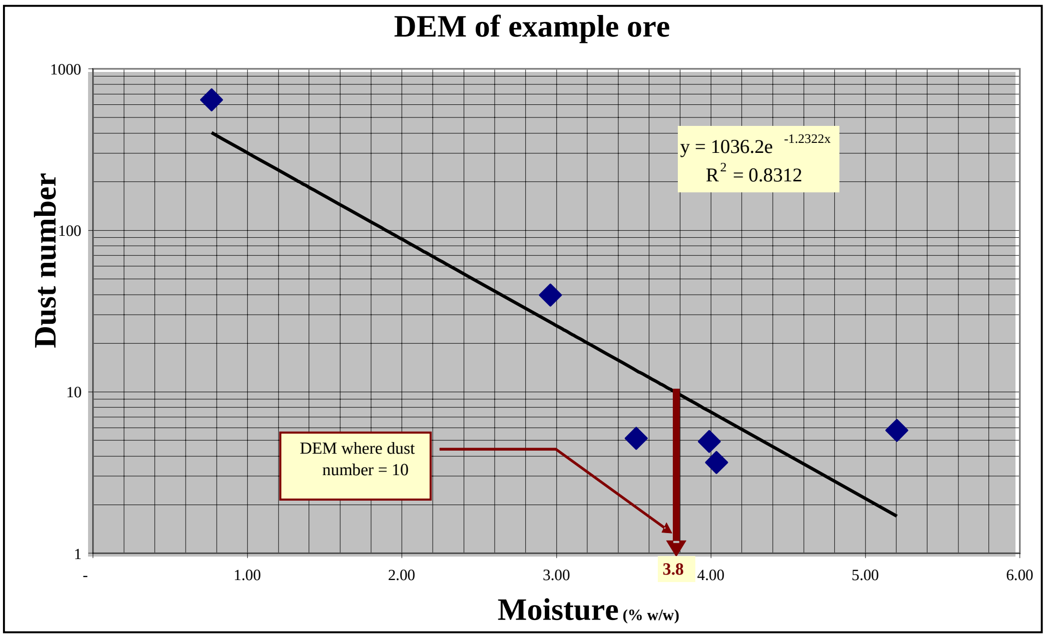
The extent to which a material will produce fine particles is a function of the minerals present. For example the grains of clay minerals tend to be finer than most other minerals so clays typically produce finer particles and larger volumes than most other minerals. In general clays are softer, less dense, more porous and can be broken down by water if exposed to it for some time. This means that clays will absorb more water per tonne than most other minerals.

It is important therefore to understand the mineralogy of the ores, wastes and soils in the operational area.

Moisture

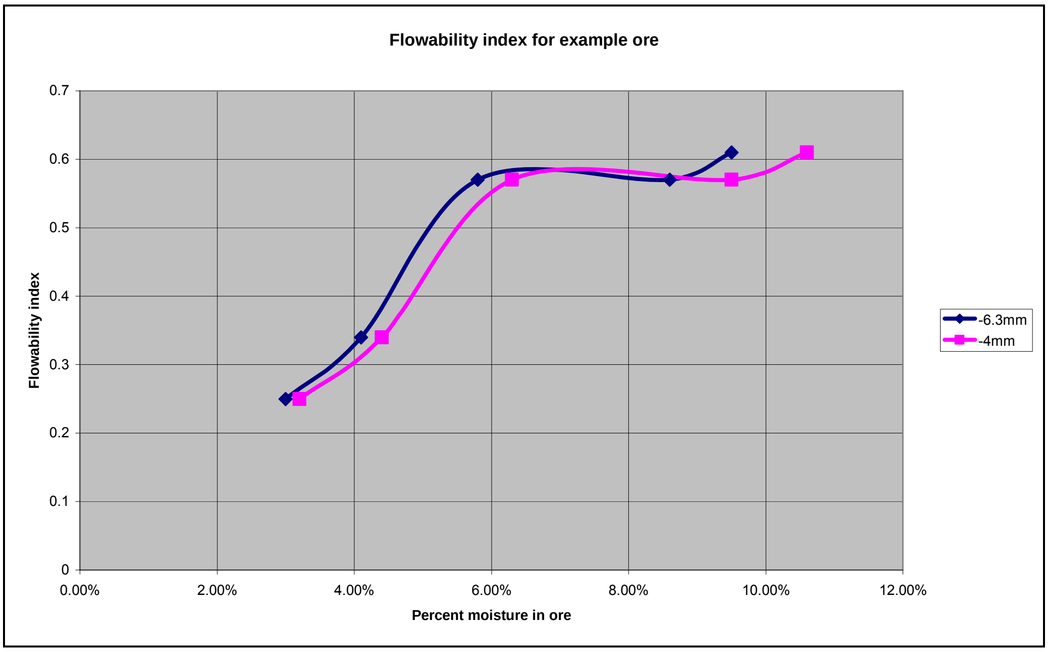
Moisture is the most significant mitigating agent available for controlling particulate emissions, so in general higher moisture means less dusty conditions. Unfortunately there is also a point of moisture addition at which most materials become sticky which can cause blockages in the plant and cause the material to hang up in dump trucks and rail wagons.

There are several moisture “factors” that are tested for in order to understand the nature and behaviour of the material. Each ore has two moisture limits that are critical to understanding the nature and behaviour of the material: the Dust Extinction Moisture (DEM) and the Materials Handling Moisture (MHM). The DEM, which is the lower moisture limit, is the moisture at which the material is no longer dusty. The MHM, which is the upper limit, is the moisture at which the ore becomes sticky and begins to cause materials handling problems. These two levels are determined during the same test program. The DEM and MHM[6] can be determined by a suitably equipped materials handling testing facility such as TUNRA at the University of Newcastle. The figures below depict typical data sets associated with DEM and MHM determinations.



[6] These upper and lower limits are not exact figures and should be reported as ranges, not as a single point, in much the same way that tolerances are given with an engineering specification

DEM (upper moisture limit)



MHM (lower moisture limit)

Because moisture is constantly being drawn from ore by the sun and wind, it is prudent that the moisture level of any ore that will be handled be kept at least one or two percent above the DEM to ensure that particulate emissions are not generated. Moisture analysers are also required to keep track of the moisture of the ore as it is handled and water addition points should be placed at all available sites.

The DEM and materials handling moisture levels of each ore body should be determined by testwork and a test program should be developed to perform this work. However, when the nature of the ore changes, such as the fines lump ratio, or the clay content, its DEM and materials handling moisture levels will also have changed, so the testwork should be carried out again. In fact, when ores that have known moisture limits are blended, the blended ore will behave differently again to the separate ores and it is always best to perform these tests again using the planned ore blends.

<u>Particle size distribution</u>

The next factor that affects the dustiness of products is the particle size distribution. In general the finer the grain size the more dusty the behaviour of the material. Finer grains are lighter and can therefore be more easily blown about.

Once suspended by the wind, finer grains tend to stay airborne more readily and are therefore also transported further from the particulate emissions source. Fineness is of course a function of the mineralogy but it is also dependant on the energy imparted into the material by blasting, crushing, grinding, and so on.

Hydrophobic Nature of Some Ores

Very dry, very fine particulate emissions particles can often behave as if they are hydrophobic for three reasons. Particulate emissions particles of this size can be electrostatically charged, resulting in widely dispersed clouds of particulate emissions, and they can often be the same charge as the water droplets that are being used to wet them. The natural result of this is that the water and particulate emissions particles repel each other.

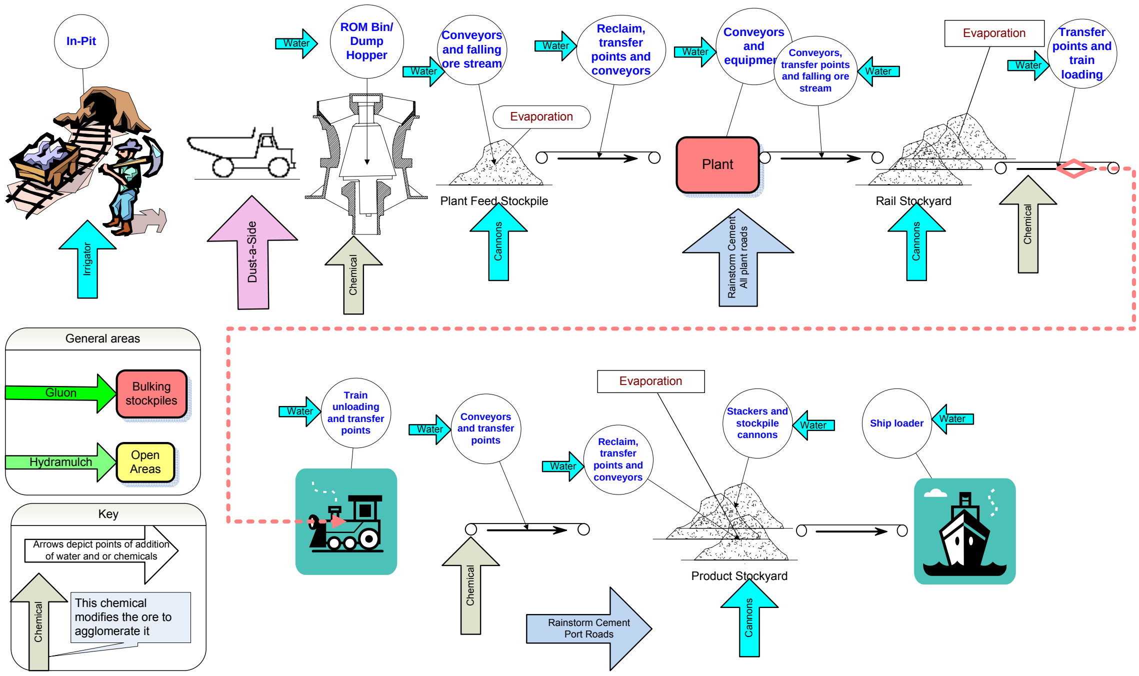
In the second case, the particulate emissions particles can actually be hydrophobic for some chemical or surface tension reason. In the third and final case, the particles can behave in a hydrophobic manner as a result of a high surface area for each particle, which means that it requires larger volumes of water per tonne of ore than would normally be the case. The only way to determine which of these three causes for hydrophobicity are at work with the ores that have been labelled hydrophobic is to perform the appropriate testwork.

The particulate emissions value chain map

The most effective way to manage total group operational costs, human resources, etc. is to take a value chain approach, so too with particulate emissions mitigation. The effect of a particulate emissions reduction project carried out in the pit will not only benefit the pit and the associated plant but the downstream operations as well.

As a result it is important to understand where and how particulate emissions mitigation projects can be carried out in the value chain and what benefits can be realised elsewhere.

The particulate emissions value chain map (below) is a pictorial representation of the ore value chain used to provide examples of points in the ore value chain that can be used to modify the ore moisture or to inject chemicals that prohibit particulate dustiness. The map is broken up into four areas which are mine, plant, rail and ports and general areas.



The mine value chain map for particulate emissions control

2.2 Planning Phase

Impacts of dust and other emissions need to be carefully considered in the planning phase. Mine design and layout are vitally important, as are the methods of assessment and approaches to approval decision-making.

2.2.1 Environmental Assessment

An environmental assessment is normally required for a new project, and it is important that your team is suitably qualified and experienced. Much time and money can be lost in responding to regulators on inadequacies in air quality assessments. It is therefore important that the assessment is as complete and accurate as possible, identifying all the potential sources of emissions and assessing their impacts.

The air quality assessment may involve establishing the baseline conditions, identifying emissions sources and their characteristics relevant to dispersion, compiling data on meteorology and emission rates, modelling the ground level concentrations of key pollutants (normally particles), describing mitigation measures and, importantly, conveying information to the potentially affected community.

As an example, the Victorian EPA's PEM for Mining and Extractive Industries sets out three levels of project:

- A level 1 assessment is required when developments are located close to residential areas or urban areas and have the potential to give rise to significant offsite impacts. These assessments are the most rigorous and require the most extensive modelling and monitoring data.
- A level 2 assessment is required when the proposed development is in a rural location with residences in close proximity or where a small operation is located in an urban area.
- A level 3 assessment is required when the development is in a rural location with no residences nearby. A level 3 assessment is the least onerous due to a lower potential risk arising from emissions from the proposed operations compared to operations requiring a level 1 or level 2 assessment. A level 3 assessment may be required when the development is small, in a location remote from residences, or where it is considered that the off-site impacts would be small compared to sites requiring level 1 or level 2 assessments.

For mines and quarries with less than 50,000 tonnes/yr extraction, no modelling assessment of air quality is required but emissions on site must be controlled by the application of best practice site management. These specific requirements will differ in detail from one jurisdiction to another, but are indicative of the rationale. The major pollutants of concern are related to dust and specific substances that may be contained within the dust (e.g., crystalline silica or heavy metals).

For proposals requiring an air quality assessment, it is normally necessary to assess $PM_{10,}$ which is the main airborne particle indicator. Depending on the jurisdiction and the circumstances of the site, it may also be necessary to consider $PM_{2.5}$, respirable crystalline silica (defined as the $PM_{2.5}$ fraction), arsenic, heavy metals (e.g., antimony, lead etc), hydrogen cyanide and CN, polycyclic aromatic hydrocarbons [PAHs](as benzo-a-pyrene [BaP]), naturally occurring asbestos and radio nuclides or radon. Dust deposition may also be required. Early advice from the regulatory agency is strongly recommended.

Uranium mining poses specific issues around potential exposure of workers and the public to radioactivity. For members of the public, the most important pathways for an operating mine are generally radon transport and ingestion of radio nuclides following surface water transport. For a rehabilitated mine over the short term, the most important pathways are likely to be inhalation of radon progeny and radioactive dust re-suspension, and direct irradiation. Over the long term, groundwater and surface water transport of radio nuclides and/or bioaccumulation into edible animals and plants that feed or grow on site or associated water bodies may become more significant (http://www.environment.gov.au/ssd/research/protect/index.html). Uranium mining proposals require detailed evaluation of these risks.

Some assessment procedures are deemed significant enough to warrant a public inquiry, to ensure that all issues are suitably aired and decisions on approval and conditions are appropriate. In NSW, for example, some projects are subject to public hearings by expert panels who make technical comment and recommendations for government consideration in the final decision. An example is the process that was invoked for the assessment of the Anvil Hill (now Mangoola) coal mine project in the Hunter Valley. A key aspect of this process was the way in which decisions about private property acquisition were made in the light of uncertainties about the accuracy of model predictions of air and noise impacts in the surrounding community.

Case Study : Mangoola (Anvil Hill) Coal Mine Assessment Process, NSW Department of Planning

The Anvil Hill (now known as Mangoola) coal mine proposal in the Hunter Valley was classified as a major project under Part 3A of the NSW Environmental Planning and Assessment Act 1979. After public display of the environmental assessment, the Minister for Planning directed that an Independent Hearing and Assessment Panel (Panel of Experts) be constituted in accordance with section 75G of the EP&A Act to assess key aspects of the proposal in more detail.

The Panel held meetings with community stakeholders, Government agencies, and with the Proponent in Muswellbrook from 17 to 19 October 2006. The Panel provided a report on its findings to the Director-General of Planning and the Minister for Planning was required to consider the Panel's report in deciding whether or not to approve the project. A Panel of Experts exercises its functions in accordance with arrangements made by the Minister but is not subject to the direction of the Minister regarding the findings and recommendations of its report.

The Department received a total of 2,040 submissions on the proposal and the Panel heard 28 submissions at the hearings. The then Department of Environment and Conservation (DEC)[7] initially stated that it could not support the proposal on account of noise, vibration, air quality, threatened species, Aboriginal cultural heritage and water quality impacts. The DEC was concerned that the proposal would 'represent an unacceptable impact on an entire community' at Wybong, 20 km west of Muswellbrook.

[7] Now the Department of Environment and Climate Change

The main grounds for objection were (in decreasing order of mention) greenhouse gas emissions and associated global warming/climate change, flora and fauna, surface and groundwater , noise and blasting, dust and socio-economic impacts (given the large number of property acquisitions required for the proposal).

Noise

The impact assessment indicated that, under worst case operational and meteorological conditions, the project would have a moderate to significant impact on a large number of private properties at some stage during the course of the project.

Notwithstanding mitigation measures, the project would result in a residual noise impact to a large number of private properties. At the time of the EA, the number of properties affected by operational noise was 179, including 106 significantly affected properties. The proponent's land acquisition program had reduced the number of affected private properties to 118 at the time of the panel report, including 49 significantly affected properties. Independent analysis by the Panel indicated that noise predictions in the EA may be marginally underestimated for properties to the northwest, which would possibly result in an addition of around 10 properties being significantly affected by noise.

To compensate for noise impacts, and given the very low background noise conditions of the locality, noise conditions[8] be placed on the project are significantly more stringent than the standard approach to noise management. These included requirements on the proponent to:

- undertake (with landowners consent) architectural noise treatments at all residences where operational noise levels meet or exceed a noise criterion of 35dB(A);
- undertake (with landowners consent) architectural noise treatments at all residences where traffic and rail noise levels exceed the relevant road and rail noise criteria;
- purchase (with landowners consent) any private property that experiences operational noise levels at or above 40dB(A), and
- establish and implement a comprehensive noise monitoring program, which includes real-time monitoring of noise impacts with the view to modifying mining operations as appropriate to reduce noise impacts.

[8] http://majorprojects.planning.nsw.gov.au/files/6563/Project%20approval%20and%20conditions.pdf

Air Quality

The Panel recognised that air quality modelling contains inherent uncertainties, and that the available criteria do not fully address all aspects of dust impacts, particularly in relation to the nuisance potential from dust deposition. Therefore, it could eventuate that, over time, either more or fewer properties than were identified in the EA would be adversely affected by dust.

A primary issue with the predicted dust impacts was the potential for nuisance, associated with excessive dust deposition, which tends to be concentrated over time into discrete events.

However, there are difficulties in adequately measuring and assessing such short-term events, and 24-hour average PM_{10} concentrations are the main short-term assessment benchmark.

The EA identified proposed measures for controlling both wind-blown dust and dust generated by mining. These measures include disturbing the minimum area necessary for mining and rehabilitating completed overburden areas as soon as practicable; use of water carts on coal handling areas and haul roads; use of water sprays on coal stockpiles; use of dust suppression equipment on drill rigs and the lowering of dust aprons; and confinement of blast charges.

