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Climate adaptation in the Australian mining and exploration industries

Climate Adaptation Flagship Working Paper #5

Helping Australia Adapt to a Changing Climate

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1. EXECUTIVE SUMMARY

Climate change research and activities in the mining and exploration industry typically focus on what can be done to reduce mining's impact on climate change. Such efforts are aimed at the 'effect of mining on climate change', rather than the 'effect of climate change on mining'.

Climatically imposed impacts and how the industry might adapt to reduce unwanted effects of climate change has had little attention but may be important and thus is the focus of this study. The effect of climate change on other primary industries such as fisheries, farming and forestry is already being investigated and climate impacts and adaptations identified. Like other primary industries, mining is situated 'on the ground' – it is geographically constrained and therefore vulnerable to changes in weather and climate patterns.

There is a huge amount of evidence that the Australian and global climate is changing and that there is a clear human fingerprint in these changes resulting from human activities, such as the combustion of fossil fuels. Projections are that average temperatures in Australia will increase between 0.4 to 2.0°C by 2030, in addition to there being changes in rainfall patterns and the frequency and/or intensity of extreme weather events such as drought and severe storms. More substantial changes are projected out to 2050 and 2070.

The projected climate changes may impact on a mine's operational costs in terms of its ability to source staff, to ensure health and safety for workers within the mine site, to ensure that production can continue at projected rates and to maintain the industry's strength into the future. Not all impacts will necessarily be negative; all potential impacts should be identified to assess whether the industry is generally 'climate-change-proof' and if it is not, ascertain what action is required to ensure that mining is sustainable under changed climatic conditions.

Adaptation to hotter, drier or more extreme weather events to prevent risk to life, resources and revenue is likely to be better in the form of a proactive defence as opposed to a reactive process. For example, simple adaptation at a mine site, such as more frequent maintenance of equipment to prevent operational down-time under extreme conditions, may be a low cost option that is easy to implement.

A preliminary review of literature and assessment by CSIRO suggests that, although most stages of mining (from pre-mine planning, through planning and development, production, post-production and closure, and post-mining) are already influenced by climate and extremes, the production stage is likely to be the stage that is most at risk from climatic events and climate change in the future. Specifically, the risks to water and energy availability, in addition to health and safety within and around mines during production, are issues that should be better understood. Extreme events may cause mining districts to lose power; the risks this poses to both production and disaster mitigation can be analysed and alternative energy sources be identified to reduce the effects. Similarly, where water resources are uncertain or scarce, production and processing may be threatened, so methods that use less water may be investigated for such regions. Hotter or wetter climatic conditions pose a risk to the ability of both equipment and mine personnel to function effectively; additionally the conditions my cause greater hazards for people. Mine-automation is already an on-going development program at CSIRO and may be a useful future adaptation strategy to counteract some of the effects of weather and climate changes.

The mining industry is highly adaptive and typically well-versed in reacting to adverse conditions. Although the industry is well-positioned to cope with a changing or more variable climate in future, it will likely benefit from additional knowledge and data to provide proactive adaptation options. Nevertheless, some experts have suggested that there may be some resistance to adaptation requirements due to short-term financial constraints and the notion that climate and weather variability may not be a real threat. Therefore, education and exposure of the facts to the industry will likely stand the industry in good stead and allow it to be fore-warned and forearmed.

This report outlines the needs for such a project, why CSIRO is performing it, a brief introduction to previous studies and the preliminary results of a workshop held at CSIRO to explore the thoughts and knowledge of some mining experts.

The systematic analysis currently being performed is the first of four planned phases for this project. The next phase (2010-2011) is to continue this preliminary overview by assessing adaptation strategies already used by mines and identify the consensus held by mines regarding future changes and the need to adapt along with cataloguing adaptation work already underway. Through workshops and interviews based in four quadrants of Australia (Fig. 1) with mine company personnel with hands-on experience of dealing with climate-related adaptations in addition to mine planners, specific case studies for future research will be identified with a view to provide a more detailed understanding of adaptation needs into the future. Case-study analysis (2011-1012) will involve industry co-investment and with studies based in each quadrant to maximise learning and identify real-life problems and solutions for climate affects and climate change adaptation strategies. The final phase (2012-2013) will involve a synthesis of the results with an aim of producing a set of guidelines for companies and regions to follow so they can perform their own assessments for adaptation strategies.

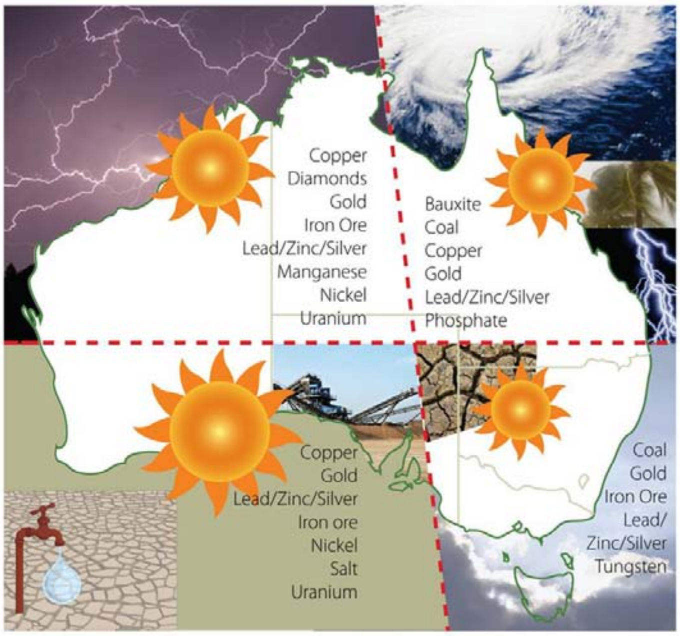

Figure 1: Quadrants of Australia showing variety of minerals mined and some variations of weather issues likely in the future. Note – boundaries between each quadrant are ‘fuzzy’: mining types and weather patterns are not strongly defined by these boundaries.

2. INTRODUCTION

There is strong and growing evidence that the Earth is heading towards a period of changed climate, based on current trends, scientific analysis and forward climate modelling. Many of the projections indicate that by 2030 temperatures will increase by between 0.4 and 2°C in Australia. Current trends in temperature place us at the high end of this range with markedly increased temperature extremes likely. Additionally, there are likely to be variations of rainfall pattern and intensity. These changes will affect water supplies, agriculture and ecosystems that, in addition to the direct effects of climate change itself, could impact on the mining and exploration industry.

The mining and exploration industry is a vital component of Australia’s future, so threats need to be assessed and, if necessary, dealt with. There are presently more than 1000 mines operating in Australia (Geoscience Australia 2009) and, with a typical life expectancy of 8 to 30 years, a number of these may still be operating in 2030 (and later) when projected climate changes are expected to be significant. Already there have been noticeable substantial shifts in climate patterns, temperature and rainfall, consistent with projections of future change. The current changes are presently being dealt with by the mining industry. More mines are being planned, and will begin operating in the foreseeable future. These mines will be open through to 2050 and 2070, during which time climate change is projected to continue. These mines will need to operate under new climatic conditions.

Work is already underway to assess how mining is affecting climate change and how it can be adjusted to reduce net greenhouse gas emissions using technologies such as clean coal, carbon capture and storage, and alternative energy sources. In addition to this work, we explore whether the mining and exploration industry requires assessment to identify what action can ensure that the industry will be sustainable under altered climate conditions. Extreme weather events and climate change may have direct or indirect impacts on mine and equipment design. These impacts may positively or negatively affect mine and mining assurance into the future, economic stability, and health and safety within and around the mine.

The research considered here includes available knowledge and literature on:

- an assessment of vulnerable operations where there may be a need to manage the risks from climatic changes
- the technical risks likely to impact operations and hence provide information to help manage any risks
- initial expert views on the critical areas for Australian operations .

2.1 Purpose of this project

This report intends to establish a framework for further work assessing the vulnerability of mining operations to changes in local climate in Australia. Little information is available in readily accessible literature even though current climate projections suggest that there is a real and credible risk of climate changes that could affect the minerals business in Australia. The minerals industry represents 8% of Australian GDP and has contributed over $500 billion directly to Australia’s wealth since 1990 (ABS data 2009). Employing more than 60 000 people directly (320 000 if the mining services industry is included), the industry made a direct investment of $43 billion to the Australian economy in 2006. Additionally, Australia is the world's largest black coal, iron ore and gold exporter and the largest producer of bauxite and alumina. A small impact of climate on these figures represents a big impact on the Australian economy, with global implications.

CSIRO, through its Climate Adaptation Flagship and in conjunction with the Minerals Down Under Flagship initiated a scoping study to examine the literature and to identify a range of stakeholder views on the significance of this issue for Australia and Australian mining. This report presents early findings of research on the technical impact of climate change on mining operations. A companion project led by Drs Kieren Moffat and Barton Loechel at CSIRO examines the impact on mining communities. The impacts on mining and mining communities are closely related (Fig. 2) and together these projects will help define a program of further research to examine the risks and consequences of climate change on mining communities, and to help develop strategies for adaptation and for the management of those risks.

This technical review was performed by way of a literature review of national and international work, followed by collation of data drawn from a workshop held at CSIRO attended by industry experts.

This report is structured to present the outcomes of this research in terms of:

- potential climate changes
- potential effects of climate change and extreme weather events on mining
- the mining industry operational process
- a review of literature on the effects of climate change on the mining process
- the outcomes of an expert workshop on the critical issues and adaptation options.

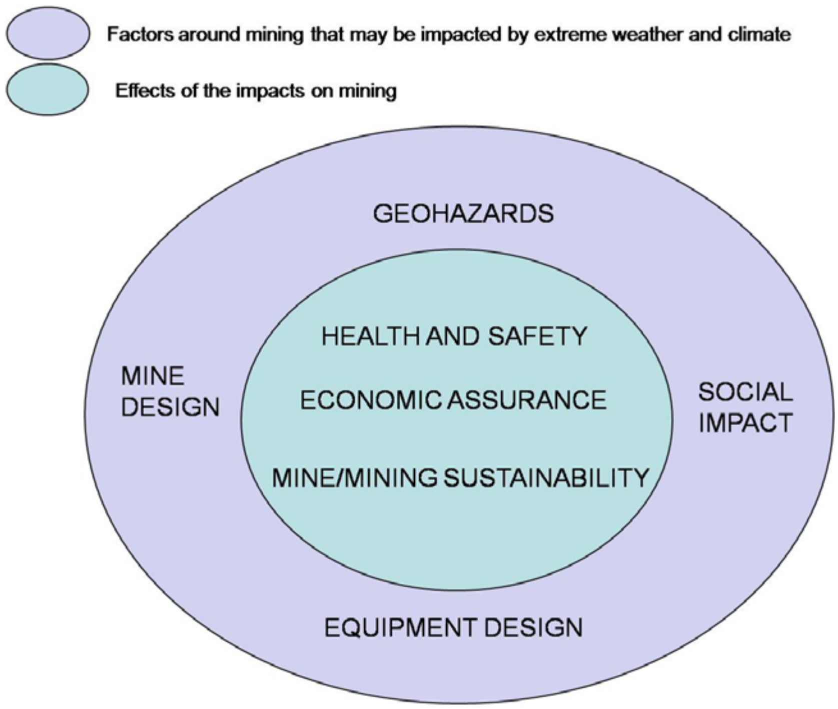

Figure 2: Some of the impacts and effects possible from extreme weather events and climate change showing a link between technical and social impacts

3. CLIMATE CHANGE PROJECTIONS

Natural variations occur in the climate over both short- and long-term time periods. That aside, there is strong and growing evidence that human influences on the climate are causing additional changes to those natural variations. Although the causes of climate change are beyond the scope of this project, both natural and human factors that influence climate have been included in understanding both past and prospective future climate conditions (e.g. IPCC 2007). Resulting from these factors, Australia's climate is projected to change in varying ways across the continent over the next 60 years.

Projections suggest that temperatures will increase by 0.4 to 2°C by 2030, and more out to 2050 and 2070, and that extreme weather events will become more frequent and/or more extreme across the continent. Generally, there will be changes to the temporal and spatial patterns of drought and extreme rainfall, and an increase in evopotranspiration (as a consequence of higher temperatures and changes in wind patterns) will impact further on drought potential. The broad trends projected from various models suggest that the southern and south-western part of Australia will receive less rainfall, and the northern region may receive relatively more rainfall. The number of rain-days is projected to generally decrease; the intensity of rain events is projected to increase and the intensity of cyclones is also projected increase (source: Climate Change in Australia website http://www.climatechangeinaustralia.gov.au).

The Climate Change in Australia website provides a synopsis of each state's projected change. Climate change projections for Queensland, for example, suggests that changes in rainfall patterns will cause longer dry-spells interrupted by heavier rainfall events, increasing the potential for mass-wasting and flooding events. Annual average temperatures across Queensland are projected to increase by up to 1°C in coastal areas and up to 1.5°C inland, relative to the climate of recent decades. By 2070, the projected increase is up to 2°C across most of the state under a low emission scenario, and up to 4°C under a high emission scenario. Slightly less warming is expected in coastal regions. Small decreases in relative humidity inland, with little change along the coast are predicted. Small increases in average wind speed in south-east Queensland and the increased intensity of tropical cyclones are also projected.

Although there are still uncertainties surrounding the potential climatic changes that may occur, forward modelling of the climate by CSIRO (Crimp et al. 2009) has presented us with a number of climate scenarios that suggest changes will occur in each of 11 regions of mining (Fig. 3). Projections (Table 1) were based on the top four performing models, validated against historical climate data. The scenarios were calculated based on a 'middle-of-the-road' view of future emissions. Thus, these projections are conservative as emissions are currently at the high end of the scenarios (Canadell et al. 2007) and likely to stay that way for the foreseeable future, given expectations of global economic growth.