Given some uncertainty about precisely how many and which properties might be affected by 24-hour PM_{10} concentrations above the 50 $\mu g/m^3$ assessment criterion, effective ongoing monitoring, dust management and community consultation would be an essential requirement. The Panel indicated that the property acquisition program might need to be expanded further if actual mine performance were to result in higher than predicted impacts.

Approval condition 27 for the project requires an Air Quality Monitoring Program that includes a combination of real-time monitors, high volume samplers and dust deposition gauges to monitor the dust emissions of the project, and an air quality monitoring protocol for evaluating compliance with the air quality impact assessment and land acquisition criteria in the approval. Condition 26 requires the operator to regularly assess real-time air quality monitoring and meteorological monitoring and to relocate, modify or stop mining operations as required to ensure compliance with the air quality criteria.

2.2.2 Baseline Monitoring

As outlined in section 2.1.4, baseline monitoring is normally required to gather site-specific information on existing air quality. The level of monitoring will depend on the potential size of the impact and the sensitivity of the surrounding land use. Monitoring will typically not be required if the site is remote from sensitive receivers and there is an absence of other major emission sources.

For baseline monitoring it may be sufficient to establish one monitoring site, but if there are existing sensitive sites around the project area then the possibility of local variations in existing air quality should be considered, and additional monitoring sites established if warranted.

Issues of instrument selection, siting, power requirements, maintenance and data quality must be carefully considered. If a Level 1 type of assessment (as described in section 2.2.1) is required, then it will be necessary to measure PM_{10} (and $PM_{2.5}$) as well as analyse samples for hazardous components such as crystalline silica. For the monitoring of PM_{10}, if a continuous time-varying background is required for modelling then a sophisticated instrument such as a TEOM will be required. These instruments can record data every 10 minutes. Alternatively, a less detailed approach would entail a more traditional high volume sampler or a partisol sampler, gathering 24-hour average data.

It is important to gather meteorological data as part of an air quality monitoring program. Weather data are important for interpreting air quality data and can be used in dispersion modelling. If it can be demonstrated that representative background data are available from a nearby site, then monitoring may not be required.

Weather station at a remote baseline monitoring site with solar power panels and low-power partisol dust monitor (right hand side of installation).

2.2.3 Modelling and Impact Assessment

Modelling the dispersion of emissions involves the input of data on emissions, meteorology, terrain and surface roughness (which can be represented indirectly by land use categories). Models require slightly different details for point, volume or area sources to be handled. However, for each source type data are required on location, dimensions, release height and emission rate. Emission rates may be entered as constant values, or may be allowed to vary according to season, time of day or meteorological conditions.

At the planning stage, emission rates for the project must be estimated using best available data and methods, since they can't be measured. The most common approaches are to use actual data from very similar sources and scale according to size, or more commonly to apply emission factors. Emission factors are often used for NPI reporting, and are documented in NPI Manuals (http://www.npi.gov.au/handbooks/index.html) for a wide variety of activities. However, emissions estimates are inherently prone to uncertainty, and it is important to be aware of the sensitivity of emission rates to the assumptions and data choices involved in using emission factors. Default values provided for various parameters in emission factors can and should be replaced by site-specific data whenever possible.

The planning phase should involve early engagement between project planners and engineers on the one hand and the air quality consultants on the other. Preliminary modelling will identify any potential problem issues, identifying specific emission sources that are likely to have high impacts. This then allows feedback to the design process to modify layouts, processes and the like and iteratively reach a satisfactory result.

2.2.4 Planning for Locations of Operations and Clear Areas

2.2.4.1 Location

There are two considerations in terms of locating the operation. In terms of the hierarchy of control the most important way to prevent dust is to eliminate the problem entirely; this means that the location of the operation is the most important way to prevent dust becoming a nuisance to a local community.

The geographic location of the operation must be as far away from any existing village or town as is practically possible. This consideration will mitigate visual noise and dust impacts. In addition it must always be downwind (in terms of the prevailing winds) of any such settlement. Once the site has been purchased the location of the mine, plant and stockpiles must be the first consideration in the design of that site. They must be located downwind of any offices or workshops and as far away from them as possible.

2.2.4.2 Size of the site

When considering the area of land to be purchased/leased the larger the site is the better. When a new site is established the land is relatively cheap so this is the time to establish a large site. By purchasing a large area for the site the operation prevents the establishment of a local community too close to the site to ever be bothered by the site's operations.

Once a site has become operational people not associated with the operation will migrate towards the operation and with time they will begin to impose their will on the operation in terms of their environmental needs. If the site is sufficiently large then the operation's impact on this new community will naturally be minimised.

2.2.4.3 Local hills or rises

Never place an operational site on a raised area such as a hill. This is the worst scenario that can be considered since this exacerbates the effect of the visual, audio and dusty impacts of the site on the surrounding area. If a hill is on the site then the most useful place to put the operation is on the downwind side of that hill. The hill will force any wind blowing up and over the site, which will reduce any adverse impact that the site will have on the region.

2.2.4.4 The Use of Flora

When preparing the site for construction, do not allow the contractor to simply clear the entire site of all trees, bush and grass. The natural flora plays a significant part in reducing the impact that an operation will have on the region by absorbing noise, collecting the dust in the leaves, slowing any wind speeds and hiding the new operation. Specific areas should be designated and then cleared as roadways, lay down areas and construction sites and all other areas of the site are designated no-go areas for any use.

2.2.4.5 Roads

The most well known dust sources on a mine are the roads. On an annual basis the roads at an operation will produce as much dust lift-off as the dust generated by the movement of the ore.

2.2.5 Mitigation Measures

The planning phase should establish a solid outline of mitigation measures needed to ensure that the future operation will be able to meet air quality objectives. These measures may include:

- specific engineering controls on significant emission sources, such as watering systems for stockpiles;
- re-sizing elements of the project to limit emission rates; and
- identifying measures, such as limiting or ceasing activities under critical weather conditions, or applying controls such as watering, when conditions are unfavourable.

A critical aspect at this stage is to understand the implications of model uncertainty for the extent and type of mitigation measures that might be necessary once the operation is in place. If actual impacts are greater than expected, then additional measures will be needed and it is important to explore these ‘worst case’ possibilities at the planning stage.

2.2.6 Community Consultation

Most communities faced with a new mining project in their neighbourhood will have some negative feelings about it and may vigorously object to the proposal. The onus is on the company to fully and openly explain the project’s impacts on the neighbours, to be mindful of their concerns and as far as possible to work with them to resolve any misunderstandings and unreasonable impacts. Generally, community concerns and their level of negativity are greater if they perceive that information given to them is incomplete, unreliable or dismissive of the true nature of their objections. Hence, a strictly technically-based consultation process may do more harm than good, as there are usually purely personal, perceptual aspects as well as more pragmatic concerns about property value, amenity and community continuity that need to be addressed.

Hence, a sensitive and serious approach to community consultation is essential at the planning stage and an experienced consultant expert in this area is an important team member.

2.3 Exploration/Development/Detail Design Phase

2.3.1 General

At this stage of development, there is usually a limited amount of activity that will generate significant emissions. Nevertheless, any drilling, excavation and material handling and transport activity that could potentially impact on neighbours should be conducted with that impact in mind. It may require the location or timing of various activities to be managed so that they have minimal impacts, or watering of dusty operations that are close to sensitive areas.

As design detail progresses, there may be a need to refine emission control specifications based on improved inputs for modelling. Hence, it is important that the engagement with air quality consultants continues as required. Baseline monitoring, if any, will be in progress through this stage.

2.3.2 Risk Assessment

Prior to any ground disturbance a risk assessment of the operation should be carried out. An environmental specialist with particulate emissions experience should be involved to ensure an understanding of the effects of any event being planned.

There are many cases in the mining industry where an incorrect understanding of the fundamental principles of particulate emissions formation has led to a particulate emissions source at an operation that has resulted in that operation having to expend unnecessary effort in resolving the problem. This kind of situation can be avoided when the risk assessment is carried out if one of the participants has the necessary skills.

2.4 Construction Phase

Through the construction phase, there is a range of activities such as earthmoving and road construction that generate dust possibly at higher levels than during the operational stage, at least for parts of the project site. If those parts of the site are close to sensitive areas, then attention will need to be given to controlling dust emissions especially under adverse dry and windy conditions.

Any baseline monitoring will continue through this stage. If there is a potential for dust impacts on neighbours due to construction, then the situation may warrant the installation of one or more dust monitoring instruments, such as an Osiris or DustTrak which can be used at the boundary or sensitive location to capture real-time data and send an alarm when a pre-defined dust concentration is reached. In this way, activities can be controlled to minimise short-term dust events in response to the early warning capability. These types of instruments are not compliant with regulatory standards and cannot be used for compliance monitoring, but are very useful for real-time management.

2.5 Operational Phase

At the operational stage, the major emissions and air quality issues occur, requiring an ongoing management plan that is both rigorous and flexible.

2.5.1 Management Plan and System

An air quality (or dust) management plan (AQMP) may be required as a condition of approval but even if it is not, there are good reasons to have a plan in place to deal with any issues that could adversely affect the operation. Even if there are no sensitive neighbours, there might be real value in limiting dust impacts on machinery wear or vehicle operator safety. Generally, however, the main focus will be on limiting impacts on neighbours (which apart from residents might include sensitive ecosystems or farmland) and staying in compliance with regulatory requirements.

A management plan's success is gauged by measurable performance: it must be more than a document that gathers dust, instead it should be a document that is of daily relevance not only to the environmental manager but also to senior management and site operators alike.

An essential part of the AQMP is a well-structured system (AQMS) for monitoring, recording, quality checking and reporting information transparently and consistently. Capturing all information in a single data repository is an important feature: many problems can occur when data is captured on disparate platforms and can't readily be tracked over time. All data have a value, which in some cases may not be completely obvious until a later time when readily available, high quality data is important for any assessment.

2.5.2 Monitoring

Compliance monitoring may be required by licensing, in which case the regulatory agency will specify the requirement. However, the specific location(s) for monitoring may require negotiation with landowners, and allowances made for finding suitably exposed sites, power supply, ready access and so on. Once a site is established, it is important that correct maintenance and calibration is carried out to maximise the return of reliable data. Compliance monitoring requires a system that complies with the relevant Australian Standards and regulatory requirements. For particle monitoring, this will typically entail hi-vol, partisol or TEOM instrumentation. In specific cases, specialised monitoring or analysis may be required: for example, respirable crystalline silica, asbestos, radio nuclides or radon. In these cases, it is important to receive expert advice. For many sites, there may be an additional requirement for real-time monitoring, similar to the needs at the construction phase but perhaps on a larger scale. The requirement may be set out in approval conditions, or may be a voluntary move. In either case, it should be set out in the AQMP.

A real-time system may entail an array of monitors set out to provide indications of dust levels over periods as short as 1 minute. The regulator or a consultant will be able to establish a suitable trigger level for the short-term concentration that signals a need for intervention, in order to maintain compliance with the 24-hour standard. Most real-time monitors are capable of sending out electronic, audible or visual alarm signals. The siting of a real-time system should aim to provide information about the current or imminent impacts on the most sensitive locations around the mine.

At the other extreme to real-time monitoring, dust deposition measurement using standard dust gauges, which collect samples over 30 days, is a useful adjunct to the monitoring program and again may be required by consent conditions. Deposition is relatively inexpensive, but measurements can be prone to problems of sample contamination and vandalism, and care needs to be taken in siting, security and liaison with neighbours. Nevertheless, dust deposition monitoring remains a common way of obtaining an indication of nuisance impacts, and can also be important in determining if the deposition rates of hazardous components, such as lead, are at acceptable levels. An array of deposition gauges around the boundary and near sensitive locations is recommended.

A dust gauge, simple and inexpensive but vulnerable to interference.

Most dust nuisance occurs as a result of specific short-term events rather than a gradual background accumulation of dust. Because dust gauges can yield only a monthly deposition rate with no information on short-term events, their results may not correlate well with the level of annoyance or complaints being received.

2.5.3 Control and Mitigation

An array of control and mitigation efforts comes into play during the operational phase.

2.5.3.1 Matrix of particulate emission control

The following matrix can be useful as a starting point in the search for all the potentially appropriate answers.

	Design	Replace	Greening	Moisture	Chemicals	Surface Treatment	Barriers	Capture
In the pit	□	□	□	□	□	□	□	□
Underground	□	□	□	□	□	□	□	□
Stockpiles, Open Areas	□	□	□	□	□	□	□	□
Transfer points	□	□	□	□	□	□	□	□
Roads/Land Clearing	□	□	□	□	□	□	□	□
Plant (furnaces)	□	□	□	□	□	□	□	□

Definition/example	Replace: using either roads, rail, or conveyors whichever produces the least dust
	Greening: planting trees, shrubs, grasses
	Moisture: using water to control dust
	Surface treatments: using bitumen, concrete, chemicals, etc.
	Capture: collecting the dust using a bag house, precipitator or scrubber

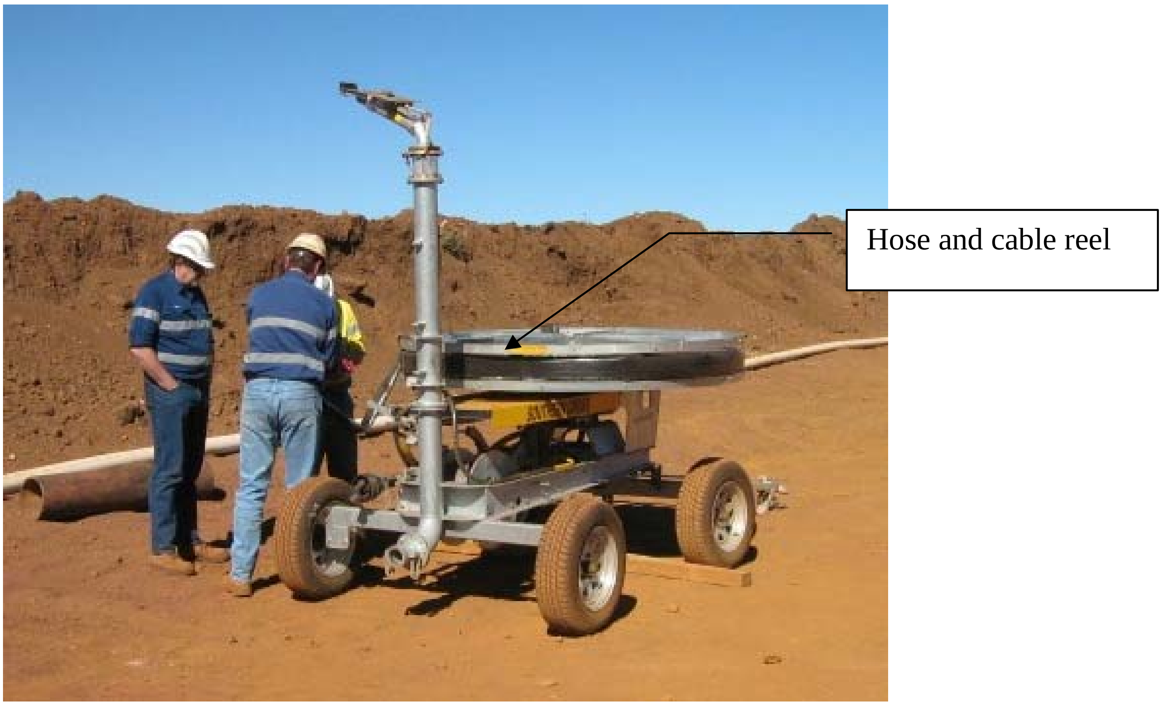
The matrix provides a useful checklist for selection of an appropriate mitigating control for various particulate emissions situations.

2.5.3.2 Mine

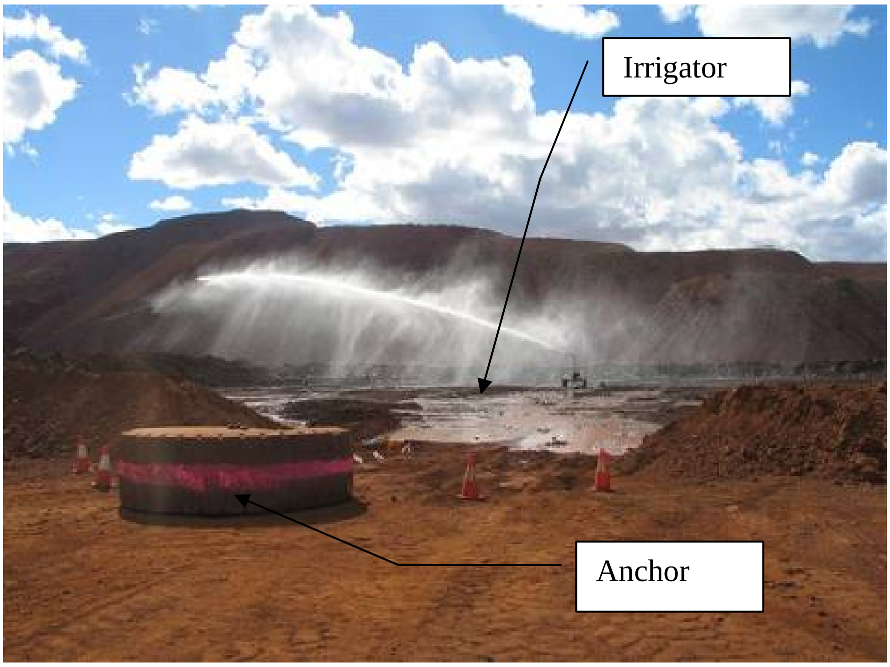
If the moisture content of the product is modified in the mine there can be a beneficial knock on effect all down the value chain. This is true because the sooner that newly exposed ore is conditioned by water the more easily it absorbs water later on. The benefits are different for different products but the following benefits can accrue. Additional moisture will reduce the dustiness of the product and can lead to some binding of the very fine particles which will cause them to behave as larger particles.

When ores are particularly dry and prone to being dusty, spraying water onto the blast prior to mining will not only condition the ore but is safe practice as well since it reduces the particulate dustiness caused by the operations of the shovel or front end loader. By wetting the ore prior to mining, the number of poor visibility events will be reduced which increases mine availability.