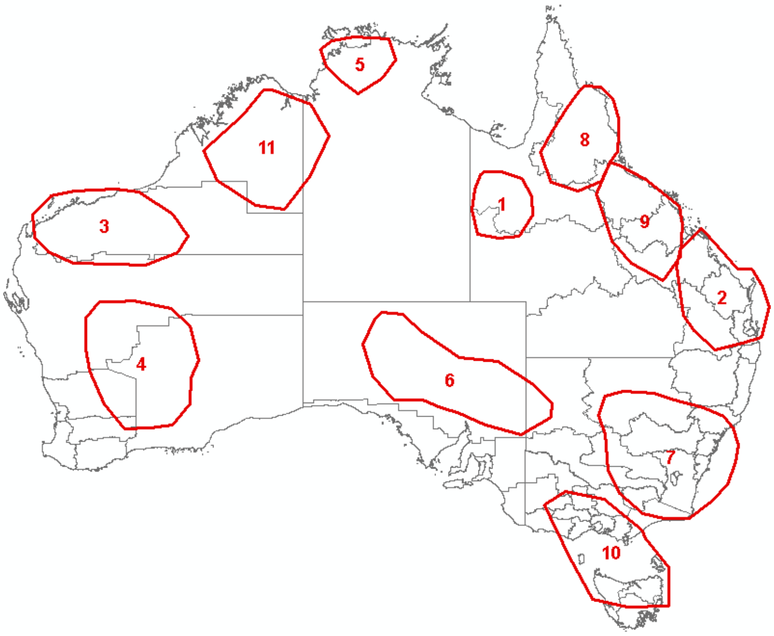

Figure 3: Map showing mining regions of Australia where climate scenarios have been projected (see Table 1) (After Crimp et al. 2009)

Table 1: Projected changes in temperature and rainfall (relative to current climate conditions) for 2030 for mining regions defined in map (Fig. 3) (After Crimp et al. 2009)

2030 – Temperature and rainfall projections

	NCAR		ECHAM		GFDL		HADGEM	
	Temp (°C)	Rain (%)	Temp (°C)	Rain (%)	Temp (°C)	Rain (%)	Temp (°C)	Rain (%)
May to October								
Region 1	1.21	-2	1.21	0	1.30	-5	1.11	-1
Region 2	1.23	-4	1.22	-2	1.22	-6	0.95	-2
Region 3	1.28	-8	1.19	-2	1.29	-6	1.02	1
Region 4	1.14	-6	1.09	-6	1.02	-5	0.76	-5
Region 5	0.88	9	0.92	0	1.15	-1	0.96	5
Region 6	1.07	-4	0.97	-3	0.94	-2	0.73	-3
Region 7	0.93	-4	0.96	-5	0.88	-2	0.64	-6
Region 8	1.03	4	1.06	-2	1.22	-3	1.08	-4
Region 9	1.20	-3	1.22	-1	1.28	-6	1.08	-3
Region 10	0.78	-4	0.82	-4	0.70	-3	0.54	-2
Region 11	1.09	4	1.07	4	1.29	-4	1.12	3
November to April								
Region 1	0.87	7	1.21	1	1.43	-5	1.17	-3
Region 2	1.04	4	1.22	-2	1.34	-6	1.07	-3
Region 3	0.87	8	1.19	-1	1.37	-6	1.08	-4
Region 4	1.09	4	1.09	-1	1.16	-5	0.93	-4
Region 5	0.70	2	0.92	2	1.05	-1	0.88	-2
Region 6	1.00	2	0.97	0	0.99	-2	0.81	-3
Region 7	0.83	3	0.96	-1	0.89	-2	0.75	-2
Region 8	0.77	4	1.06	2	1.26	-3	1.09	-3
Region 9	0.93	6	1.22	0	1.41	-6	1.14	-3
Region 10	0.79	0	0.82	-3	0.76	-3	0.64	-1
Region 11	0.70	4	1.07	2	1.27	-4	1.05	-2

4. THE EFFECT OF CLIMATE CHANGE AND EXTREME WEATHER EVENTS ON MINING

4.1 Potential impacts

Mines operating today have been designed in light of climate risks based on historical climate observations. A 'suitable' mine design ensures health and safety of mining personnel which, combined with optimum resource extraction and processing, leads to the successful continuation of a mine. New and unexpected climate conditions may threaten that mine design, so adaptation may be required to ensure the operation continues successfully.

Changed climatic conditions have a two-fold impact:

- Primary (or direct) impacts, e.g. flooding, erosion, landslip, debris flows, overflowing of waste ponds, hazards to human life, equipment, revenue and the environment
- Secondary (indirect or 'knock-on'), e.g. a preferred shift in population centres or changes in agriculture and water resources leading to improved or reduced access to land and labour forces by mining. A local labour force deficit may occur where local communities move away from mine sites due to lack of water and/or power, excessive dust, frequent isolation after storm events and threat of tropical disease.

These examples are by no means exhaustive but provide an illustration of the complex relationships that exist between climate, the mine and the 'mining community'. These relationships also lead to diverse impacts on a mine beyond employment, environmental and socioeconomic issues of the immediate community. For example, if there are other industries that share infrastructure with the mine, mine disruption could also affect nearby and regional communities. Therefore, a collection of disparate communities that are related to the mine in different ways may collectively represent the 'mining community' and collectively, they may be affected if the mine itself is impacted by a climatic event (Loechel and Moffat 2010).

Future climate impacts on a mine may simply be more frequent occurrences of events already faced, such as excessive rainfall or unexpected changes in ground conditions. More frequent events, however, will lead to greater down-time if more proactive solutions are not sought to mitigate this risk. Impacts may also be more complex: a primary effect of climate change on people, which at first may not appear to be an issue to mining, is the climatically controlled migration of tropical diseases (Garnaut 2008). This may also be a secondary threat to a mine: if such diseases threaten mining communities, the mine's ability to source labour and community support around the mine will be affected. Secondary impacts that fall upon mining communities (which in turn may cause the mine to have labour-sourcing issues further down the track) are significant. For example, where water is required at a mine for processing, will there be enough for the local community's needs? If excess power is required to pump out a flooded mine more frequently, will the local community have sufficient power at this time? If water is scarce and dust cannot be reduced to acceptable levels, will people want to live in the neighbouring towns? If communities are uncomfortable and conditions are bad under future climate conditions, a labour force may be harder to source or sustain, and fly-in-fly-out may become 'the norm'.

Geohazards – a primary impact

Geological hazards (geohazards) are events that are related to geological features and processes that may threaten life, property and the built- and natural environment. They may be caused by internal processes such as earthquakes, or external processes such as the climate. Typically they are rarely isolated events or processes and instead exist as 'geohazard chains', which are a combination of events, e.g. rainfall combined with human activities (Han et al. 2007). A geohazard chain has an element of predictability, allowing risk management strategies to provide adaptation, or mitigation under worst-case scenarios.