A Pilbara mine operation uses a mobile irrigator to wet the Iron ore at the “fingers” in the mine (below).



A typical mobile irrigator used on an iron ore mine



A typical mobile irrigator

The direction of travel is towards the anchor. There is a rotameter that is driven by the water that winds the cable up onto the cable reel.

2.5.3.3 Plant

This section covers any type of plant since the principles are applicable to process plant and any type of materials handling plant. Transfer points, operating equipment and discharge points within the materials handling systems provide the potential for significant dustiness at the operation.

If we follow the hierarchy of control, the most successful solution lies in eliminating ultra-fine particles from the ore stream. This can be accomplished by bringing the ore stream up to the DEM point. This solution, however, is not a perfect solution since water addition systems can fail and maintaining the DEM does not produce a dustless ore.

Although substitution is the next level of control this is not an option for consideration. The third level of control for preventing dust from leaving the ore stream can be done in two ways. The first way to prevent an operation from being dusty is to ensure that all the transfer points and operating equipment within the plant are enclosed and that the seals of these enclosures operate in a way that takes into account the specific application. So for example the design of an enclosure and its sealing method for a crusher is different to that for a transfer point.

This means that it is important to ensure when the ore stream enters a transfer hood/chute, there is as little open space in that entrance as possible. This limits the volume of air drawn into the chute which in turn prevents the fine particles from being blown around when they become airborne while falling.

The design of the seals for enclosures in the plant should be practical and maintainable so that the operators use them and the maintainers keep them working and replace the covers after working on the chute. There are several companies that specialise in designing this kind of plant.

Separating Lump from Fines

When the material stream has a high moisture content and prior to separating the material stream into lump and fines the material dustiness is less than is the dustiness of the separated lump and fines. There are two reasons for this. The ultra-fines tend to adhere to the lump particles and that provides stability to the fine particles. In the second place lump particles provide localised wind breaks for the fine particles lying next to them and that reduces local particulate lift off. These effects occur on conveyors, stockpiles and trucks.

Changing the flow of ore

Impact plates create particulate dustiness by imparting energy into the moving ore stream by changing the direction of flow in the same way that the flow direction is changed when the ore hits the top of the stockpile. This results in particles bouncing away opening up the ore stream and releasing the fine particles which are caught up in the moving air stream that always follows a moving ore stream.

In addition the larger particles with sharp points often lose those points when they impact on the impact plate, which causes more particulate emissions. There are three ways to control the resulting particulate emissions, described in the section concerning transfer chutes and stockpiles. Impact plates are also to be found in crusher and screen feed boxes for example and the same solutions can be applied to these impact plates as well.

Crusher Dump Pocket/Grizzly Feeder

Dust generation occurs at truck tipping points because the material is allowed to free fall, it is disturbed from its resting place, there are always high impact zones associated with tipping points and the moisture of the material is usually lower than the DEM. This is an excellent point at which to modify the moisture of the ore stream and at which an appropriate chemical can be added.

Conveyors

There are three potential sources of dust resulting from the transfer of ore along a conveyor:

Ore passing over idlers

The ore develops small localised dust clouds at particular points along the conveyor. This can be the result of the movement imparted into the ore as the belt passes over the idlers and down into the trough between the idlers. This is usually insignificant because the fine particles usually fall back onto the conveyor and are removed. If however even a gentle breeze is blowing then these fine particles are taken away from the source and a dust cloud forms. There are three solutions to this problem.

The first and best way to stop this from occurring is to add water to the ore stream at some point/s upstream of the source of dust. However if there is insufficient water available either from a lack of water (the resource itself or an inadequate delivery system) or from a lack of transfer points in the ore handling system at which water can be added, then other solutions are needed.

Here are several “rules of thumb” for the addition of water into a moving ore stream.

- Add a maximum of 0.5% by mass of water to the free falling ore stream at any one transfer point.
- If adding water to the surface of the ore stream lying on a conveyor then do not add more than 0.2% per string or on an overland conveyor per 350 m length.

- Always remember that the sprays should be aimed to direct the water at the ore stream with no direct impact on the conveyor parts or structure.

The second solution that can be employed to stop wind erosion from the surface of the ore on the conveyor is to treat the ore stream with a chemical that will bind the ultra fine particles together without detrimentally affecting the ore itself. The chemical should contain a wetting agent to aid in penetration of the ore stream.

The last way to solve the problem is to install a wind barrier over the conveyor structure with an open end allowed on the leeward side of the conveyor belt for maintenance. This solution has two benefits, it is effective and it provides clear proof to staff and the community that the company is committed to dust mitigation. The disadvantages of this solution are the capital costs and downtime (assuming a Brownfields installation) that are required for installation.

Resonating conveyor structure

If the conveyor structure is not well designed then dust is often generated by the entire conveyor structure resonating. The solution to this is to modify the structure and stop it from resonating.

Dust not removed by scrapers

The next point at which dustiness occurs is the dust that clings to the conveyor belt and is systematically removed portion by portion at each return idler. This is best resolved by the installation of belt cleaning stations that are robust and work. There are a few suppliers that provide solutions that consistently work without significant maintenance costs. They supply both dry and wet cleaning systems. If it is possible the wet cleaning systems are the most effective in removing this clinging dust.

In-plant and overland conveyor transfers

There are two industry standards for dust mitigation at transfer points. The first is to ensure that there are water sprays, washing stations on the return side of the conveyor and sealed skirts with a sealing box with stilling chambers over and beyond (3 to 4 metres) the impact points. As an alternative a localised dust extraction system with sealing skirts and a sealing box is installed with scrapers that are also included in the dust extraction system on the return part of the belt.

Transfer points

Transfer points involve a falling stream of ore the dust generation principles of which are described elsewhere. They are usually the dustiest points in the entire plant.

Dust is created at transfer points in three ways:

- Fine particles are liberated from the ore stream as the ore cascades down the transfer point as described in the section regarding entrained and induced air in a falling ore stream.
- If impact plates are used to change the direction of the ore as it cascades through the transfer point then dust will continuously be generated at this point. Small pieces of ore are broken off larger rocks by the impact of these large rocks on the wear plates (and other steel members) of the transfer point. These fine particles are liberated by the energy imparted into them as a result of the impact.
- The ore stream drags air along with it into the transfer chute and this air is expelled at the ore exit, taking with it ultra-fine dust particles.

<u>Chute Design</u>

The solutions to this problem all reduce the energy imparted into the ore stream while it is being directed through the transfer point.

Hood and spoon chutes

Although there is much negativity surrounding hood and spoon type transfer chute systems because of their perceived high capital and operating costs, these systems if designed properly will provide not only a dustless operation but the NPV of the opportunity cost can be zero. The benefits of a hood and spoon transfer point are there is no impact point where dust can be generated, they are virtually noiseless, conveyor belt wear is reduced significantly and there are no housekeeping issues caused by dust build up.

Weba Chutes

Weba Chutes can be retrofitted into most existing chutes. They introduce a series of “rock boxes” located in a close cascade from the top of the transfer station to the bottom increasing the number of impact points but significantly reducing the energy imparted at each drop by reducing the drop height considerably.

Unichutes

The Unichute can also be retrofitted into an existing chute. This chute uses loose curtains hanging in the ore stream that slow the ore stream down and redirect it onto the discharge conveyor. There are restrictions in using these chutes and the supplier will provide this guidance if asked.

Any chute will become dusty of it is not properly maintained. Holes in the sides and wear plates allow the egress of fine particles which are released from the confines of the chute.

Moisture Split

During the screening process lump and fine particles are separated from each other. The result of this separation is that the moisture remains in the fines because of the significantly higher surface area inherent in fines and as a result the lump is dry. So when lump particles are broken in processes downstream of the separation they are prone to dustiness which may mean that water needs to be added to the lump at that point. This factor must be considered during the design phase of the plant.

Moisture Mixing

When wet ores are mixed with dry ores the moisture from the wet ores mitigates dustiness from the dry ores simply by being mixed into the dry fines. There is a secondary dust mitigating effect that aids in reducing the dustiness of a dusty ore when it is mixed with a less dusty ore. The ultra-fine particles in the dusty ore will find additional particles to which they can adhere and this reduces its dustiness.

2.5.3.4 Roads

The most well known dust sources on a mine are the roads. On an annual basis the roads at an operation will produce as much dust lift-off as the dust generated by the movement of the ore.

Chemical Treated vs. Water Only Treated Roads

Roads whose surfaces are treated with water alone increase in their dustiness with time. This occurs simply because the water keeps the dust particles in place without protecting them but allowing the vehicles using the road to drive over them continuously thus grinding the particles finer and finer until the dust size becomes ultra-fine. There is some mitigation of this when the roads are graded and resurfaced as part of the normal road maintenance.

In addition roads that are wet can become a safety hazard as the road surface becomes muddy and slippery. Poorly surfaced roads cause increased operational and maintenance costs due to high tyre wear, high rolling resistance. Poorly maintained road surfaces also lead to high vehicle cleaning costs because of muddy conditions.

Indeed even roads treated with most chemicals will be a source of dust because they cannot be swept clean on a daily basis since the sweeping activity slowly destroys the surface. Roads that are treated with a chemical such as bitumen, Portland or chemical cements and are then regularly swept clean will lead to less dusty and safer operating facilities.

Active vs. idle Open areas

Vehicles are a significant dust source and what is more they will exacerbate inherent dustiness by grinding the fine material on the road surface finer each time that they drive over an area. Also drivers of 4x4 vehicles increase the dust because they use 4x4 capability to go where they should not.

All open areas that are not required for vehicle access or construction should be isolated and sprayed with a hydromulch chemical. Hydromulch will provide seeds, the required nutrients and immediate cover against dust lift-off. Active areas must be kept to the absolute minimum with roads, parking areas and no-go zones specifically designated. Keep the roads treated with a suitable chemical.

If chemical veneers can be used on the open area in question then dust can be controlled very effectively by chemically treating the area. The application can be achieved with mobile irrigation systems or aeroplanes for large areas. Mobile irrigators can also be used to spray open areas. The irrigator pulls itself along which means that it is not labour intensive.

2.5.3.5 Stockpiles/Stockyards

Stockpiles are often dusty during the stacking and reclaim processes but they are also a source of dust when the wind blows. There are many ways to stop dusty conditions in the stockpile area.

Primary stockpile discharge points

Stackers must have sprays installed onto the boom as a matter of course.

A stacker boom requires sprays at the discharge end only.

If the ore is already at DEM, the nozzles should be low volume misting nozzles directed along the ore stream to stop the immediate dust. This will prevent run-off (creates poor housekeeping) caused by too much water. If however it is necessary to add water at this point then both misting and water addition nozzles are needed to stop the immediate dust as well as to increase the ore moisture. Both sets of nozzles should form part of the water curtain around the ore stream.

The nozzles on the stackers should have automatic and local control valves. The objective of installing local control valves is to allow an operator/maintainer to perform work on the nozzle/spray bar while the stacker is operating. The valves should however remain in automatic setting under normal conditions, which means that the manual valves should always be in the open position. A spray system that includes misting nozzles and low angle fan nozzles for trimming purposes is required.

<u>Mobile reclaimers</u>

Bucket wheel reclaimers generally require two sets of nozzles to manage dust. One set is needed to spray into the face of the stockpile immediately ahead of and behind the cutting wheel to stop dust that is caused by the ore as it falls down the face. The second set is needed to pray into the ore stream as it cascades out of the buckets into the transfer chute and onto the boom conveyor. The water must not be allowed to impinge onto the structure of the boom because that will cause fine ore to stick to and build up on the structure which will in turn upset the balance of the machine.

Dust caused by reclaim

This photo demonstrates clearly how dry ore will produce dust even if there are some sprays installed and turned on. These nozzles are not directed at the source of the dust and there are no misting nozzles. The same principles can be applied to other mobile reclaim equipment.

Stockpiles that are designed with a reclaim tunnel are inherently less dusty than are surface stockpiles. A stockpile with a large well designed tunnel provides a safe and dust free reclaim operation. The source of dust is the reclaim feeder and its delivery onto the reclaim conveyor. Dust mitigation can be affected by misting sprays directed into the falling ore stream.

Stockyard Cannons

Stockyard cannons play an important role in managing dust from the stockpiles because evaporation is a continuous process while the stockpile lies dormant.

Spray Pattern: Height

The water delivered by the cannon nozzles should be able to reach just over the top of the stockpile. In a high wind the spray would be blown about and entirely controlled by the wind. It is therefore imperative that water is sprayed onto the fines stockpiles prior to any strong wind event. Once the wind has started blowing strongly it is not possible to control jet stream. The Bureau of Meteorology (BoM) website can be used to plan for these events or specialised services can provide more detailed local information. Trend information (wind speeds) produced from the local weather station can also be used to trigger the commencement of the cannon spray sequence.

Spray Pattern: Coverage

There is usually a portion of the side of the stockpile that is not covered with water by the sprays. This occurs at the midpoint between the cannons and is a function of the circular arc produced by the spray cannon motion. These areas can be covered by a water truck with the correctly installed nozzles.

Distance from stockpile

The nozzle cannon stands should be located as close to the stockpile as possible but it is necessary to ensure that they do not fowl the movement of the equipment. Generally, the further the water jet has to travel the more it breaks up and the more it loses its effectiveness by being reduced to fine nozzle. This fine spray is then easily blown away and lost to the atmosphere.

Air

Droplet fineness can be increased by the correct introduction of air into the water nozzle.

Chemicals

If fines are a problem, adding a chemical into the water deluge nozzles in the crusher dump pocket and the grizzly underpan that will modify the ore's dustiness characteristics to prevent fugitive dust from being generated.

Chemical veneer

The use of a chemical veneer on stockpiles prior to any significant wind event will stop dustiness from the stockpiles. This chemical veneer can be sprayed onto the ore using the cannon system in a reconfigured state or using water trucks.

The concentration of this chemical would be determined taking into account the estimated wind speeds and the duration of the anticipated wind event, which means that the cost of the chemical is dependent on the anticipated event. These chemical veneers bind the fine particles together but do not stop water ingress or evaporation from taking place. The veneer looks somewhat like a spider's web when viewed close up.

Foam

Foam can be employed to drop dust at the discharge points of transfer chutes and along conveyors. However there have to date been no tests that have proven successful with this type of chemical.

Water trucks vs. water cannons

Water trucks and water cannon provide different ways to deliver water to the surface of the stockpile. The cannon is the mainstay of the delivery system but trucks being mobile can reach areas not covered by the cannon and can also be deployed when the canon system is down.

2.5.3.6 Water Management

Dust mitigation is most effectively achieved with water which means that a representative of the water management team of the operation should be involved in discussions, plans and changes to any dust mitigation system. Someone from the water management team should also be present during a risk assessment that is focussed on dust mitigation.

2.5.3.7 An automated particulate emissions control system

Managing particulate emissions effectively requires a coordinated site wide system whether the system is automated or not. An automated system can include the use of information gathered from:

- Weather prediction data (anticipated wind speed, precipitation, relative humidity and temperature);
- Local weather stations, (measured wind speed, precipitation, relative humidity and temperature);
- Planning for ore, waste and soil movement (blasts, mining, area clearing, delivery to and reclaim from stockpiles, plant operation, road use);
- Ore, waste and soil characteristics, (DEM, flowability, etc);
- Moisture information from analysers and laboratory samples;
- Weightometer readings;
- Site real-time particle monitors (e.g., Osiris); and

This information is then used to control:

- Material movement.
- Setup of water addition and mist spray systems.
- Chemical treatment system setup.
- Belt wash systems.
- Particulate emissions removal system run time setup

Particularly for larger operations, all these systems should be linked together to create a whole of site particulate emissions management system which is monitored by the operator, internal and external particulate emissions monitors, moisture analysers and weather monitoring systems and principally controlled by a PLC. The operator should only turn the system off when there is a system failure.

Specific menus for each ore type can be written for the PLC as the principal determinant of the water management scheme for that ore type, using local weather conditions and anticipated storage time on the stockpile as variables that modify water addition and/or chemical treatment. There are many scenarios that can be set up to run automatically if a complete system is implemented. For example when rain is anticipated it could mean that the use of water through the cannon system can be reduced if not turned off altogether. In the case of predicted high winds it may be necessary to spray the stockpiles either with water or chemically treated water depending on the strength of the winds prior to the arrival of the windy period. If a period of dry, hot weather is expected then the water cannon sequence start frequency can be increased to deliver more water.

The particulate emissions control system at Dalrymple Bay Coal Terminal is an example of a system that controls water dams, borehole and delivery pumps and water addition using ore movement, moisture analyser data, BOM and local weather station information as the inputs. Other systems now available incorporate the various data inputs into a real-time model that not only shows current impacts but also uses forecast data to predict air quality (dust, SO_2 and other) impacts ahead of time, and enabling various control scenarios to be tested by modelling ahead of time.

2.5.3.8 Taking the wind into account

Windbreaks and Wind Fences

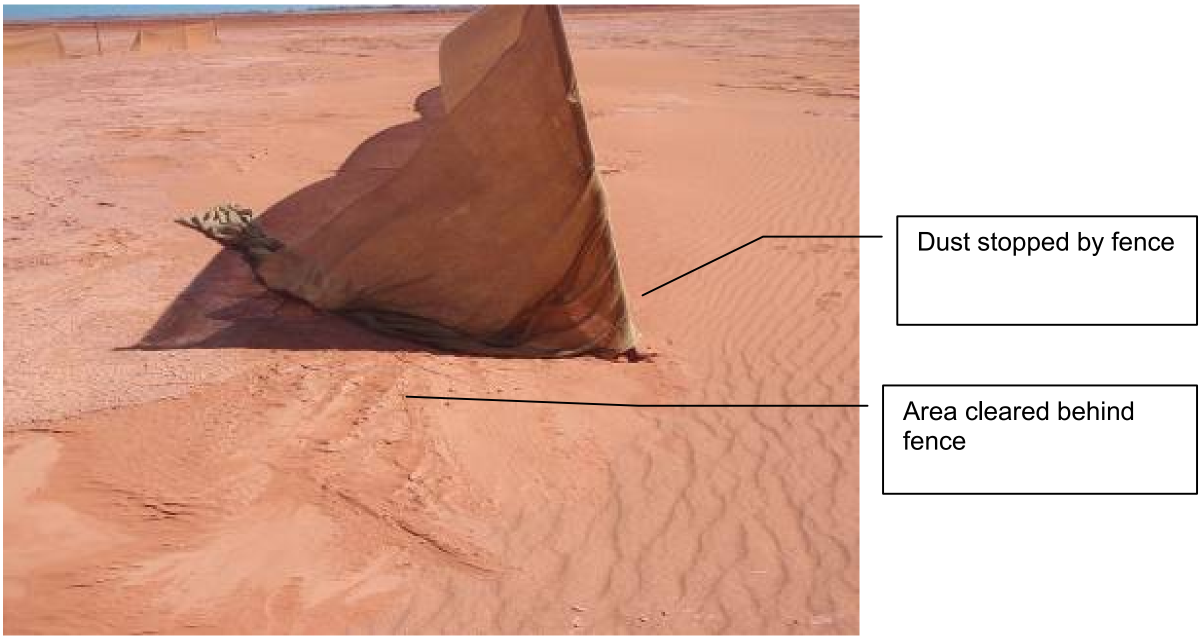
Windbreaks can comprise of fences, trees, hills and simply distance between the dust source and sensitive receptor.