Rainfall is commonly understood to be one of the main landslide triggers and is the subject of much research (e.g. Terlien 1998). Geophysical evidence shows that an increase in pore water pressure caused by increasing groundwater levels can induce landslip in addition to movement on fault planes by reduction of friction. Changes in rainfall patterns and groundwater levels would therefore lead to changes in geohazard potential around mines where slope stability requires monitoring and managing. Additionally, fast flowing flood waters through or around a mine may erode and undermine the toe of a slope, causing rock fall, landslip or debris flows.

In the Philippines, the Department of Environment and Natural Resources prepared a geohazards map (available at http://www.denr.gov.ph/article/articleview/5765) that identifies landslide and flood prone mining regions. The map integrated land use planning, land development, disaster risk reduction and climate change adaptation. Extreme weather was cited as being a potential cause for future 'catastrophe' around mine sites and for the local community, and indeed, in 2009, typhoons and associated landslides displaced 50 families around the mines. Geohazard maps in and around mine sites should be assessed on the basis of a new set of climatic conditions as necessary.

Surface loading caused by extreme flooding over an underground mine may also be of concern for mine design and fault reactivation potential. Increased overland flow may also produce flooding potential of underground pits. Mine design includes an understanding of groundwater flow and groundwater drainage based on past and present groundwater levels. If future groundwater levels are going to be different, modelling must consider this.

Kabir et al. (2008a; 2008b) assessed the influence of climate change on groundwater and on rehabilitation at the Ranger uranium mine in the Northern Territory. Under wet conditions, when groundwater levels can rise significantly, solute transport can increase; under prolonged dry conditions, groundwater levels will decrease causing rehabilitation to struggle. Modelled transport pathway and volumes, in addition to water availability for rehabilitation, would require additional data for modelling future events to be considered, as well as usual climate variability. The consequences of climate change on such rehabilitation projects is an additional risk that should be addressed more widely in order to ensure that rehabilitation of a mine site is long-term and can be sustained under altered and variable climate conditions.

4.2 What is being done

In 2007, CSIRO and the Bureau of Meteorology issued a report called 'Climate Change in Australia' that provided the projections of Australia's future climate change with an assessment of observed climate change across Australia and the likely causes. Also in 2007, the Australian Government Department of Climate Change (now the Department of Climate Change and

Energy Efficiency) performed a broad assessment on the potential impacts and costs of climate change for each state and confirmed that Australia will get hotter and likely to become dryer in the south likely changes in tropical cyclones, large hail, fire weather and drought frequency (CSIRO and BoM 2007).

As a result of this general acceptance that our climate will change in the foreseeable future, a number of initiatives have been set in motion to assess the risks, and to develop a national approach to long-term adaptation to climate change. These initiatives are listed on the Department of Climate Change and Energy Efficiency website (http://climatechange.gov.au) and include:

- Climate Change Adaptation Flagship – investment of $44m over five years for CSIRO to develop climate change adaptation research science to inform policy responses to climate change and add value to how we adapt.
- Climate Change Adaptation Research Facility – investment of $20m over four years to establish a research facility based at Griffith University in Queensland. The facility brings together national expertise to help Australian industries and communities adjust to the impacts of climate change.
- Australia's Farming Future – provides $130m over four years to deliver three major components: the Climate Change and Productivity Research Program, the Climate Change Adaptation Partnerships Program, and the Climate Change Adjustment Program. Australia's Farming Future will improve the ability of primary producers to respond to climate change and manage their emissions.
- Caring for our Coasts – investment of $25m over five years to help prepare coastal communities for the impact of climate change. Part of this program will include a national coastal vulnerability assessment and a national coastal summit.
- Preparing Australia's Forest Industry for the Future – provides $8m for Australia's forestry industry to better prepare for climate change, including the development of a Forestry Adaptation Action Plan and assessment of capacity for forests to sequester carbon.
- Local Adaptation Pathways Program – provided almost $2m in funding to help local government build their capacity to respond to the likely impacts of climate change.
- Climate Change Adaptation Skills for Professionals Program – an investment of almost $2m to fund tertiary education, training institutions and professional associations to revise or develop professional development and accreditation programs for architects, planners, engineers and natural resource managers.
- Water for the Future – the largest investment in climate change adaptation provides $12.9 billion to invest in fixing the national water crisis. The Australian Government is funding alternative water supplies for our major cities in order to reduce reliance on rainfall, and improved water security for our smaller cities and towns. In the Murray–Darling Basin, the Australian Government is investing in restoring river health, and in improving irrigation water management and efficiency to assist irrigation communities to adapt to a future with less water. The Murray–Darling Basin Authority is also developing a basin-wide plan and 'cap' on water use that addresses both the legacy of past over-allocation and the emerging impacts of climate change.

Water resources, farming and forestry industries, coastal communities, and training for professionals have all been specifically selected to receive funding for research. The CSIRO and Griffith University funds are less specific in the Government remit. CSIRO's Climate Adaptation Flagship charter states that '*Australia's ecosystems, water resources, agriculture, built infrastructure, regional and remote communities, and health all have vulnerabilities to climate change*'. Although the mining and exploration industries were not mentioned it is also stated in the charter that:

> *"The Australian export sector is particularly exposed to climate change due to the vulnerability of our key export commodities including:*
>
> - *agriculture*
> - *forestry*
> - *fisheries*
> - *fossil fuels*
> - *tourism."*

The internal documentation on which the Climate Adaptation Flagship was developed did, however, explicitly include initiating adaptation studies with the mining industry.

The Queensland Resources Council website (http://www.qrc.org.au) has a section devoted to 'Energy and Climate Change' that focuses on how climate change can be mitigated using new technologies. However, there is no suggestion that work will look at how new technologies and research can assist the resources industries to adapt to climate change for continued success.

Outside of Australia, the AON Benfield Hazard Research Centre (University College London) has started to research the effects of climate change on a host of geological hazards globally. The research centre is largely funded by insurance companies. Australian insurance companies may have an interest in funding future research to assess risk and identify adaptation option strategies for mining companies.

4.3 Measuring vulnerability

A simple approach to assessing the vulnerability to the effects of climate change of mining processes is via the identification of the exposure to changes, the sensitivity to exposure, and the ability to adapt. A diagram describing this model was presented in the Garnaut report (2008) and shown in Figure 4.

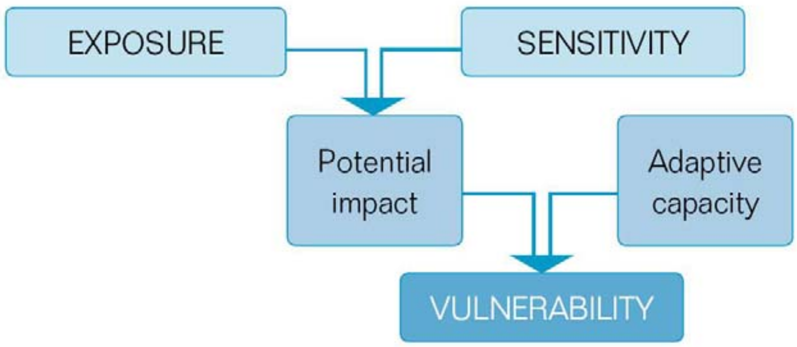

Figure 4: Model for assessing vulnerability (The Garnaut Climate Change Review 2008 6.1 p. 125)

5. GENERIC INDUSTRY FLOW CHART

Some of the main processes involved in mining are shown in Figure 5. Flow charts for processes specific to particular commodities will be developed for more detailed analysis and case studies as required.