Trees, bush and grass

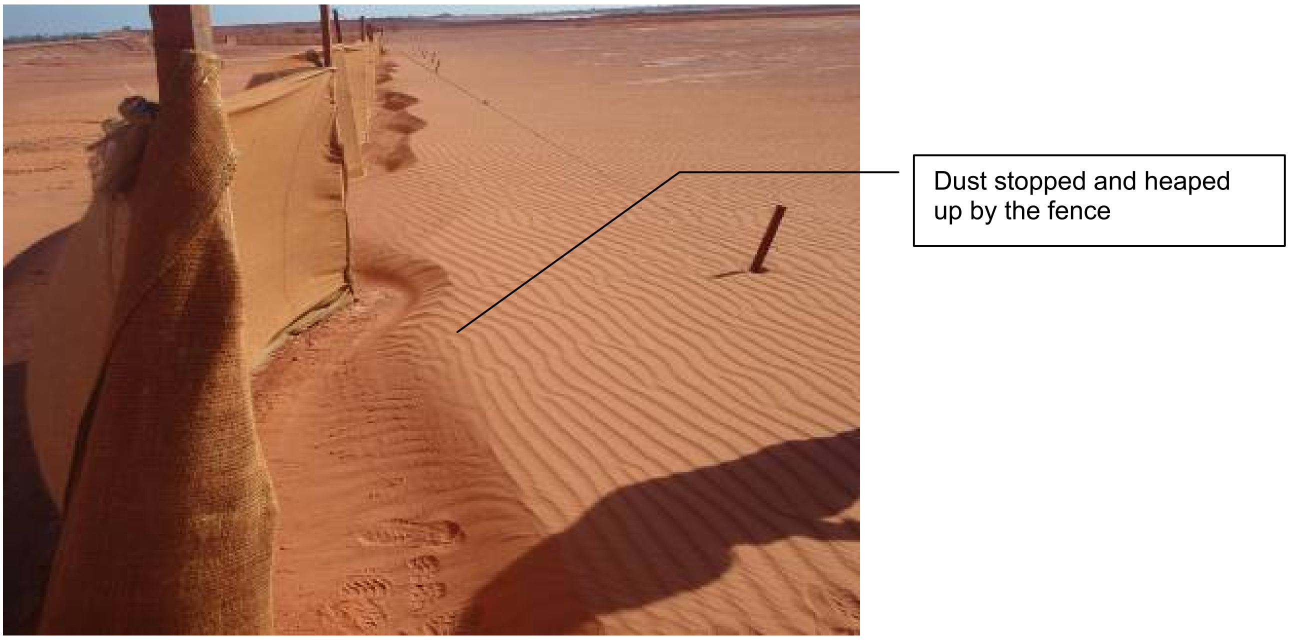
The most effective barrier to wind erosion and therefore dustiness on a site is to plant trees, bushes and grass both upwind and downwind of stockpiles, open areas and operating plants. They provide wind and noise protection. This is obviously a long term solution.

Wind Fences

Wind fences are used to stop dust from interfering with the local community in many places around the world but particularly and very successfully in Japan. A windbreak is more effective if the top of the windbreak is significantly higher than the area which it is designed to protect. This is why the Hessian fences in the figures below do not reduce the wind speed significantly but they prevent the low level dust from migrating across the surface.



Hessian Fences Stopping Dust Migration



Hessian Fences Stopping Dust Migration

The wind fence will change the wind speed on the ground as a distance away from the fence as far as 30 times the height of the wind fence. The fence porosity should be between 60% and

90%. Wind fences positioned upwind can be used to prevent dust problems by lifting the wind up over areas that have dusty materials on them.

In order for the fence to lift the wind off the dusty surface the fence is erected upwind of the dusty material. For example, a 12 m fence with a wind speed of 14 m/s will only really stop dust lift-off up to around 200 m. In general the dust lift-off wind speed is 10 m/s. Wind fences positioned downwind of the area with the dusty material will act as a dust barrier and will halt dust that has been picked up by the wind and drop it at the foot of the fence.

The problem with this option is that the fence must be raised as high as the dust cloud reaches to be completely effective and this is usually impractical. However this kind of wind fence provides partial protection by dropping the lower layers of dust (these layers generally contain the nuisance dust that causes community issues), and disrupting the wind forced to go up and over the fence which causes more dust to be dropped on the leeward side of the fence by slowing the wind speed there.

2.5.3.9 CFD and Dust Plume Modelling

Wind fences are expensive and with each terrain there are always disruptions to the wind velocity profile that will either increase or decrease the effectiveness of the wind fence. CFD modelling can provide the means of understanding and therefore optimising the effectiveness of a wind fence.

Modelling the prevailing wind velocity and terrain interaction is critical to understanding the effect that a windbreak will have on reducing the dustiness of the planned operation. CFD modelling should go hand-in-hand with wind tunnel testwork because there is always a need to calibrate the CFD model. Two different calibration types are necessary, the dust lift off factor and the wind velocity profile.

Once a CFD model is calibrated for a material, then it can be used to model many scenarios on that site in future without significant cost per run. The total cost of performing CFD and wind tunnel modelling can be paid back in months if the wrong location is selected without it being excluded by the modelling. The CFD modelling provides the wind velocity information and the dust plume modelling takes that information and demonstrates where and how the dust will be blown and finally be deposited.

2.5.3.10 Real-time and forecast weather information

The Bureau of Meteorology website http://www.bom.gov.au helps operators to keep abreast of the anticipated wind and weather predictions for the next day and week. This information can be used to plan activities that involve land clearing, ore movement, etc., and enables planning to avoid periods when there will be strong winds. In addition, use of the site weather station data is useful in real-time mode to verify conditions.

Detailed wind and rain predictions tailored to specific sites can be helpful if BoM data are not sufficiently targeted. Commercial services are available from some consulting firms, providing web-based data and predictions that utilise sophisticated models. An example of a frequently-updated predictive model is the ACARP forecast system for the Hunter Valley.

Case Study: Blast Overpressure Prediction System, Hunter Valley

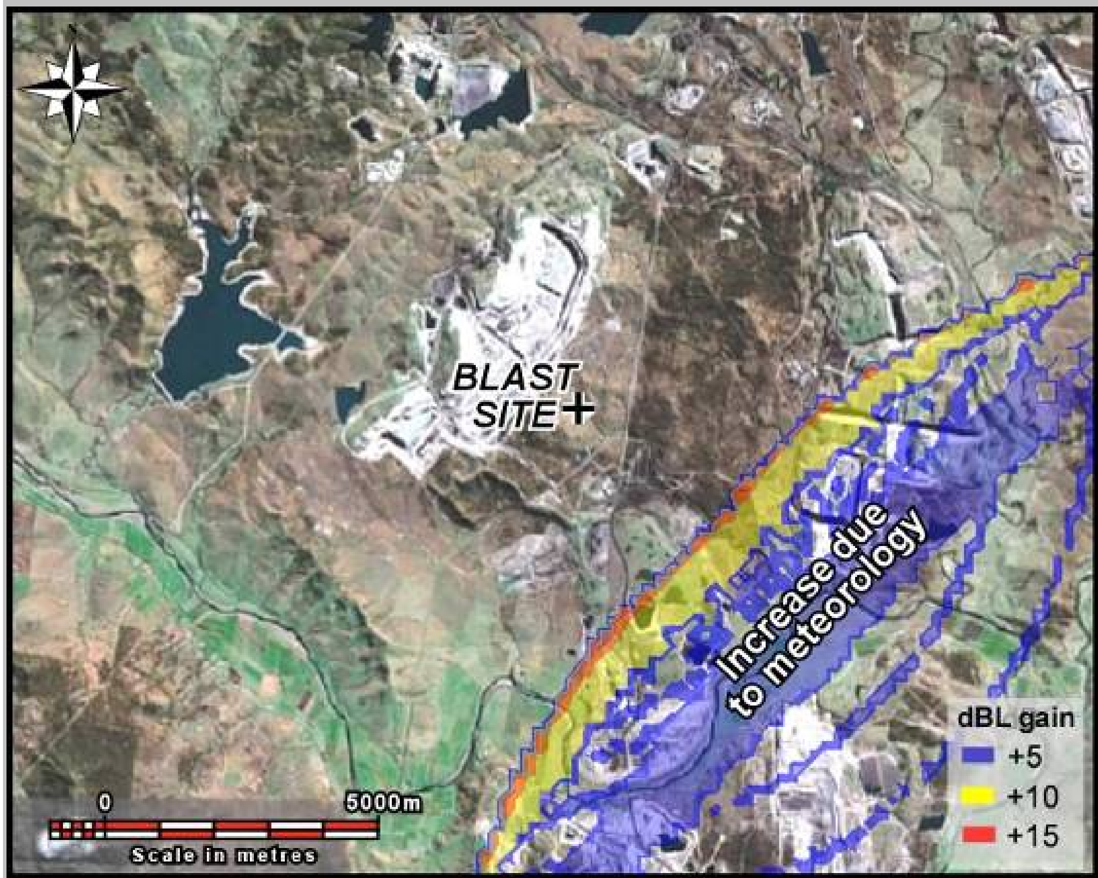
Blast overpressure levels experienced from operations on open cut mines depend on many factors including the design of the blast, the distance from the blast to the receiver and the prevailing atmospheric conditions. The way in which temperature and wind vary along the path through which the over pressure wave travels from the source to the receiver is particularly important in determining the overpressure experienced at the receiver.

ACARP Project 12036 (http://www.acarp.com.au/abstracts.aspx?repId=C12036) provides mine operators with information on meteorological conditions that allows the effects of atmospheric conditions to be taken into account before making the decision to blast. The approach taken uses the MM5 mesoscale meteorological model (http://www.mmm.ucar.edu/mm5/) with 24-hour hour forecasts from the Bureau of Meteorology supplemented by local observations of wind speed, wind direction and temperature in the lower atmosphere, to predict three-dimensional meteorological fields in the Hunter Valley. The local observations are provided by a SODAR and RASS (http://www.sodar.com/about_sodar.htm; http://eflum.epfl.ch/research/sodar-rass.en.php) centrally located in the modelling domain. In addition wind speed and direction data from ground based (10 m) sensors are also supplied to the MM5 model.

The model is run at least once a day and also at user selected intervals. The model output is processed to extract information on the predicted vertical profiles of wind speed, wind direction and temperature, extending from ground-level up to 1.6 km. Each time the model is rerun it assimilates local meteorological observations provided by the SODAR, RASS and other surface stations.

The model results are reprocessed to tabular and graphical summaries at selected sites coinciding with mine sites and other sites of interest. Data are uploaded to a public web site (www.huntervalleymet.com). Users can obtain data on wind and temperature profiles for any area of interest on the grid in a format suitable for input to a blast overpressure prediction model (http://terrock.com.au/envmet/envmet.html), or for any other use such as predicting dust events.

The model predictions are ultimately used to predict the enhancement of blast overpressure levels. This is done using a model provided by Terrock which uses MM5 data to predict (1) the level of enhancement (positive or negative) caused by meteorological conditions and (2) the absolute level of overpressure resulting from a blast. The results are presented as contour plots overlaid on a map of the area surrounding the blast. An example showing blast overpressure enhancement is provided in the figure below. The results are promising and the system appears to be a useful tool, in its current state of development, to improve the management of impacts from blasting.



Predicted blast overpressure levels showing zone of re-enforcement due to atmospheric conditions

2.5.4 Complaints Management & Community Liaison

One of the aims of dust management is to avoid or minimise the level of complaints. Complaints are an indicator of problems, and should be taken seriously, investigated and causes addressed. However, because complaints represent a subjective response to specific events or series of events, you cannot simply use the number of complaints as a definitive measure of performance. Complaints may be withheld for various reasons, or may be exaggerated to make some (sometimes broader) point. The absence of complaints does not mean that people are not being annoyed by dust. Therefore, it is important to maintain regular contact with potentially affected neighbours to ensure that there are no hidden issues that should be addressed on site.

Complaints should be documented in detail and recorded in a database that forms part of the AQMS. Recorded information should include the time, location, complainant details and nature of the complaint; who took responsibility for interviewing the complainant and what they reported; investigations on site to establish a cause; actions identified and taken to rectify the problem, and communication of the actions back to the complainant. In rare cases, there may be a vexatious complainant who will demand a significant amount of attention, without evidence of a real problem. In these cases, it is important that the situation be assessed carefully, and it cannot be judged on the basis of a single complaint: a vexatious complainant can only be identified after a series of unwarranted complaints, forming a clear pattern of behaviour. Once this does become clear, however, it is important to discuss the problem with the regulatory agency. Your clearly documented approach to dealing with this problem will be vital.

With dust or other air quality complaints there is often a question of properly identifying the specific emission source. A weather station on site, recording wind and other data every 1-10 minutes will provide a very useful basis for identifying the source. The short-term data will identify wind variations that may be crucial in getting a good result, as often the travel time between source and complainant will be only minutes or tens of minutes. It is now possible to use real-time systems to quickly display a calculated air trajectory from the site of the complaint back to a potential source. Such an approach is particularly useful where there are multiple possible sources of emission that could contribute to the problem, either different mines or industries in the area, or specific sources on an individual mine site.

As part of keeping the community informed about environmental performance, some companies provide public access to websites that display current and recent air quality monitoring data. For example, Rio Tinto Iron Ore and BHP Billiton Iron ore monitoring systems are on display at these sites: http://www.pilbarairon.com/ecotechindex.htm; http://newmandust.r-box.com.au/; http://porthedlanddust.r-box.com.au/

If making real-time data available via the internet, it is important to make the distinction between validated and un-validated data: sometimes raw data will need to be corrected or discarded after quality checks.

2.5.5 Reporting and Performance Reviews

An important part of the AQMP is reporting and review. The data collected by monitoring systems should be reported in ways that clearly show compliance with imposed or voluntary targets and objectives, and provide explanations of causes and remedial actions associated with any non-compliance. While a suitably detailed report should be provided, it is also important to make a simplified summary that conveys the essential performance measures in an easily appreciated graphical format.

Periodic, at least annual, internal review of performance is necessary to ensure that:

- compliance efforts are effective both technically and administratively;
- objectives remain appropriate;
- no new issues are emerging that require systematic attention; and
- information is being communicated to stakeholders effectively.

In addition, regular third-party audits of the program and performance are strongly recommended and may be part of site's quality system requirements. A successful outcome from the audit process will require that the AQMP and associated reporting is complete and transparent.

2.6 Closure/Rehabilitation

At this stage of a mine's life, the key air quality issues are generally associated with wind-generated dust from exposed areas. For closed uranium mines, radon flux from rehabilitated areas may also be significant, requiring careful monitoring procedures for accurate flux determination and hence management of the area (Bollhöffer *et al*., 2006).

Rapid rehabilitation of waste dumps and mined areas is the best way to reduce the dust potential, and this can occur progressively through the operational stage as well, as areas reach this condition. Apart from incompletely rehabilitated areas, there may be other sources of residual emissions notably tailings disposal areas, which by nature may be difficult to revegetate and which may be potentially large reservoirs of fine dust particles, in some cases containing hazardous components. For tailings areas there is no silver bullet for dust control or prevention. The best way to stop dust from affecting sensitive areas is to use several diverse factors or methods of dust control:

- Natural barriers.

- Chemical veneers.
- Water application.
- Wind fences.

Each of these methods provides different dust control effectiveness, utility and cost implications.

3 NOISE

3.1 OVERVIEW

Noise is amongst the most significant issues for communities located near mining projects. The growth in public awareness and expectations about environmental performance has led mining companies to focus their attention on the management and mitigation of potential impacts. Noise can interfere with day to day activities, particularly relaxing at home in the evening and trying to sleep at night time.

Noise from the resources sector is a common source of community concern because operational noise generation can occur on a continuous basis. In particular large mines plan to operate 24 hours per day 7 days per week and the mine may operate for many years. As the mine develops over large areas, different receivers are affected at different stages of the mine life.

Quarries may not operate continuously throughout the night, but may often want to commence loading at sunrise and work into the evening. They are also often located much closer to residences. Ancillary processes, such as transportation of product by road, rail or ship, including port operations also generate their own unique noise impacts. While site noise at source or even at the site boundary is generally well understood and is within the control of the Mine, understanding the likelihood of complaint is far more complex for two key reasons:

- Changes in meteorological conditions can result in significant daily fluctuations in noise levels at receivers (for identical on site operations). This is primarily wind direction and prevalence of temperature inversions, and
- Sensitivity to noise can vary significantly from person to person and carries a degree of subjectivity.

In other words, what happened yesterday is no indication of what will happen today and just because one resident is happy doesn't mean their neighbour is or the person they sell their house to will be. Remember, who came first has little relevance as to whether the noise is termed offensive and the Mine could be considered to be in breach of their approval conditions.

Nowadays it is likely that an acoustic consulting company would assist the Mine in much of the detailed analysis including interpreting state regulation, undertaking noise measurements and predictions, assessing potential impacts and designing mitigation measures. These organisations therefore just need to be effectively managed by the Mine's managerial, operational or environmental teams, who need an appreciation of the important issues.

It is the purpose of this booklet to give the Mine an overview of how they can achieve leading practice in environmental noise management during the critical phases of any mine development, which are categorised as follows:

- Planning Phase (Environmental Assessments) - establishes the existing environmental conditions and identifies potential impacts and mitigation methods including optimisation of the mine layout or the way in which the exploration program is conducted.
- Detailed Design Phase - once a mine development has been approved there is more certainty about a project and the opportunity for business to invest more heavily in the detailed design. This phase may therefore involve a repeat of many of the tasks undertaken in the planning phase, with the outcome being a comprehensive Noise Management Plan. This details the methods for management, monitoring and complying with the mine's environmental objectives and should also address a proactive liaison with the community.
- Construction, Commissioning and Operation (Monitoring and Audit Programs) - this is the time when all the talk is over and noise is now being generated on site. It therefore assures the Management Plan and quality objectives are continually verified and deals with complaint response.

In the various phases this includes techniques to reduce noise which the Mine can control and information to help the Mine understand and manage the effects of noise they can't control. Case studies have been included throughout to illustrate the effective use of leading practice techniques to mitigate and manage noise.

The benefits of leading practice environmental management to minimise noise, are immediate and while some may include an upfront capital investment, they ultimately provide cost savings through increased efficiency and in many instances improved occupational health and safety. In addition to benefiting individual companies in the short-term, the resources sector will profit both economically, and in the improved regulatory / community acceptance and attitudes towards mining activities.

3.2 Sources of noise

Resource exploration, extraction, processing and transportation have the potential to produce significant levels of noise which may impact on the surrounding environment. Communities can experience noise and vibration impacts from mining operations in many ways, not just from the mine site. Rail and truck haulage are also required off site, with product leaving via ports which are all part of the logistics.

Open cut mines require large earth moving equipment such as dozers, excavators, loaders, haul trucks and face shovels, plus kilometres of conveyers. Air track drills are required for blasting. For underground mines large ventilation fans are required. Processing of materials requires stackers and reclaimers, crushing and screening plant, coal washeries with the associated noise of material being tipped and separated, again conveyers and rill towers and rail or truck unloading facilitates are common.

3.3 Health Amenity

Noise levels at residences surrounding mines are generally not high enough to have direct effects on health, such as hearing loss. The effects of noise and vibration on the health of people exposed to excessive levels have been extensively documented. Investigations have found that prolonged exposure can adversely affect mental and subsequently physical health, particularly in those most sensitive to noise.

There are very specific ways that noise produces psychological effects. These are, essentially, interference with communication or concentration and sleep disturbance. These factors lead to irritability which is the first sign of the psychological impact of noise. The psychological response to noise is determined by personal factors and by factors associated with the noise itself.

Low frequency noise can be particularly annoying and can result in complaints many kilometres away from the source. Low frequency noise can be considered to range in frequency from about 10Hz to 200Hz. The common sources are large pumps, motors or fans and crushing circuits and screens. The perceived loudness and annoyance due to low frequency noise increases extremely rapidly with increasing level above the threshold of hearing.

Sound in the frequency range below 20Hz is normally defined as infrasound and can be heard (or felt) as a pulsating sensation, pressure on the ears or chest, or can cause secondary effects such as rattling of windows or doors.

Because low frequency noises between 20Hz and 200Hz propagate with minimal attenuation over large distances and transmit more easily through building fabric they can be perceived as more annoying when inside residences because some of the masking effect of higher frequencies is absent. When determining compliance, most regulatory authorities have objective tests to determine if low frequency noise is present, which requires an adjustment to measured levels to be made to account for the increased annoyance.

The attitude or mood of the person, his or her environment, the degree of arousal or distraction and whether the noise is felt to be an invasion of privacy or disruptive will dictate personal response. This is important for shift workers who sleep during the day. The predictability of noise and how frequently it occurs will also influence the reaction.

3.4 Fauna

The effect of noise on animals can be similar to the effects observed in humans. Noise can adversely affect wildlife by interfering with communication, masking the sounds of predators and prey, cause "stress" or avoidance reactions and (in the extreme) result in temporary or permanent hearing damage. Experiments have also shown that exposure to noise impulses throughout their sleep period resulted in poorer task performance, remembering some animals are nocturnal.

Research into the effects of noise on animals is relatively scarce. The results obtained from the studies conducted are frequently contradictory or inconclusive. It does appear reasonably conclusive however, that as with humans, animal reactions to noise vary from species to species.

3.5 Propagation of Noise over Large Distances

One factor the mine has no control over is the influence meteorological conditions have on the propagation of noise, particularly over large distances (greater than 500m). Some understanding of these effects is critical if the Mine is to effectively manage noise impacts.

3.5.1 Wind Effects

Steady light to moderate winds produce higher noise levels downwind, and lower noise levels upwind from a given source than in still air. Wind effects on noise are influenced by the following factors.

In general (and depending on the amount and type of local vegetation), a steady, gentle breeze of less than about 1.5 m/s can increase noise levels without increasing background noise levels. On the other hand, winds of higher velocity tend to increase background levels due to turbulence or movement of trees and shrubs, and obscure other noise sources. Downwind, wind velocities up to about 1.5 m/s can enhance noise levels by in the order of 5 dBA relative to still conditions, assuming flat topography between sources and receiver and more if shielding is provided by natural topography . Conversely, noise levels upwind may be reduced by a similar amount.
It should be noted that noise enhancement due to wind effects is extremely site specific and significant variations from the "typical" changes in level can be expected.

3.5.2 Vertical Temperature Gradients

Air temperature normally decreases with altitude, a condition known as temperature lapse. A temperature inversion occurs when a layer of air has its temperature increasing with altitude, or at the boundary between a lower cool layer and a higher warm layer.

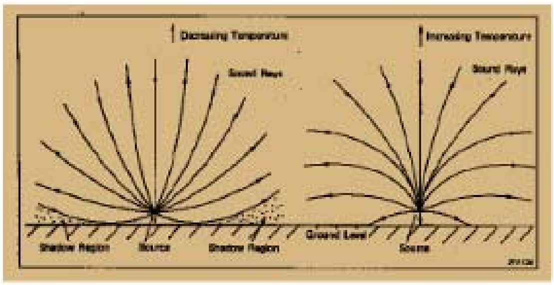


Figure 3.0 Noise Propagation Under a Temperature Inversion
Source: after Hassall, J R & Zaveri, K, 1979

In winter, radiation inversions are normally associated with drainage flows. The drainage flow is modified by topography and the extent of this effect would depend on the depth of the inversion layer.

Wind and temperature inversion effects generally apply to all noises. Temperature inversions appear to affect low frequency sound more than higher frequency sound. This is possibly because of the relatively large distances involved, the higher frequency sounds are readily attenuated by other effects (eg atmospheric absorption). Since temperature inversions normally appear at night and disperse an hour or two after sunrise in the summer period, noisy events should be planned around these periods. In areas which are prone to severe inversions, excessively noisy activities should be avoided on overcast days when possible.

In summary, certain meteorological conditions can result in increased received noise levels so what seemed acceptable yesterday may cause complaint today.

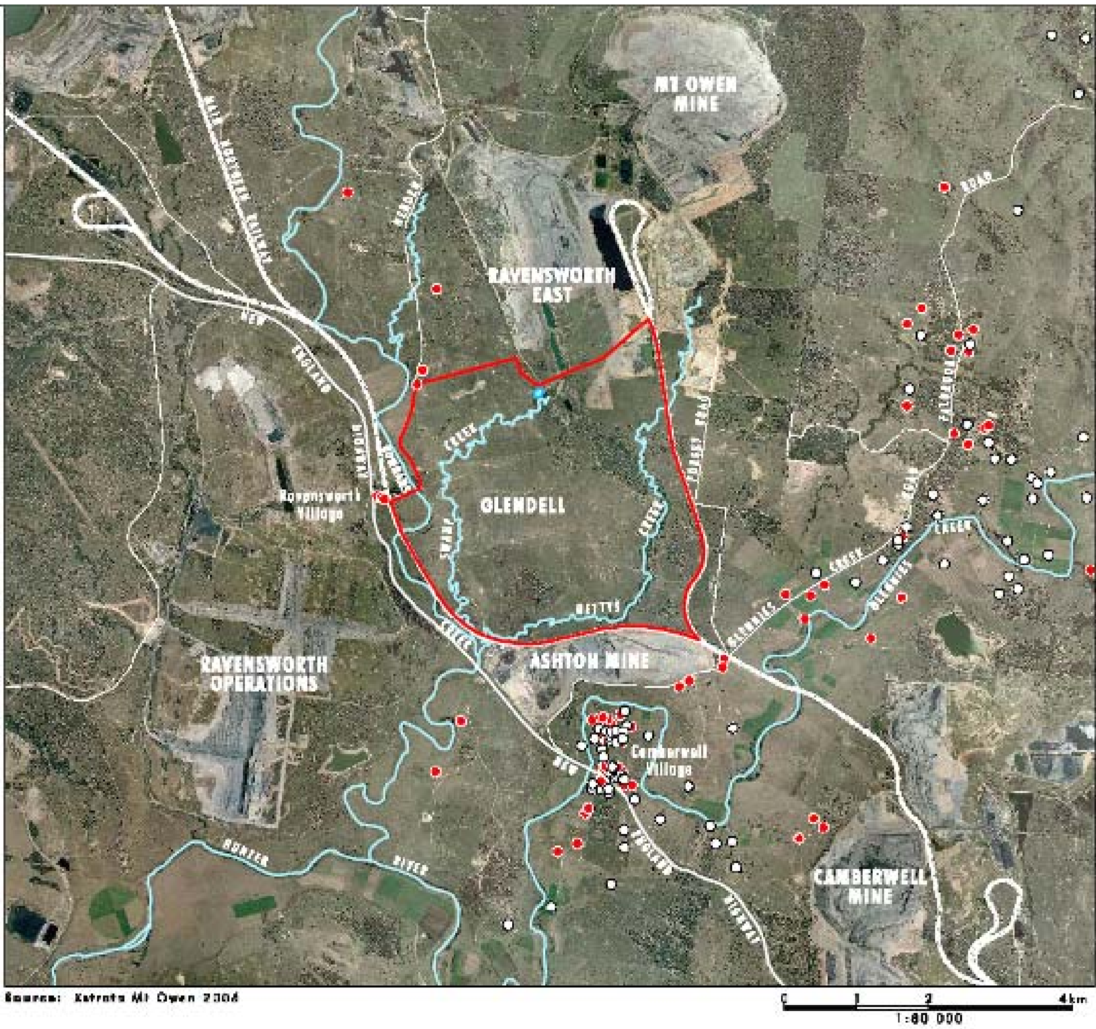
3.5.3 Low Frequency Noise

Propagation over large distances can also exacerbate the effects of low frequency noise. Higher frequencies are more readily attenuated by atmospheric absorption and ground effects which can remove the masking effects provided by these frequencies.

3.6 Cumulative effects From Multiple Mines

Not all states have noise guidelines to effectively address and prevent the cumulative noise impacts from multiple mines, such that the individual mines need to understand and address this issue, in conjunction with their neighbouring mines.

In some regions there may be multiple mine sites which can affect the same residential receiver, albeit not at the same time. A good example is the village of Camberwell in the Hunter Valley, as shown in the attached Figure, which has at least six separate approvals across three mining companies.



3.7 Noise characteristics and Glossary of Acoustical terms

The annoyance characteristics of noise are also subjective. Whether or not a noise causes annoyance mostly depends upon its reception by an individual, the environment in which it is heard, the type of activity and mood of the person and how acclimatised or familiar that person is to the sound.

Sound is measured in decibels (dB). When measuring environmental noise, a weighting network is used which filters the frequency of the sound so that it better corresponds to the response of the human ear. Noise measurements made using this weighting network are expressed as dBA.

The decibel scale is logarithmic to manage the enormous range of sound pressures able to be detected by the human ear. This often leads to confusion. For instance, if two machines emit exactly the same noise level of 80 dBA, the total noise level is not 160 dBA, but 83 dBA a doubling of intensity, which is barely noticeable from one day to the next. Also, a 10 dBA increase in sound level (whilst a 10 fold increase in intensity, only represents a subjective doubling of loudness.

Typical examples illustrating the decibel scale are shown in Figure 1.0

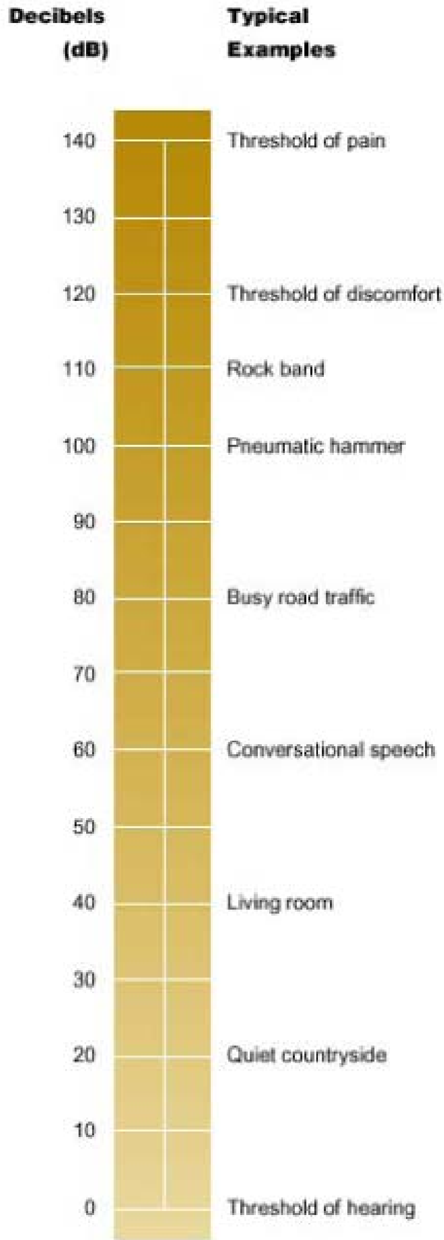
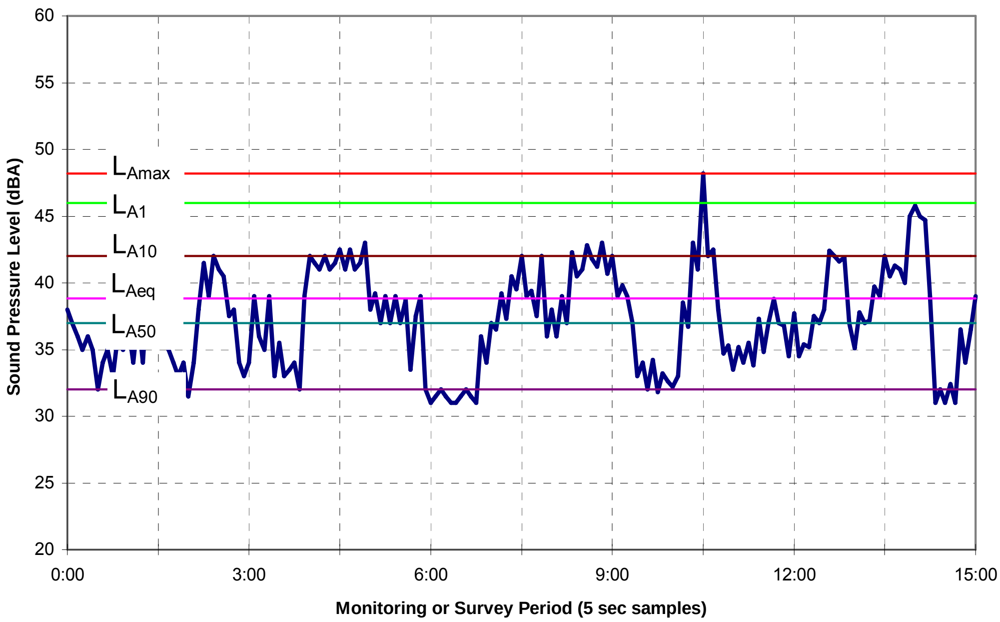


Figure 1.0 The Decibel Scale

Noise emissions are measured using sound level meters which detect and record changes in sound pressure. More expensive models can also include frequency information. For surveys of background noise, environmental noise loggers are generally used, which are really sound level meters in a “black box”.

To describe the overall noise environment, a number of noise descriptors have been developed and these involve statistical and other analysis of the varying noise over sampling periods, typically taken as 15 minutes. These descriptors, which are demonstrated in the graph below, are:

- Maximum Noise Level (L_{Amax}) – The maximum noise level over a sample period is the maximum level, measured on fast response, during the sample period.
- L_{A10} – The L_{A10} level is the noise level which is exceeded for 10% of the sample period. During the sample period, the noise level is below the L_{A10} level for 90% of the time. The L_{A10} is a common noise descriptor for environmental noise and road traffic noise.
- L_{Aeq} – The equivalent continuous sound level (L_{Aeq}) is the energy average of the varying noise over the sample period and is equivalent to the level of a constant noise which contains the same energy as the varying noise environment. This measure is also a common measure of environmental noise and road traffic noise.
- L_{A90} – The L_{A90} level is the noise level which is exceeded for 90% of the sample period. During the sample period, the noise level is below the L_{A90} level for 10% of the time. This measure is commonly referred to as the background noise level.



3.8 Planning / Environmental Assessment Phase

Good planning is essential to mitigate noise impacts which might otherwise affect the surrounding community or the natural environment. Optimising the design and layout of a mine from the very earliest phase, or the way in which an exploration program is conducted, with the assistance of an acoustic specialist can minimise impacts and assist in meeting community expectations.

The first step in implementing leading practice for a new project or redevelopment of an existing project is to ensure you have appropriate expertise on your team. The team will conduct an environmental assessment that examines the proposal in detail and identifies all the potential sources of noise. The stages of work in the planning phase can be broadly categorised as follows:

- Background or Ambient noise monitoring within a potentially affected community.
- Setting noise criteria / design goals for assessing adverse impacts including on site and off site noise. The criteria vary slightly from State to State so are not covered in detail; refer to the EPA in each state.
- Predict noise levels for a number of future scenarios including on site and off site (transportation). This typically involves a comprehensive computer noise model.
- Where the assessment shows that the noise criteria will be exceeded, there is a requirement for feasible and reasonable mitigation measures to be incorporated which will enable impacts to be effectively reduced. Where this is not possible it is likely that acquisition of properties will be necessary.