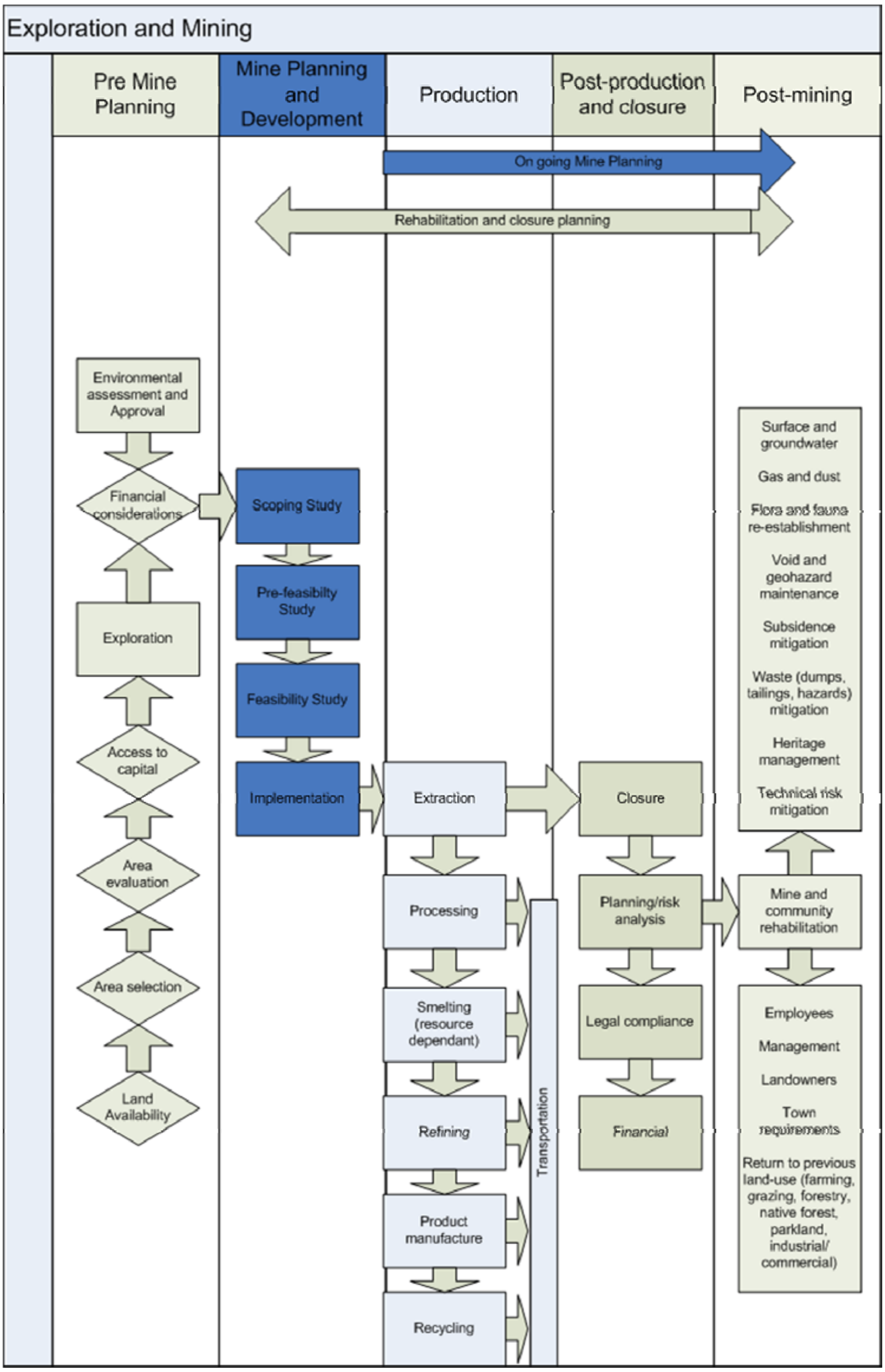

Figure 5: Generic exploration and mining process flow chart

6. LITERATURE REVIEW

Adaptation to climate change will require the adjustment of systems, using new technologies to prepare for increased probability and consequences of severe weather events as a result of climate change (Lapp 2005). Colls (1993) identified mining as an Australian industry whose decisions are affected by the local weather and climate, and where such variability impacts the cost of mining operation and design. These costs were associated with water storage design, disposal of effluents, location and construction of the plant, and design of offshore facilities. To date, however, few reviews have been conducted on the impact of weather and climate on the mining industry specifically, although this is a necessary step in formulating adaption strategies.

A report assessing the effect of climate change on the top 100 stocks listed on the Australian Stock Exchange (Australian Stock Exchange 100, or ASX100) identifies those companies most at risk and most likely to benefit from climate change (Citigroup Global Markets/Equity Research 2006). The report states that climate change affects companies’ profits and value through both the cost of carbon, and the physical weather and climate impacts. Additionally, the report states that insurance companies are already reducing their exposure in high risk regions, as changes in weather patterns are already having an impact. The cost of carbon is an issue in itself that will affect the way in which companies do business. However, the physical impact of weather and climate change on companies also has its cost. The impacts may be gradual or they may be the result of severe events. The report noted that energy companies may benefit from higher air conditioning demand but did not identify benefits for other companies related to the mining sector. Those at risk in the near-term included coal exporters. At higher risk in the longer term were those companies with exposure to lower growth in the Chinese economy (caused by widespread flooding), and companies situated in high-risk geographic regions where infrastructure is at risk from severe weather and flood events (e.g. mines in tropical regions). Other companies at risk include those that are dependent on water for processing, including mining companies. Australian temperatures have risen approximately 0.9°C since 1910 and there has been a marked decline in precipitation on the east and west coasts along with many other climate changes as well as sea-level rise and ocean acidification (Hennessy et al. 2007). These changes are congruent with projections of future climate (Hennessy et al. 2007).

Companies in the ASX100 who are addressing physical climate risks include:

- BHP Billiton (reviewing design criteria for oil and gas assets)
- Boral (water being an essential raw material, efficiency being assessed)
- RioTinto (previously working with the UK Met Office, and a follow up may be conducted).

Insurance Australia Group (IAG) has identified multiple increases in damages from extreme climate events, even from small changes such as small increases in temperature. This is because even small increases can affect the behaviour of extreme weather events. IAG state, for example, that a 25% increase in peak wind gust strength can generate a 6.5-fold increase in building claims (Citigroup Global Markets/Equity Research 2006). Lloyd’s has stated that research into the impact of climate change on business and the insurance industry should be undertaken (Citigroup Global Markets/Equity Research 2006; Lloyd's 2006).The impact of insurance claims in the mining industry wasn’t specified but needs to be identified.

Pearce et al. (2009) assessed the exposure and sensitivities of the Canadian mining industry to the impacts of changing climate. The report also assessed the industry's attitudes towards climate change and the extent to which it is responding to climate change through mitigation and adaptation.