3.9 Background or Ambient Noise Monitoring

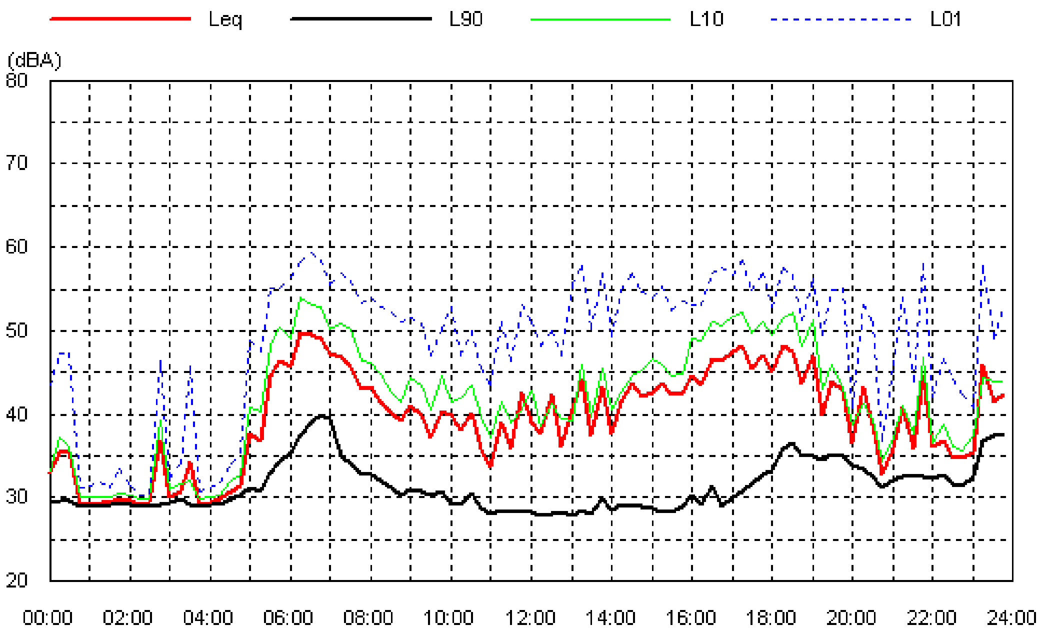
As part of the environmental assessment process for any project there is normally a requirement to understand and measure the existing ambient noise environment. Monitoring normally takes the form of unattended measurements using an automatic noise logger. The monitoring should be conducted over a sufficient time period to reflect the true and repeated conditions typically experienced in the area which are not unduly influenced by seasonal variations due to temperature inversions, winds, insects etc. In practice, continuous monitoring is conducted for a minimum of one week period at representative surrounding residences or other noise sensitive receivers (e.g. schools or churches) ideally prior to the mine being operational or while the mine is not operating.

The information obtained from these measurements (see figure below for example) is normally used to set criteria for the project. Of most importance is the black line known as the background noise level (technically the L_{A90}), which is normally measured in 15 minute periods.

Meteorological conditions can significantly influence noise levels. Steady wind, for instance, generally causes an increase in background noise levels due to wind in trees. Strong winds and rain can lead to falsely inflated noise levels. To enable periods of adverse weather to be identified, a weather station should be set up to continuously monitor wind speed and direction and rainfall. Noise data should then be filtered for periods of weather conditions that had an influence over the recorded noise results.

Some residences surrounding new mine sites already experience noise from road traffic, rail lines, other existing mines, or other intrusive noise. In these situations, in addition to unattended monitoring there may also be a need to do attended noise monitoring to understand the existing noise levels and estimate the contribution from each of these sources. These measurements may also provide a way of validating the noise prediction methodology to be used in assessing noise from the project. Often measurements many be done at one or two representative properties in order to validate any predictions.

Example of environmental noise logger in operation.



Example of chart output from noise monitor.

3.10 Regulations

3.10.1 Operational and Construction

Noise guidelines vary across Australia but generally they comprise two different aspects - a control on the emergence of mine noise above the background level, and/or an absolute level which would vary between daytime, evening and night time.

In very quiet areas the criterion is normally determined based on the emergence above background, while in areas with existing industrial or road traffic noise it may be the absolute or "amenity" criteria which is most stringent. The "emergence" criterion is for mine noise (typically measured over a 15 minute period as an L_{eq} or L_{10}) to not exceed the background noise level (measured as an L_{90}) by more than 5dBA. If the mine noise has "unpleasant" characteristics at the receiver ie tonality or, impulsiveness, then it is necessary to add a correction factor to the measured or predicted mine noise.

To prevent successive developments from causing "background creep", planning levels are often set below the existing background to ensure that the cumulative effect does not result in the background noise environment exceeding an acceptable level.

In addition to these criteria, there is also the requirement to consider the potential for sleep disturbance at night time. This could occur due to noisy crashes and bangs from shunting wagons, or the first load being dumped in an empty haul truck. The assessment normally considers an emergence above the background level, but addresses the short term maximum noise level rather than an "average" L_{eq} or $L_{10.}$

3.10.2 Transportation Criteria (Off Site)

Rather than needing to achieve a "background +" criteria, the approach for transportation noise sources often just nominate an absolute limit to be achieved either on an hourly, daytime and night time or 24 hour limit. If these criteria are already exceeded due to existing "traffic" then the normal approach is to limit any further increases in noise.

3.11 Modelling future Mining scenarios

Predicting noise emissions from mining projects is usually conducted using environmental noise modelling software. There are a variety of noise prediction software packages available and so long as they use industry recognised algorithms they should be acceptable. Your acoustic specialist will normally have a preference and you should understand which one they are proposing to use and how output from the model will relate to noise levels in the community. Its ability to handle different meteorological conditions is very important

A noise model will require three critical bits of information:

- Ground topographic data to represent the mine footprint in several stages of its life. This includes depth of pits, location and gradient of haul roads;
- Location of all plant and equipment and an estimate of its noise generation at that time. You need to imagine an aerial photo taken at a time, representative of a typical worst case scenario (not an absolute worst case), to describe where equipment would be. This will probably be revisited several times during the modelling; and
- Meteorological conditions from on site station (or nearby) over several years.

Noise models can be particularly useful in determining the ranking of noise sources on site and therefore changes in noise contribution from a mine at a residence, as a result of changing operational scenarios or incorporating noise mitigation measures. As a planning tool they may provide data on "average" noise levels expected at receivers, sufficient to allow planning type decisions.

Of course at this stage of the project there is no alternative, but the Mine must understand the limitations of any noise model. What a noise model can't do (at least on day 1) is predict with a high degree of accuracy (1 or 2dBA) what the noise level will be at a particular residence over a 15 minute period for a specific site operational scenario. Over time (several years) with enough validation, the noise model should evolve during the detail design phase and also operational phase such that it becomes very site specific and more accurate.

3.11.1 Uncertainty of Models/sensitivity to input data

Noise models are only as good as the information entered. Most are developed using empirical data based on measurements conducted in various parts of the world over the last 30-40 years. They are poorly developed with respect to meteorological conditions and assume that only 1 "set of conditions" exist along the noise path from source to receiver. This clearly does not occur in practice, hence a range of measured noise levels would be expected for a "set" of wind speed and direction or temperature inversion strength. Models can therefore represent the best fit or average of measured data. It is important to realise that the range of noise levels can easily be 5dBA and up to 10dBA for the meteorological conditions which are considered to exist at the time.

3.12 Mitigation / Acquisition

At the planning phase "in principle" measures need to be identified to reduce noise at source, but at many sites the Mine will also need to consider the acquisition of some properties. On site control measures that have been used successfully by companies employing leading practice include:

- Selecting low noise plant.
- Optimising mine layout to shield noise generating plant and haul roads.
- Additional silencing of fixed and mobile plant and mine ventilation fans.
- Acoustic enclosures around process plant.
- Use of "smart alarms" to minimise complaints regarding reversing alarms.
- Minimising tonal components or impulsive or intermittent characteristics.
- Strategically designed bund walls for acoustical screening.
- Incorporating buffer zones and landscaped setbacks.

3.13 Exploration/Development/Detail Design Phase

Now planning approval has been granted or is expected to be granted, the detail design phase commences. During this phase of the project most of the work done during the planning phase will be revisited in more detail. Three critical documented outputs (which all interrelate) are required from this phase as follows:

- A detailed plant and equipment noise specification for suppliers to achieve;

- A far more detailed review and design of mitigation measures including a schedule showing position and height of noise mounds or engineering designs or performance specifications for special enclosures and cladding of buildings; and
- A Noise Management Plan. Developing such a plan is often a condition of approval and implementing the plan will fulfil licensing requirements.

3.13.1 Plant / Equipment specification

It is critical that assumptions about noise levels of equipment made during the EA process are understood and correctly transferred into specifications for the supply of plant and equipment. This should specify noise levels under certain load or speed conditions at certain distances from each side of the plant. There are Australian or International test standards which should be quoted where possible to avoid any ambiguities in the supply of equipment. The specification should also require testing by independent accredited personnel once delivered or installed on site (refer Section 3.14.1).

If buildings or claddings which house equipments are being specified, either a detailed design or performance specification should be included. Unfortunately where noise is concerned it is the little things and attention to detail which matter. A rule of thumb is that 90% of the noise can escape from a 10% opening. So if you have gone to the trouble to design a concrete clad building with excellent sound transmission loss, but forgotten to treat the openings for fresh air, the effort and expense will have been in vain.

3.13.2 Environmental Management Plan including Noise & Vibration MP

Developing a Management Plan for noise is the documented outcome from the next phase of any Mine development. The Noise and Vibration Management (NVM) plan should be developed during the mine detailed design phase. Its major purpose is to demonstrate the company's commitment to achieving environmental goals (usually noise criteria in conditions of consent) by clearly establishing the existing environmental noise, stating the design objectives, statutory requirements, control measures, emissions monitoring and reporting program and procedures for handling of any exceedances and complaints and community liaison procedures.

It is likely that more ambient noise monitoring is conducted (refer Section 3.14.2) and the computer model developed for the EA is further refined and updated as more certainty about plant type and location are developed (refer Section 3.14.3). In addition, the noise mitigation techniques should be reviewed in detail

3.13.3 Hierarchy of controls

Measures which are commonly adopted include (in order of decreasing effectiveness):

- Selecting lower noise plant and equipment incorporating available noise control kits. This should be among one of the first measures chosen to minimise noise impact. For example, exhaust and radiator silencers on large earthmoving plant will generally result in a 5dBA noise reduction. When investigating engineered solutions for plant and equipment, at the very least consideration should be taken for thermal performance, servicing requirements, OH&S, and weight limit restrictions.
- Adding attenuators to mine ventilation fans. As with silenced plant items, this should be one of the first management options to ensure that fan noise levels will be reduced by a predetermined margin and emissions will not exceed acceptable limits.
- Providing acoustical enclosures and acoustical treatment of process buildings. This is a very effective solution for crushing plant, coal washeries and the like. A reduction in the order of 10 dBA can be expected from a lightweight sheet metal enclosure. Ventilation openings should be oriented away from noise sensitive receivers.
- Regulating emissions from reversing alarms. "Smart" alarms can be selected which limit the reversing signal to 10 dBA above the ambient noise level, thus reducing intrusiveness particularly at night.
- Optimum placement of waste dumps, location of haul roads, location of fixed plant such as crushers and loading hoppers. Waste dumps, stockpiles etc can be used to shield fixed items of plant which generate noise.
- Eliminating tonal, impulsive or intermittent noise emission characteristics. These characteristics are more likely to cause annoyance because the likelihood of complaints is less for a continuous broadband noise than one which is intermittent and/or tonal. Tonal components are often due to a fault in the machinery and may be eliminated by appropriate maintenance. Advanced control systems allow for switching between audible alarms during daytime operations and light alarms during the quieter night period. Using strobe or flashing lights will eliminate intermittent and impulsive noise generated by audible alarms.
- Provision of sound walls and acoustical screening. This option is generally effective when plant is operating at ground level in close proximity to the bund wall. Also, earth embankments can often be constructed from overburden, etc from stripping and initial excavation works and provide an alternative means of stockpiling soil for future rehabilitation works. However, the use of bunding becomes less effective the further the noise source and the receiver are located from the bund.

- Incorporating optimum buffer zones and setback distances. This is most effective where large distances are involved. In general, doubling the distance between the source and receiver will result in a 6dBA reduction in noise level.
- Acoustically treating dwellings. This is generally seen as a last resort as the overall reduction achieved often does not justify the cost involved. Also, no improvement in outdoor amenity is achieved.

Low frequency noise can be particularly difficult to mitigate due to the long wavelengths involved. All building materials attenuate higher frequencies more readily than low frequencies. Massive building elements such as concrete walls, or drywall type construction with large air cavities will be required. Ventilation openings are likely to be a particular issue as most louvres and attenuators struggle to make a dent on low frequency noise. Specialist advice should be sought for the design of enclosures around equipment with significant low frequency components such as pumps, crushing circuits, screens and large motors or the like.

3.14 Construction/ Commissioning/ Operations

The third phase in the management of noise is to implement a comprehensive monitoring and audit program during the construction, commissioning operation and even the closure/rehabilitation phases. This program provides the mining company with a means to maintain a continuous record of environmental noise emissions. The development in technology now allows for data from monitoring locations at residences around the mine to be available real time to the mine manager on which operational decisions can be reliably made. The audit program also addresses the company's procedures for dealing with complaints and ensuring quality objectives are met.

3.14.1 Compliance monitoring on site (Equipment Noise Monitoring)

During the commissioning or early operational phase of the mine that the mine owner will often want to confirm that the equipment supplied meets the Sound Power Level (SPL) values assumed in the environmental assessment process (which should have formed part of equipment specifications).

This form of monitoring is normally undertaken by experienced acoustic consultants in attendance at the mine site with either a conventional sound level meter or more sophisticated measurement techniques such as noise intensity or even acoustic cameras. Generally sound pressure level measurements are made at a known distance from a source which can then be converted to a Sound Power Level for comparison with a specification.

In addition to an overall sound level measurement (dBA) these sorts of measurements can also be done in octave bands or third octave bands in order to determine the frequency content. Detailed procedures for such measurements are generally found in Australian or overseas Standards, and for comparison with contract specifications these procedures need to be followed accurately.

Intensity techniques can be useful to isolate particular sources or breakout of noise from buildings. The acoustic camera gives a clear visual indication of hot spots, when used by a professional who understands the technical limitations of their particular device.

3.14.2 Compliance monitoring off site -Compliance / Complaint Response Monitoring

This is probably the most controversial area of noise monitoring, not because the measurements are complex, but because there is much room for interpretation regarding the quality and quantity of data required to get the "right" answer. Much of this interpretation relates to the question of whether consent conditions require that noise criteria never be exceeded under any circumstances, or whether they would allow noise criteria to be exceeded over a small proportion of the time (typically less than 10%).

Compliance monitoring has traditionally required attended visits to the site once a quarter to monitor for possibly only one or two hours at a number of representative receivers surrounding the mine site. Monitoring is generally conducted at night. Clearly the noise levels at this time are heavily dependent on the actual activities on that night and in particular the weather conditions. If a residence is upwind, noise levels could be inaudible and not measurable. Alternatively, a residence downwind on a particular night could have high levels of noise that are not experienced very often. There are clear shortcomings in compliance for a whole year being determined by such measurements over such a short amount of time.

As an alternative to attended compliance monitoring, equipment similar to that used for background noise monitoring can be deployed at the site. But often in these rural / semi rural environments there are many other sources of ambient noise which occur at the same time as noise from the mine site and therefore mask mine activities, such that it is almost impossible to determine when noise can be definitely attributed to the mine. Only if noise from the mine site is constant in nature, such for a residence very close to a ventilation fan, can this technique be used with some confidence.

The one advantage of attended compliance measurements over unattended measurements is the ability of the engineer at the time to be able to estimate what proportion of the noise is attributable to the mine site. Depending on the relative contribution of mine noise and ambient noise this could be up to 2-3dBA in error. While this is not a large difference, it is important enough, and in some cases can change the result from assumed compliance to non compliance

Recently there have been significant technological improvements in noise monitoring and communications equipment, and a corresponding update of approval conditions which more often now have requirements for “real time” monitoring. As these sorts of conditions become prevalent, both unattended monitoring with “unintelligent” devices and attended monitoring are likely to be used much less frequently.

Example of Remote Monitoring set up including noise, weather and wireless comms

The changes in measuring technology evolve as computing power increases. It is now possible to store large amounts of data on memory which can be downloaded either real time over a network or physically onto an external hard drive or USB stick. Unattended monitoring devices as a minimum should now be able to:

- Measure overall dBA levels;
- Include a low pass filter (so low frequency noise normally associated with a mine can be separated from higher frequency noise from birds and insects);
- Record data (continuously or on trigger as required) in either a .WAV format (preferred) or mp3 if just rudimentary source detection is required; and

- Update a central database on a real time basis - typically every 5 minutes.

These minimum equipment features, together with post processing of data (including listening to recorded files to eliminate non-mine noise), and some knowledge of the site and its operations, allow a much better evaluation of compliance. Further enhancements to the features above are also available such as Directional Noise Monitoring. This technology is capable of determining the level of noise which comes from the direction of the mine (including options such as low pass filtering), and can compare this value directly to the criteria for the mine, without the need for post processing.

This equipment can be set up remotely (solar/batteries) and, with either wireless or mobile phone communications, can feed real time data back to the mine site. The information can not only be used for compliance reporting on a daily, weekly, monthly or quarterly basis, it can also give real time information to the production manager such that mine operational activities can be altered on an hourly basis (if need be) to ensure that noise limits are achieved when weather conditions could produce noise levels exceeding the limit.

In the context of maximising production and remaining within noise limits at all times this technology is a viable approach:

- Summary of measurements exceeding the criteria levels, and description of the noise and whether it can be determined if the plant or operations caused these exceedances. A comparison of the measured noise levels to a verified noise model should also be included.
- Details of corrective action applicable to criteria exceedances and confirmation of its successful implementation. The status of corrective action should be indicated.
- Details of any complaints regarding noise and vibration including the complainants home, address and contact number.
- Details of the response to complaints (including supplementary monitoring, corrective action etc).

Directional Noise Monitor

3.14.3 Real time model (Noise Profiling)

As discussed above in relation to noise monitoring often the ambient noise environment includes many noise sources of which your Mine is only a component of overall noise. Therefore when monitoring noise, the ambient noise may exceed a project noise goal. However this does not necessarily mean that the noise criteria are exceeded due to the Mine. By using a site specific noise model, the noise contribution from the mine can also be predicted for the prevailing weather conditions and consequently compared to both measured levels and project noise goals to more accurately understand the likelihood of exceedances from the Mine (Case study of noise model to profile noise to receivers). Once a mine has been using this sort of approach to mine noise management over several years, with regular validation against measurement results, it becomes a very useful tool for managing noise and understanding likely implications for “what if” scenarios when planning or changing operations.

Some leading practice businesses have already embarked on attempting to link their real time monitoring data, with real time weather data into a noise model to allow the mine manager the most sophisticated information possible to ensure operations can always meet noise limits.

3.14.4 Community Liaison

Liaison between mining companies and the community is important at every point, from the beginning of the proposal stage, throughout the investigative, assessment and approval processes, and throughout the mine's operation. The community must be kept informed and involved in the decision-making process affecting them if a good working relationship is to develop between all involved parties. A good working relationship is the keystone to a win/win approach involving mining and the community.

Implementation of an effective community consultation program will gain public confidence and lead to a smoother planning and approval phase and a more efficient operational period. Lack of knowledge and understanding frequently lead to the fears in the community surrounding a mining proposal. The misconceptions which can then arise commonly result in objections and difficulties which serve no constructive purpose and promote a spirit of non-cooperation.

By providing information and a contact point at the onset of a mining project, and continuing to respond to community concerns, mining companies are in a better position to implement a successful environmental management program. Community consultation and involvement aspects are discussed in a separate booklet in this series.

As part of a Noise and Vibration Management Plan, a mining company must develop a policy for community liaison in dealing with noise and vibration issues. The management plan should establish the protocol for handling complaints which will ensure that the issues are addressed and that appropriate corrective action is identified and implemented if and where necessary. This protocol should be pro-active and responsive, and, as a minimum, involve the following (including identifying the people responsible for the various actions):

- Identify contact persons at all potentially affected properties, and give them a project outline (together with details of the procedures for lodging complaints and the expectations they may have about the response mechanisms that will be implemented.
- Forward all complaints to the person responsible for handling them.
- Keep records regarding the source and nature of the complaint.
- Investigate the complaint to determine whether a criterion exceedance has occurred or whether noise and/or vibration have occurred unnecessarily.
- If excessive or unnecessary noise and/or vibration have been caused, corrective action should be planned and implemented.
- Corrective action should be planned and implemented if excessive or unnecessary noise and/or vibration has been caused.
- Report details of complaints and corrective action should be reported.

- Inform complainants that their complaints are being addressed, and (if appropriate) that corrective action is being taken.
- Carry out follow-up monitoring or other investigations to confirm the effectiveness of the corrective action.
- Inform complainants the successful implementation of the corrective action that has been taken to mitigate the adverse effects.

3.15 Closure/Rehabilitation

Impacts are likely to be significantly reduced during this phase compared with the “normal” operations, but they can’t be ignored as earth moving equipment remains operational and often in exposed locations as the final landform is created.

Case Sudy: The World’s Quietest Caterpillar Truck

The Project History

Mines in the Hunter Valley of NSW have some of the most stringent operational noise compliance criteria in the mining industry. GHD was engaged by WesTrac to acoustically attenuate 3 new CAT 789C haul trucks with the purpose of successfully achieving 113dB(A) for both static and dynamic tests.

The first Caterpillar 789C haul truck was successfully noise tested achieving 110dB(A) for dynamic tests and 106dB(A) for the static test compared with 123/119dB(A) of the untreated truck respectively. In addition to the acoustic performance, the noise performance was achieved with no impediment to the truck's cooling system.

GHD began the project by discussion with the end-client and their expectations, which were then followed by testing an acoustically untreated 789C haul truck to gather baseline noise data. The noise measurements undertaken involved the following methods:

- ISO 9614 - 1 Acoustics - Determination of sound power levels of noise sources using sound intensity - Part 1: Measurement at discrete points. Sound intensity was measured using the 01dB Symphonie Sound Intensity System and 01dB dBFA32 software package.
- ISO 4872 ALT B Acoustics - Measurement of airborne noise emitted by construction equipment intended for outdoor use method for determining compliance with noise limits.
- ISO 6395 Acoustics - Measurement of exterior noise emitted by earthmoving machinery - dynamic test conditions.
- (The Specification utilises ISO 4872 ALT B for its stationary compliance testing).

Therefore, sound intensity measurements were also undertaken. Sound intensity measures the directionality of a noise source in addition to the magnitude of sound which can provide a more accurate assessment of where problematic noise sources are located on a machine.

Baseline measurements taken based on ISO 6395 and ISO 4872 ALT B provided GHD with acoustic information that established how much a standard CAT 789C needed to be acoustically attenuated in order to successfully pass MAC's specification. However, these measurements did not provide sufficient information for the isolation of problematic noise and specific frequencies. Detailed noise mapping and analysis of the trucks was undertaken using sound intensity with consideration to ISO 9614 - 1. The acoustic analysis carried out enabled the isolation of specific problematic noise areas and their dominant frequencies. The acoustic analysis provided an indication of where the attenuation needed to be focussed while giving an indication to the engineering team where a less aggressive attenuation approach could be undertaken. Critical information gathered through discussion with the client (and operators) provided the engineering team with invaluable information to address key serviceability and functional performance criteria.

Design process

- Consideration of manufacturing techniques
- Acoustic modelling
- Exploratory manufacture / test manufacture
- Consideration of serviceability, OH&S, standardisation, functional performance (payload

and truck cooling), durability including exposure to engine liquids, dirt accumulation and fatigue, as well as high pressure water canon cleaning

- Design of related items ie. access systems (stairs, bumper system, walkways)

Case Study: Anglo Dawson Central dump station

One of the major dump stations for the Anglocoal 'Dawson Central' operations in Moura was located close to a residential property. The homestead for the property was located approximately 1200m North-East of Dump Station 4, on elevated land with a clear line of sight to the Dump Station. The current owners had resided on the property since June 2000. Complaints were received since the dump station was upgraded in mid-2002

Ambient noise logging at the site showed low background levels typical of rural area, but no clear pattern of elevated noise levels in relation to dump station activities. There was no clear correlation of high noise levels with high coal throughput, nor low noise levels with low coal throughput. This made it difficult to understand the extent and nature of the problem.

Measurements during the daytime period typically showed that mine noise was inaudible, and natural noises such as insect and bird noise dominated. Measurements were repeated during the night-time period to understand the conditions during the times when complaints were typically made. Noise levels at night increased by 5 - 6 dB(A) compared to daytime levels due to the presence of adverse weather conditions such as temperature inversions. Background noise levels were very low. As a result, noise emission from the dump station dominated the ambient noise environment. The major noise sources audible were:

- Engine and track noise from dozers,

- Conveyor noise,
- Clangs from coal dropping through the rill tower, and
- Noise from trucks unloading at the dump station.

The coal stockpile also acted as a noise barrier for the mobile equipment operating behind the stockpile. It was found that noise levels from this equipment could increase by up to 12 dB(A) when the stockpiles were low.

Methods were proposed to reduce these noise levels, including:

- Replacing tracked dozers with rubber-tyred dozers,
- Controlling the size of the coal to reduce the impact noise on the rill tower,
- Shielding the overland conveyor through, and
- Maintaining coal stockpiles at a high level during night-time periods.

In the end, Dawson Mine helped to relocate the homestead to the opposite side of the property, away from the Dump Station. Noise emission from the Dump Station was completely inaudible at this location, even with background noise levels of 18 dB(A).

This case study demonstrates that noise logging alone is often insufficient to properly characterize a noise problem and determine a solution. Background levels can vary considerably with seasons, which, coupled with variability in the noise source and weather effects, can make it difficult to draw conclusions from the logging. Sometimes there is no substitute for attended night time measurements under the ‘typical worst case’ operating conditions.

4 VIBRATION

4.1 Introduction

Background vibration is a normal feature of the environment. This background level is generally acceptable to the community because it has no significantly adverse impacts such as annoyance, injury to people, disturbance of sensitive equipment and instruments, or damage to structures. When this background level is exceeded, vibration can achieve a nuisance value which is unacceptable to the community.

Unwanted effects of vibration due to mining activities include:

- Nuisance or annoying vibration,
- Injury to people,
- Damage to sensitive equipment, and
- Damage to structures (including rock strength in mines).

Ground vibration from blasting is the radiation of mechanical energy within a rock mass or soil. It comprises various vibration phases travelling at different velocities. These phases are reflected, refracted, attenuated and scattered within the rock mass or soil, so that the resulting ground vibration at any particular location will have a complex character with various peaks and frequency content. Typically, higher frequencies are attenuated rapidly so that at close distances to the source such frequencies will be present in greater proportion than at far distances from the source.

The magnitude of the ground vibration together with ground vibration frequency are commonly used to define damage criteria. The choice of the appropriate damage criterion may require consideration of the frequencies arising from the blast. Studies and experience show that well designed and controlled blasts are unlikely to create ground vibrations of a magnitude that causes damage. Particular structures such as tall buildings, or abnormal ground conditions such as water-logged ground, should be carefully considered in a specialist study.

Cracks in buildings may be attributable to causes other than ground vibration, including ground or foundation movements (settlement and swell) associated with reactive clay soils during periods of prolonged dry or wet weather. Seismic events from underground mine activity rarely affect surface structures. Where there have been cases of damage it has been associated with some of caving operation or pillar collapse in conjunction with unusual geological conditions. There is usually a band of strong and brittle material that acts to collect and transmit the vibration to some zone at the surface where the hard band outcrops or comes near to the surface.

4.2 Statutory controls

Due to the potentially severe and irreversible impacts of excessive ground vibration, particularly structures, statutory limits have been put in place in most jurisdictions. These limits are based on studies and measurements designed to establish the minimum criteria for human comfort and structural damage.

In Australia, there are a number of government agencies responsible for regulating ground vibration resulting from blasting. Mining authorities are generally responsible for regulating blasting activities by the application of legislation and subordinate standards. However, in respect of human comfort levels of ground vibration, diverse authorities such as a Workplace Health and Safety Authority or Environmental Protection Agency may have jurisdiction and it is important that the relevant agency or agencies having jurisdiction be established prior to the activity commencing. In some cases, local government may also have a role in regulating the activity, usually through development consent processes.

4.3 Definition of ground vibration

Vibration transmitted through the ground may cause damage to structures and architectural elements or discomfort to their occupants. The vibration levels at which people become annoyed are well below vibration levels at which damage occurs. The likelihood of such damage or discomfort may be ascertained by measuring the vibration from a blast close to the location of concern such as a building or other structure.

For all limits it is necessary to measure in three orthogonal directions, one in the vertical direction and the other two in perpendicular horizontal directions. Such measurements align with most structural members in man-made structures. From such measurements it is possible to derive the Vector Peak Particle Velocity (VPPV) and the Peak Component Particle Velocity for each direction (PCPV).

The magnitude of the vector particle velocity (vp) is the amplitude of the vector sum of three time-synchronised velocity components directly measured by an instrument. When not measured directly it may be determined by the following Equation:

$$v_p = \sqrt{v_x^2 + v_y^2 + v_z^2}$$

v_x, v_y and v_z are the synchronized instantaneous velocity components of the x, y and z axes, respectively. The VPPV is the maximum of v_p.

4.4 Why control ground vibration?

Blasting operations may cause excessive noise and vibrations impacts on the community. Excessive levels of structural vibration caused by ground vibration from blasting can result in damage to, or failure of, a structure. People are able to detect vibration at levels much lower than those required to cause even superficial damage to the most susceptible structures.

The criteria set out in this document assist in minimising annoyance, discomfort and damage that may be caused by blasting at activities such as mining, quarrying, construction and other operations which involve the use of explosives for fragmenting rock. Leading practice environmental management will enable the minimization of the likelihood of adverse effects being caused by the impact of ground-borne vibration in noise-sensitive places and people living in or using the surrounding area.

4.5 Ground vibration limits

The maximum levels for ground vibration for human comfort, which some authorities have chosen, are provided in the Human Comfort Limits table below. Recommended limits for ground vibration for control of damage to structures are provided in the Damage to Structures table.

Frequency-dependent limits have the capacity to precisely deal with the hazards presented by ground vibration and are seen as the basis for best practice blasting. The particular frequency-dependent criteria should be reported with the measurements. All the limits given in the tables are peak component particle velocities, as used in overseas Standards and guidelines. The classification of type of structure may be difficult and when in doubt, a more conservative limit from the nearest description in the Structural Damage table should be applied.

4.6 Human comfort limits

Because of the variation in human response being dependent on such factors as vibration levels, location and time of day, different statutory requirements for human comfort limits for ground vibration may apply in respective jurisdictions. For further information, general guidance on human response to building vibrations is given in AS 2670.2, ISO 2631-2 and BS 6472.A typical set of limit criteria for human comfort is shown below.

GROUND VIBRATION LIMITS FOR HUMAN COMFORT		
Category	**Type of blasting operations**	**Peak component particle velocity (mm/s)**
Sensitive site*	Operations lasting longer than 12 months or more than 20 blasts	5 mm/s for 95% blasts per year 10 mm/s maximum unless agreement is reached with the occupier that a higher limit may apply
Sensitive site*	Operations lasting for less than 12 months or less than 20 blasts	10 mm/s maximum unless agreement is reached with occupier that a higher limit may apply
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	25 mm/s maximum unless agreement is reached with occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely effect the equipment operation
*A sensitive site includes houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people.		

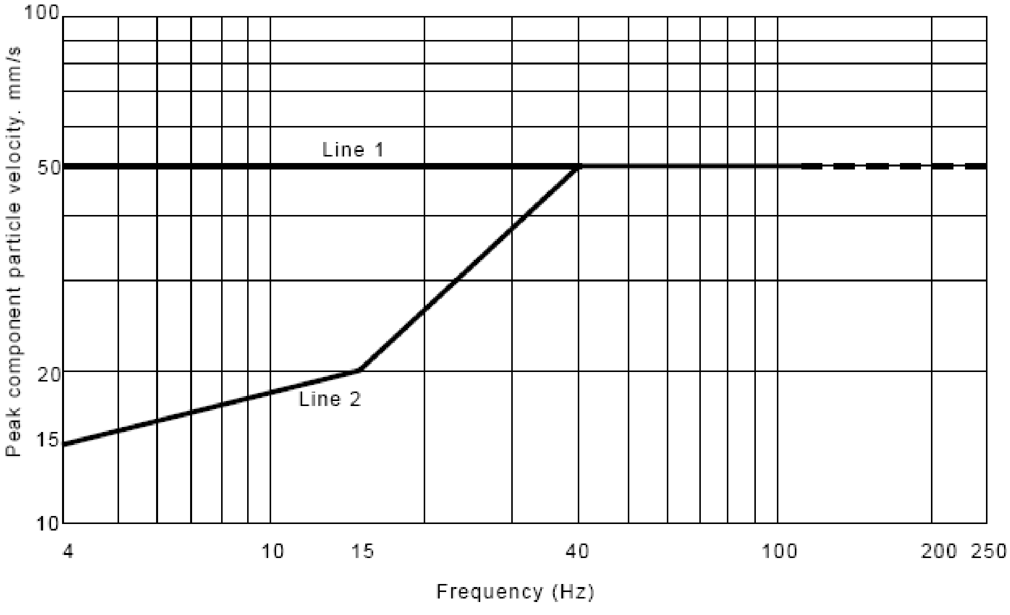
4.7 Damage limits

Frequency independent and frequency dependent guide levels are described in both British Standard BS 7385-2 and the United States Bureau of Mines (USBM) RI 8507. The levels specified are peak component particle velocities, and the methodologies used for assessing the frequencies are similar in both documents.

Frequency-dependent criteria are important for assessing the blast-induced vibration effects on buildings and other structures and are the recommended approach. Frequency-dependent criteria may not be readily implemented for all applications. For blasting operators who do not have the facilities to use frequency-dependent assessment methods, the levels specified in the table below, which are more conservative for most blasting applications, will reduce the potential for damage. The table should be used in conjunction with the notes.

Wherever possible, the ground vibration levels from all blasting operations must be limited to the damage limit criteria shown below at all sites not in the ownership or control of the organisation commissioning the blasting.

TRANSIENT VIBRATION GUIDE VALUES FOR COSMETIC DAMAGE (BS 7385-2)			
Line	**Type of building**	**Peak component particle velocity in frequency range of predominant pulse**	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structure. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above
NOTES:			
1	Values referred to are at the base of the building.		
2	For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.		



TRANSIENT VIBRATION GUIDE VALUES FOR COSMETIC DAMAGE (BS 7385-2)

BS 7385-1:1990—DAMAGE CLASSIFICATION

Damage classification	Description
Cosmetic	The formation of hairline cracks on drywall surfaces or the growth of existing cracks in plaster or drywall surfaces; in addition, the formation of hairline cracks in the mortar joints of brick/concrete block construction
Minor	The formation of cracks or loosening and falling of plaster or drywall surfaces, or cracks through bricks/concrete blocks
Major	Damage to structural elements of the building, cracks in support columns, loosening of joints, splaying of masonry cracks etc.