The report found that:

- The mining sector has experienced stresses that were related to changes in precipitation, temperature, storms and extreme weather, which have affected mining infrastructure and operations in the past. These stresses continue today.
- Long-term adaptation planning is largely not occurring in the mining sector; mitigation, rather than adaptation is the major emphasis in addressing climate change in the Canadian mining sector at present.
- Effective technologies and strategies currently exist for adaptation to climate change. Although they are typically expensive, it is understood that investment in adaptation today may save money when compared to reacting to climate risks in future that may be costly.
- There is a considerable misunderstanding of future climate change trends and its implications for human activity – poor understanding of the issue will exacerbate vulnerability and 'the mining sector is unlikely to adapt to something that it does not first understand'.
- Climate change could present a potentially serious risk for mines in post-operational and closure stages where planning was based on current and past climate trends. Additionally, abandoned mine sites have not yet been assessed for vulnerability to climate change.
- The seriousness of potential threat by climate hazards may be overshadowed by other more immediate factors such as commodity price swings, project financing, land-use management and conflicts, public opinion of mining operations.
- Adaptation is frequently driven by experience with previous events caused by climate or extreme weather rather than proactive approaches based on scientific assessments of likely future climate change.
- Workers at mine sites whether on the ground or in the office were found to have different perceptions, as those on the ground had more hands on experience with day-to-day interaction with climate effects at the operation level.

The report concluded that the mining industry's reluctance to take a pro-active stance on adaptation is largely due to the uncertainty about emerging climate, and that future research and action is needed to reduce vulnerability. Communication of the potential risks posed by climate change is needed in the mining sector, and the most cost-effective measures and technologies must be identified to allow mining to adapt to climate change and extreme weather events. Regulations are needed for mine plan from operations through to decommissioning to ensure mines plan for climate change. Improved climate modelling and communication of projections will assist mines with understanding risks and allow them to plan better. Collaboration between associations, companies and regulators will enhance the chances of adaptation success..

Broderick and Hendel-Blackford (2007) identified the need for the mining industry to adapt to the consequences of climate change. They pointed out that 'there are many threats that climate change brings to the mining industry, such as increased frequency of storms, temperature extremes and changes in precipitation (to list but a few).' They also noted that even if we manage to get carbon dioxide emissions under control, we are still going to experience 'a certain amount of unavoidable climate change and rise in average temperatures' due to the time-lag between emission to the atmosphere and its effect on the climate. The report states that Queensland, in particular, has experienced a strong drying trend over the last 50 years. With a continued decline in rainfall and increased evopotranspiration, together with increasing population growth and water resource demand, water availability for mining activities will be strongly affected. Additionally, the threat of extreme events will increase the incidence of heatwaves and potentially more blackouts. The article concludes that the mining sector should assess the vulnerability of activities and prioritise adaption options.

Garnaut (2008) briefly mentioned that reductions in water availability will lead to an increased cost in mining activities, in addition to causing temporary cutback in production over the next 90 years in Western Australia.

Butcher et al. (2009) identified that an accurate, baseline weather scenario is important even at the conceptual stage of mining. However, even using a no-change scenario, many future mine sites may lack full in-situ observation records and hence, synthetic data is typically modelled to complement existing data. Influences of longer term variability (such as El Niño) must also be captured in such datasets. Additionally, a basic overview of how climate change may affect the proposed mine would also be beneficial at the conceptual stage. At the pre-feasibility and feasibility stages, hydrological and ecological modelling will also benefit from climate analysis and at this stage, social and environmental impacts can also be assessed. Butcher et al. (2009) state that '…knowledge of the weather thresholds that impact a mine's operations on a day-to-day basis can be used to tailor site-specific forecasts, which can provide warnings of severe weather'. For example, a mining company may choose to move expensive equipment and personnel away from danger, and ensure that the drainage systems are working 'properly' in the case of an extreme rainfall forecast. The report points out that although 'weather and climate are important to all aspects of the mining cycle…the risks associated with extremes of weather can be minimised' by better understanding the processes that will occur. This concept is simple but fundamental to encouraging the industry to effectively adapt to future changes.

7. POTENTIAL IMPACTS OF CLIMATE AND EXTREME WEATHER ON MINING PRACTICES – WORKSHOP RESULTS SUMMARY

Impacts of extreme weather events and climatic changes on mining were discussed in interviews with both CSIRO and industry experts, and at a workshop held at the Queensland Centre for Advanced Technologies (QCAT) on 12 November 2009. A number potential areas of concern and vulnerability were identified. These are summarised below and examples are given where available. The main themes discussed arose from the generic mining-process chart shown in Figure 6. A more complete review has been produced by Moffat (2009).

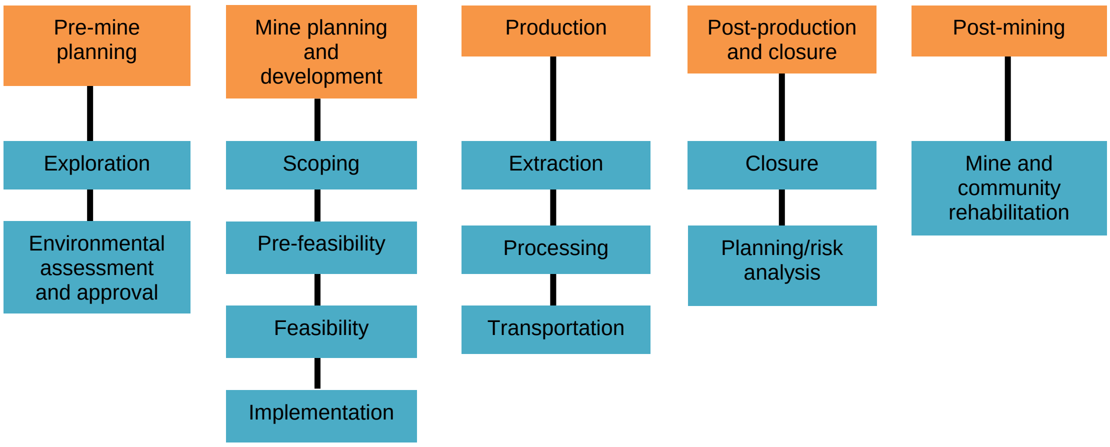

Figure 6: Generic mining processes discussed in CSIRO workshop

7.1 Pre-mine planning

Geophysics

It was agreed that the strength and behaviour of the rock determine the mining methods that will be selected for the mining process, so these methods will not be affected by climate variation.

Mine sustainability

Energy for the mine to operate may be affected by extreme weather events, e.g. if diesel cannot be brought in on flooded roads, or if power or rail lines become unusable due to such an event. Alternative and local power sources, such as wind, solar or geothermal, may be useful at the mine site for mining operations and for mine and local community emergencies during extreme weather events. Longer term power storage, such as large diesel stores or better solar-power batteries, were also suggested as development and adaptation options. Water usage at the mine was discussed and where water is scarce due to weather patterns, it was suggested that desalination of saline water and cleaning of polluted water may be an option, although research and development would be required to make this more economically viable.