USBM DAMAGE CLASSIFICATION

Uniform classification	Description of damage
Threshold	Loosening of paint; small plaster crack at joints between construction elements; lengthening of old cracks
Minor	Loosening and falling of plaster; cracks in masonry around openings near partitions; hairline to 3 mm cracks (0 to 1/8 in); fall of loose mortar
Major	Cracks of several mm in walls; rupture of opening vaults; structural weakening; fall of masonry, e.g., chimneys; load support ability effected

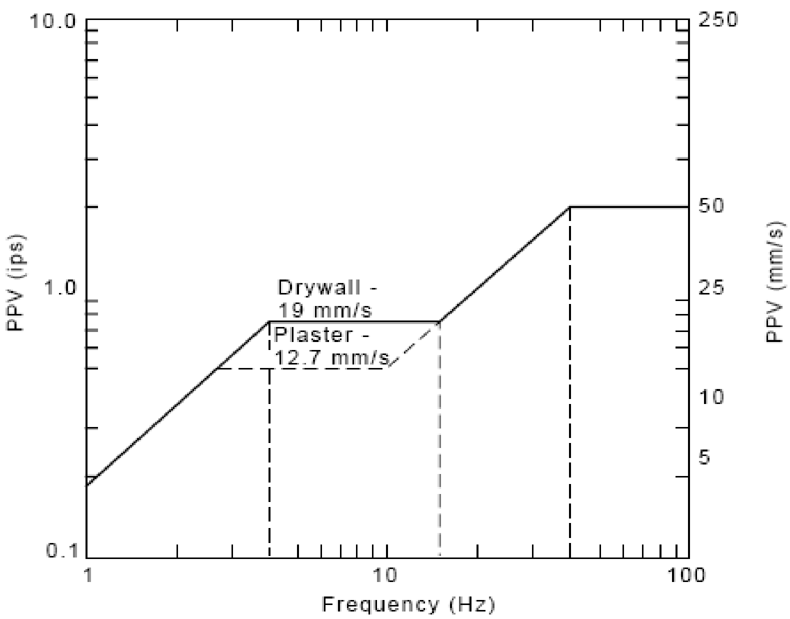


FIGURE J4.4.2.2 USBM 'SAFE' BLASTING VIBRATION LEVEL CRITERIA

Investigations suggest that the guide values and assessment methods given in BS 7385-2 and (USBM) RI 8507 are applicable to Australian conditions, and are recommended for explosives users with the facilities to make use of these methods. The estimation of the frequency of each vibration component to be used in structural damage assessment is complex. Simple approaches suggested within the BS 7385-2 and (USBM) RI 8507 includes:

- Frequency of the maximum PPV amplitude peak;
- Dominant frequency of the component vibration time history; and
- Zero crossing frequency of the PPV amplitude peak.

The (USBM) RI 8507 and BS 7385-2 methodologies for assessing frequencies have been widely used for many years, and were suitable for use with desktop and laptop computers with the power that was commonly available in the 1980s and early 1990s. It appears that the motion frequencies determined by simple methods, such as zero crossing, are conservative for assessing damage potential.

4.8 Best practice blasting

Using electronic initiation of blasts rather than traditional shock-tube detonators significantly reduces vibration impacts caused by the blast. Electronic detonation has been shown to:

- Reduce the maximum vibration readings.
- Reduce the number and intensity of high vibration readings.
- Increase the uniformity of the blast.
- Control the vibration frequencies to minimize the low frequencies.
- Increase dig rates.

Electronic detonation allows for precise timing of initiation of each charge. This reduces the vibration levels. This system has been extensively used at Newcrest's Telfer mine.

Case Study: Comparison of electronic and traditional detonators.

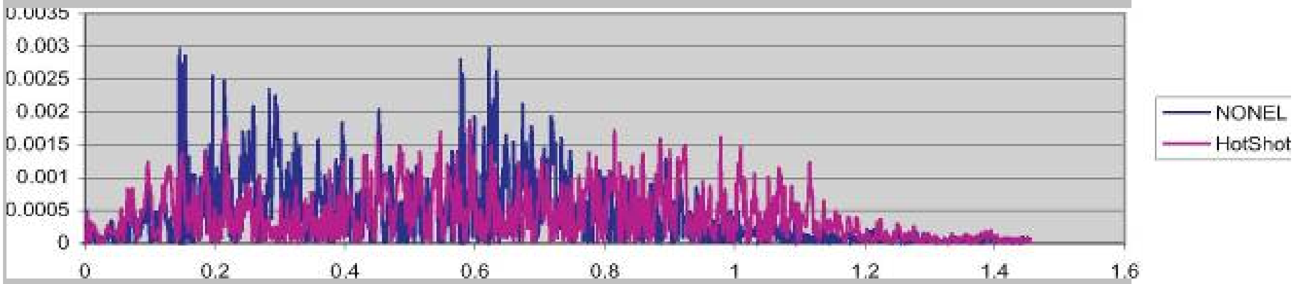
A trial was carried out at AngloGold Ashanti Sunrise Dam Open Cut Gold Mine, where two blasts were carried out, one using electronic detonators and one using shock tube detonators. The design parameters of the two blasts remained constant. The selected location of the two blasts was chosen so that the geology was as consistent as possible. Blast design parameters were determined by engineering to suit the geology and these parameters were kept constant for both shots, including initiation timing.

The results of the blasts showed:

- Muck pile profile and swell
    - The electronic blast increased the fragmentation on the surface of the blast.
    - The electronic blast achieved a much more consistent heave.
- Productivity
    - A 16 % increase in dig rate was achieved with the electronic initiated blast in comparison to the shock tube initiated blast.
- Fragmentation
    - The electronic initiated blast achieved an improvement in overall fragmentation
- Crusher
    - Electronic initiated blast achieved higher average throughput and maximum throughput than the shock tube initiated blast.
- Vibration analysis
    - The vibration readings achieved from the electronic initiated blast was more uniform though not significantly lower.

Electronic blast muck pile.

Shock tube blast muck pile.



Shock tube (NONEL) and Electronic (HotShot) geophone vibration comparison

Full details of this case study can be found in the technical paper:

M Vaughan, E Hall, D Varga, G Billing and K McSweeney, *Blast Improvements with Electronics at Sunrise Dam Gold Mine,* EXPLO Conference*,* Wollongong, NSW 3-4 September 2007.

5 CONCLUSION

This handbook has presented, by way of text, photographs, figures, tables and selected case studies, a toolkit of how best to implement leading practice in the management of airborne contaminants, noise and vibration on mine sites. There are many examples of leading practice in Australia and internationally and space limitations restricted highlighting only a few including:

- Dust – iron ore in the Pilbara and coal in the Hunter Valley;
- Noise – coal in the Hunter Valley and the Bowen Basin, and exploration drilling in Victoria; and
- Vibration – gold mining in Western Australia.

The life cycle approach is core to the management of these issues, through exploration to development to operations and finally, closure. There are different risks and issues arising in each stage and each has to be managed systematically. Management strategies should be integrated into the systems and plans, such as the mine management or environmental management plan, as a tool for operational staff.

The handbook adopts a risk management approach to these three issues. This involves identifying the dust, noise or vibration hazard, assessing the risk and implementing controls. Monitoring and management to ensure the controls are working effectively is a common message throughout the booklet.

Even though the handbook necessarily focuses on the hard engineering controls to eliminate or mitigate the risk, the significance of the community is also stressed throughout. Without community involvement, engagement and ultimately empowerment in all aspects of the mine’s life cycle, the “social licence to operate” will be quickly withdrawn and the operation simply will close. At the end of the day, it is all about integrating, in a practical manner, sustainable development into your mining operation. This handbook provides a practical means of doing so in these three critical areas.

CASE STUDY: LGL BALLARAT GOLDEN POINT VENTILATION

Overview

Sinking a 315m ventilation shaft is challenging enough, when you place that project in a residential area of a regional city you need to do your homework. LGL Ballarat started planning for the Golden Point Ventilation shaft in 2006. With the residents as close as 60m from the worksite, significant time and effort went into planning to minimise the impact of the project to the neighbours. Extensive consultation with the community was undertaken prior, during and after each phase of the project. One on one consultation with the immediate neighbours took place during the early planning stage using diagrams of each phase of the project. Each neighbour was then asked to voice their concerns, with the main issues being blast vibration, noise, work hours and dust.

LGL Ballarat has a long history of good community engagement, so many of the community were interested, aware of the project and in fact supportive of mining returning to Ballarat. With the information gathered from the community the company finalised its plans incorporating concerns of the neighbours. Site layout changed to accommodate two neighbours, moving parking bays, installing visual screens to ensure car lights did not shine into the neighbour's property and moving a tipping bay to reduce dust and noise impacts. LGL Ballarat strives to minimise the impact to the community further than simply achieving the compliance limits set by regulators. In the case of the Golden Point Shaft project LGL Ballarat set internal targets well below compliance levels for blast vibration. The internal limit was a Peak Particle Velocity of 3mm/sec, 1/3rd of the maximum P.P.V. 10mm/sec regulatory compliance limit.

<u>Examples and Learning's</u>

Noise- *Picture Noise monitoring with neighbour sound wall in background.*

A locally produced recycled paper and concrete noise attenuation product was identified as being suitable for the 6m high compound walls. The compound housed the mining activities including shaft winders, air compressors, rock dumping, truck loading and equipment handling. A noise attenuated diesel power supply used on film sets and public events ensured no interruption to the neighbours power supply. These noise attenuated generators were placed within a smaller noise attenuated compound on the far side of the project site. All vehicle reverse beepers were changed out to low frequency 'squawkers'.

Blast vibration and noise*- Picture Birds eye view of worksite with Ballarat in background.*

During the planning phase independent house inspections were offered to neighbours with concerns of cracking from the blast vibration. Four investigations were undertaken prior to commencement and two during the project. The independent inspector and LGL monitoring gave residents a level of satisfaction that there was minimal chance of damage occurring to their properties.

Birds eye view of worksite with Ballarat in background.

Consultation with explosive manufacturers and peer review by independent blast experts ensured a high level of control over the blast design process. A decision to free dig the project with a small excavator to a depth of 70m reduced the impact of near surface blasting.

Once blasting started electronic detonators were used to provide a more reliable timing of blast delays and a larger range of delays compared to the more commonly used initiation methods. This enabled blast vibration to be minimised and eliminates the use of blasting cord which can be a source of blast noise. Three blast monitors with geophone and linear microphone were used during the project, two sites stayed stationary while the third was used for reactive investigations at residents with blasting concerns.

One of the key learning’s from the project was the benefit of a spoken telephone text message service to warn residents immediately prior to blasting. Many of the residents were startled by the blast vibration and noise, simply alerting them 5 minutes prior to the firing LGL Ballarat alleviated this issue.

Dust- The use of collected stormwater and recycled mine water was used as a temporary dust suppressant until asphalt was laid. Other technologies were trialled but with tight turning circles of heavy vehicles and a need for constant reapplication they failed to deliver satisfactory results. During blasting sprinklers were engaged to reduce dust rising out of the shaft.

Community Consultation - Initial consultation was followed up with one on one contacts, letter drops and community newsletters throughout the project. The site was also incorporated into LGL's public open day. Information supplied focused on current and upcoming activities and ensuring the community had an open line of communication with the company.

Once the site preparation was completed and shaft works had begun, the community realised the company was going to deliver as promised. While there were periods of complaints and technical challenges the company adjusted and continued to modify practices to ensure constant improvement. The biggest reward for the project team was in the form of initial objectors becoming supporters and acknowledging the efforts undertaken and the comment from a regulator who stated "going beyond compliance is gold"

Case Study: LGL Ballarat Noise Suppressed Surface Exploration Drill Rig

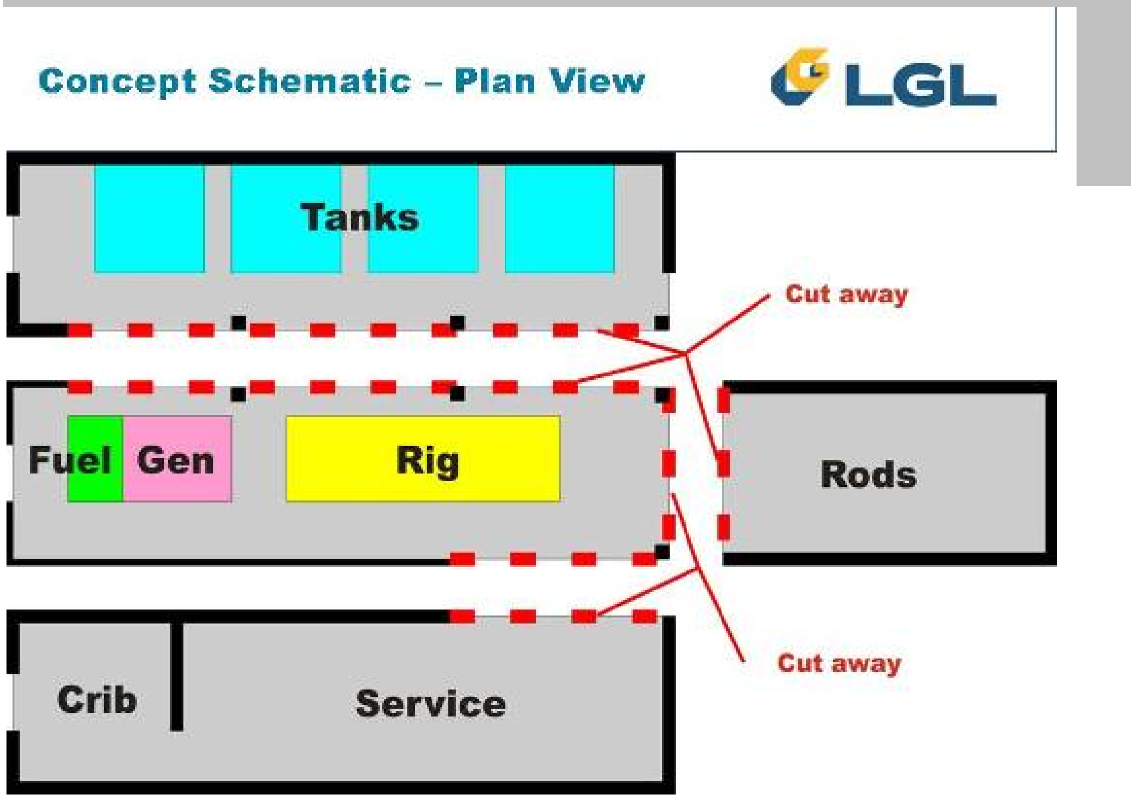
For many years LGL Ballarat has struggled to fully drill out its exploration leases due to the noise restrictions involved with operating machinery in a built up urban area. LGL have experimented with many forms of noise suppression including, surrounding rigs with shipping containers, large hay bales, erecting sound walls and even digging large pits for the drilling rigs to work in. These measures all had some degree of success but were far from ideal. In 2007 LGL Ballarat purchased an Atlas Copco CS14 drill rig with the intention of enclosing unit within a fully noise attenuated containers.

The LGL Ballarat drilling department identified the need to make the system modular and self-contained. Six sea containers were utilized; four on the ground floor and two for the mast of the rig encapsulate the entire worksite. Everything from drilling fluids, tools, drill rods, power generation and even the crib room are enclosed within the system.

After consulting with acoustic engineers the decision was made to use a mixture of noise attenuation products on the walls of the containers to reduce noise both internally and externally. The noise attenuation products included sound deadening paint, 50mm sound absorbent foam and a 6mm nylon sound barrier.

The combination proved to be extremely successful, reducing noise emissions from 110dB at the machine to a measured 52dB immediately outside the containers and 38dB measured at 200m. With a 30dB reduction inside the containers the noise attenuation was celebrated as a great win in terms of operator comfort and safety. The containerized rig has now successfully completed six months of 24hr drilling at two sites, both sites are within 200m of residents. To date no complaints from the surrounding neighbours have been received.


The Finished Product
LGL
52 dB


Concept Schematic – Plan View
LGL
Tanks
Cut away
Fuel
Gen
Rig
Rods
Crib
Service
Cut away

5 BIBLIOGRAPHY

Bollhofer A, Storm J, Martin P, and Tims S, 2006. Geographic Variability in Radon Exhalation at a Rehabilitated Uranium Mine in the Northern Territory, Australia. Environmental Monitoring and Assessment, 114 (1-3), pp31-330.

British Standard BS 7385-2, 1993. Evaluation and measurement for vibration in buildings. Guide to damage levels from groundborne vibration.

Department of Resources, Energy and Tourism,2008. Risk Assessment and Management handbook.

Department of Resources, Energy and Tourism,2008. Mine Rehabilitation Handook

Department of Resources, Energy and Tourism,2008. Mine Closure and Completion handbook.

Hassall J R, and Zaveri K, 1979. Acoustic Noise Measures. Bruel and Kjaer.

Queensland Environmental Protection Agency, Guideline – Noise, Noise and Vibration from Blasting, 23 March 2006

Siskind D E, Stagg M S, Kopp J W and Dowding C H, 1980. Structure response and damage produced by ground vibrations from surface mine blasting. US Bureau of MinesResearch Investigation RI- 8507.

Standards Australia, AS 2187.2-2006, Explosives – Storage and Use, Part 2 – Use of Explosives, 2006

Vaughan M, Hall E, Varga D, Billing G and McSweeney K, 2007. *Blast Improvements with Electronics at Sunrise Dam Gold Mine,* EXPLO Conference, Wollongong, NSW 3-4 September 2007.

6 GLOSSARY

Term	Description
ACARP	Australian Coal Association Research Program
AQMP	Air Quality Management Plan
CFD	Computerised Fluid Dynamics
dB	dB (linear) peak is the maximum reading in decibels (dB) obtained using the "P" time – weighting characteristic as specified in AS 1259.1 – 1990 with all frequency weighted networks inoperative
DEM	Dust extinction moisture
MHM	Material Handling Moisture
MIC	Maximum instantaneous charge (MIC) is the maximum amount of explosive in kg on any one specific delay detonator in any one blast hole
NEPM	National Environmental Protection Measurement
NPI	National Pollutant Inventory
NVM	Noise and Vibration Management
PCPV	Peak Component Particle Velocity
PEM	Protocol for Environmental Management
PM_{10}	Particulate matter less than 10 microns in diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter
ppv	Peak particle velocity (ppv) is a measure of ground vibration magnitude and is the maximum instantaneous particle velocity at a point during a given time interval in mms^{-1}. (Peak particle velocity can be taken as the vector sum of the three component particle velocities in mutually perpendicular directions)
SO_2	Sulphur Dioxide
TEOM	Tapered Element Oscillating Microbalance
TSP	Total Suspended Particulate Matter
VPPV	Vector Peak Particle Velocity