Mine geomechanics and exploration were discussed although no specific themes were identified as being vulnerable to climate and weather extremes at the stage of pre-mine planning.

Social/community impact

It was suggested that mining companies generally have a short-term view (18 months) of the local community. Such a view may have implied that any social impacts of climate and weather extremes on mining to be greater than would otherwise be due to adaptation opportunities being identified and implemented 'too late'. Proactive adaptation would require a longer-term view of potential impacts on the community, as opposed to reactive adaptation.

Temperature and rainfall

Temperature was identified as being a potential concern at this stage of mining. For example, under higher temperatures, more electricity may be lost during transmission from its generation source. Alternative or more local power sources could be identified at the early mining stage to counteract this issue. Alternative energies could be part of the pre-mine planning process. Although rainfall itself was not deemed to be an issue at this stage of mining, water resources and inundation potential would be valuable to be assessed for the life of the mine, in order to plan the mine's operations accordingly.

Data

More accurate climatic return periods (including rainfall, wind, evaporation and temperature) in addition to sea-level and inundation information where appropriate are required to assist in assessment of adaptation requirements during pre-mine planning

Uptake

Due to a mine's requirements to provide investment returns in the short-term (18 months), there may be a limited capacity to use new technologies and methods from the outset. However, mine planners typically have medium- and long-term views and with this in mind, uptake may be reasonably well embraced.

7.2 Mine planning and development

Climate change planning

Feasibility studies could reduce uncertainty and assist planning for extreme weather events. Plans must ensure there is sufficient water available for the community and for mining processes. Additionally, infrastructure needs to be able to deal with the expected extremes and plans must be formed that ensure such tolerance. It was noted that insurance premiums increase after disasters and that this should be borne in mind during the planning and development stage.

Mining communities

Plans must identify the models for individual future mines (e.g. fly-in-fly-out, communities living around the mines) based on future climate projections. Creation of a regional hub to serve mine communities and staff another possibility that may better suits the climate and mine planning. It was suggested that mines may become automated to remove people from unpleasant and unworkable situations, but it was noted that this creates fewer local jobs and more local dissatisfaction. This option, however, would remove the need to bring in people from outside as is presently necessary in some mining districts.

Infrastructure and other industries

Climate changes and extreme weather conditions can decrease the viability of ports, railway lines and roads. Additionally higher temperatures may affect the efficiency of equipment and people, resulting to lower productivity and higher costs. It was suggested that some daytime activities may be rescheduled to night to prevent heat problems if temperatures are to increase significantly.

Waste ponds were identified as a potentially important environmental issue, and it was suggested that plans and development should concentrate on prevent high-volume rain events from bursting these ponds. Attention should also be given to pit development to prevent extreme flooding and equipment damage. However, this was also connected with higher costs that need to be minimised. Conflicts between mining and agriculture should also be addressed at the planning and development stage, where both industries will be competing for potentially limited water resources.

Temperature

It was agreed that planning a mine could include greater tolerances for infrastructure and the mine design must allow for more extremes. The plans may also allow for the effects of floods, winds and higher temperatures on ports, railways and roads. Temperatures may be expected to impact on some equipment and employees, leading to reduced effectiveness and possible health and safety issues. Some activities may be rescheduled to night time when it will be cooler. It was suggested that alternative energy, more creative use of energy or using less energy should be explored during production, for processes including cooling underground mines, machinery efficiency and dust control.

Data

Better data on projected changes in extremes, for rainfall events, maximum temperatures, wet/dry days and projected changes in stream flow, was identified as being a requirement at this stage of mining, including. Seasonality data would also be of value to identify the onset of cyclone seasons and times of heat stress. The need for accurate climate data and future modelling scenarios would help reduce the uncertainty in a pre-feasibility study, providing more security for financing the operation.

7.3 Production

Water

Water availability and evaporation rates were discussed at length. Increased evaporation rates would affect tailings dams, heap leaching operations, and also increase dust production. New technology is required to remove the dust from areas where people work or live (or to remove people from the areas of dust). Where more rainfall is expected, some outdoor production activities may require re-designing, including covering of some operations and equipment. It was noted that some areas of Australia, such as Tasmania, are already very wet and mining practices there could be adopted by areas that do not currently deal with as much rain. In some regions rainfall may decrease and production may require adaptation to require less water or water may need to be brought in. Either will be at extra cost, although the technology is available already. Where surface and groundwater levels may be likely to change, slope angle may require adjustment to prevent slope instability.

Transportation

Washouts of roads, railways and bridges are possible during high-volume rainfall events. Land in central Australia is particularly flat, with implications for rain events affecting railway lines. See also the following example for energy availability

When roads are closed due to flooding in Western Australia (diamond mining), the product can be flown out instead of transported by road. However, other commodities, such as iron ore, have no other alternative for transportation if their main route (rail or road) is closed. (Ian Gipps, pers. comm.).

Energy availability

It was stated that many ‘problems’ that mining may face because of climate and weather issues can be managed at the cost of extra energy. Therefore, more efficient energy use could be required during production. Increased automation and remote control may increase energy costs. However, it may reduce heat removal from mines because temperatures can be kept higher if people are not down the mines. Additionally, dust suppression may not be necessary if people are removed from the environment. Nevertheless, it was pointed out that machinery often is more efficient if the ambient temperature is cooler.

The Super Pit gold mine in Kalgoorlie, Western Australia, produces up to 850,000 ounces of gold a year. Here, pumps are required to drain the open pit of water after heavy rainfall. When the pumps are turned on, however, the power supply in the local town is affected and lights dim. Power is so severely affected that light bulbs do not last very long. Power resource conflicts such as these may become more widespread if more mines have to start pumping after excessive rain events in future (Eleonora Wdyzick-Capehart, pers. comm.).

Where roads are closed after a storm, diesel may be unavailable for the mine to continue production. After such events, mines may adapt by installing larger longer-term storage facilities to store more diesel (Ian Gipps, pers. comm.) or by exploring alternative energy-provision options.

Events

The potential for more frequent extreme weather events was discussed at length and the impact on production was seen to be potentially high, even though stockpiles should be sufficient in most cases to prevent lack of supply throughout an event. The lack of water in regions of extreme drought was of concern. In open pits, flooding and high wind can harm equipment such as draglines. Additionally, rainfall may affect underground mines if overland flow can enter the pit, although it was deemed as unlikely. However, where open pits have become underground pits, there is a potential for high-rainfall events to cause excess surface loading on the roof of the mine, and it was suggested the pit roof should be thicker to allow for this. It was also suggested that groundwater should be monitored, as an increase in groundwater may cause excess loading above an underground mine, increasing the danger of flooding.

Ensham Mine in Emerald, Queensland was affected by a significant flood in January 2008. The flood cost the mine millions of dollars in repair and loss of production. The flood was deemed to be a 1-in-200 year event, based on previous and present climate scenarios. Mine flood protection at the mine was designed for a 1-in-100 year event. The mine is situated at the confluence of Fairbairn and Theresa River systems. Although the dams were not at full capacity prior to the rainfall events, rain still filled the dams. The amount of excess water overwhelmed and breached the levy banks round the mine and the mine became flooded. Production had ceased prior to flooding and people were evacuated by helicopter. Where possible, equipment was moved to higher ground although some was too slow to move, such as a $100m dragline that became inundated. The mine did not return to full production until a year after the event. The mine hadn’t seen this type of event before and didn’t know how high the water would rise. It has been suggested that had the Fairbairn dam been less depleted of water prior to the rainfall event, flooding and subsequent damage would have been worse. Insurance covered some of the loss and the rest was written off to bad debt.

Temperature

The impact of heat on production equipment was discussed. While it was suggested that most equipment may cope sufficiently in excessive heat conditions, an example was given where heat caused equipment to fail. At the Mt Isa Inlier, reverse circulation drilling during one of the hottest months (November) ceased after the temperature hit low to mid 40s with little wind. Previously drilling had been able to continue all day. The rig’s onboard compressor stopped due to overheating, after which drilling could only continue for approximately10 minutes at a time. Despite efforts to cool the equipment with water spraying, the equipment continued to fail. Subsequently, the hole collapsed and it took a couple of days to free the rods and complete the hole. When temperatures dropped, drilling all day was able to resume (Cameron Huddlestone-Holmes, pers. comm.). It was suggested that the equipment may not have been sufficiently serviced to cope in the heat, which suggests mines may need to increase servicing frequency to allow the equipment to cope under hotter conditions.

Data

Action plans to match forthcoming events, in addition to more information on incoming weather conditions, were identified as crucial to production being able to cope with extreme weather events. Additionally, projected changes in rainfall intensity, evaporation rates and stream flow may be required. Closure should be planned to tolerate post-mining weather events to prevent contamination and hazards under new conditions. Processes may be augmented by adaptation of methods already used in regions already exposed to more extreme conditions.

7.4 Post-production and closure

Any changes in climate should dictate a mine's rehabilitation plan rather than automatically attempting to rehabilitate based on pre-mine conditions, as new conditions may not support the pre-mine environment. The same holds for social conditions. The complexity of rehabilitation and closure of the mine, whether en-mass or in stages, is increased if climatic conditions alter throughout the life of the mine. Additionally, rehabilitation was considered to be 'difficult' to plan for when future temperature and rainfall conditions may be uncertain.

7.5 Post-mining

Discussion of this subject focussed on rehabilitation after mine closure including backfilling, revegetation, acid drainage and other pollution, flooding potential, communities and agriculture. With regards to backfilling, it was suggested that erosion problems may occur if rainfall patterns change and more intense events occur. Climate changes may impact on revegetation at the end of mining where a change in climate conditions means that vegetation is different to that prior to mining. Tailings dams should be planned so that they can deal with more frequent high rainfall events, and not cause over-spill.

8. SUMMARY

This project finds that the mining stage that may be most affected by weather and climate variability and extremes is production. The areas deemed to be most at risk (and which will be the subject of further consultation) are:

- Energy availability: more efficient use of energy, methods of production requiring less energy and better storage of energy for longer-term use in emergencies
- Water availability: more efficient use of water and methods of production requiring less water
- Equipment and human resources: ability to perform under more extreme or more frequent extreme conditions
- Health and safety: safety of people under more extreme conditions and the potential extraction of people from dusty, hot or wet conditions.

Additionally, it is important that companies and government bodies are suitably educated on the possible impacts of climate change on the mining industry so that they take necessary action to adapt proactively. Potential funding sources include:

- private industry, e.g. companies such as RioTinto
- Australian governments, e.g. for assessing the status of already abandoned mines and for ensuring a future mining industry
- insurance companies, who will have a vested interest in understanding risk to mines, infrastructure and people under more extreme or altered conditions.

Better construction and communication of future climate scenarios, and associated impacts and potential adaptations, will also encourage suitable action to be taken.

9. ACTION PLAN

The project is intended to be undertaken in four phases (Fig. 7). The next phases in this project are to:

- identify examples of adaptation already in progress within the main areas of risk detailed above
- assess sensitivity to climate change for each of the main areas of energy, water, infrastructure and people
- identify research and development opportunities
- source localities and representatives for case studies.

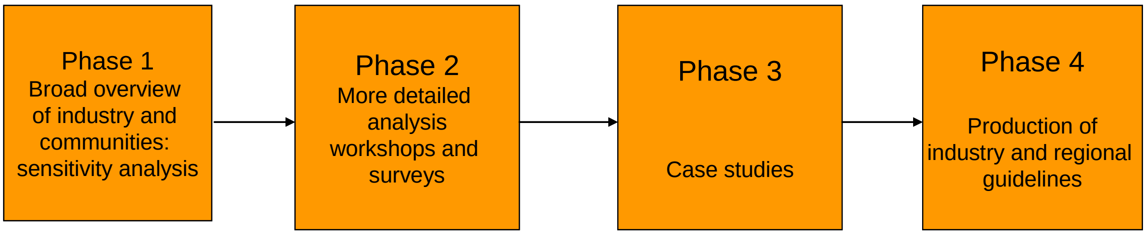

Figure 7: Flowchart showing each phase of the project

Phase 1 (2009-2010)

This project is currently in the first of four phases in which the systematic analysis of industry and associated communities are assessed to identify how they exhibit sensitivity to climate variability and climate change and review early-stage adaptation options. This document reports Phase 1 and the early stages of Phase 2.

Phase 2 (2010-2011)

The second phase will involve assessment at a more refined level, via a series of regional workshops in each of the four quadrants of Australia (Fig. 1) and through online industry-focussed surveys. The surveys will be adapted from those performed previously by CSIRO's social science analysis on various industries' views on climate change (Gardner et al. 2009).

In each quadrant, separate workshops will be held for industry and community participants, however they will be linked to one another so that the relationships between the outcomes can be assessed. The workshops will maximise learning by ensuring there is a broad coverage of different climate issues for different extractive industries across Australia.

The aim for this phase is to develop a synthesis of how people and companies view the impacts, and vulnerabilities across the industry and related communities, and the capacity and requirements for adaptation. During this critical phase, an overview will be obtained that will define which parts of the industry require more information, where adaptation work is already being done and those who wish to participate in activities with CSIRO in the future.

Phase 3 (2011-2012)

From the workshops and survey results, the third phase of the project will develop case studies. The case studies will be selected to maximise learning by ensuring that a broad and varied range of mining and communities are closely analysed. Importantly, this phase will be conducted in a 'hands-on' approach with industry and communities. This phase will be co-investment based to provide results directly to the interested and involved parties, in addition to providing 'real-life' examples for publication material.

Phase 4 (2012-2013)

In the final phase of this project, the results will be used to provide a set of guidelines for companies and regions to develop their own assessments for their adaptations to climate change.

Publications

Throughout the project, publications of the progress made will be presented to the science community through conferences, journals and reports, and we specifically aim to provide a publication for the next Intergovernmental Panel on Climate Change report.

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