

Mapping and Prioritising Rehabilitation of Abandoned Mines in Australia

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ABSTRACT

With more than 50 000 recorded abandoned mines in Australia, effective management strategies are needed to prioritise and manage health, safety, environmental and socio-economic risks and opportunities. This paper reviews international leading practices for abandoned mine management and identifies key issues that need to be addressed in the Australian context. As well as the academic literature, this review draws on a 2008 global legacy site survey and forum in 2008, a Churchill Fellowship study of abandoned mines and the recently released '*Strategic Framework for Management of Abandoned Mines in the Minerals Industry*' (MCMPR/MCA, 2010).

A conceptual model was developed to identify the relationship between key issues affecting the management of abandoned mines in Australia. The conceptual model is then used in the development of a maturity chart which draws on risk management principles to provide leading practice guidance for abandoned mine managers, jurisdictions and stakeholders. The maturity chart approach for risk management has been successfully used elsewhere to evaluate safety, environmental and socio-economic maturity.

INTRODUCTION

Australia is experiencing considerable mining growth, particularly in Western Australia and Queensland, placing significant demands on regulatory personnel focused on the approval of numerous new mines, some of which are large with complex approval processes. As a consequence of this growth, the costs of managing legacy issues associated with abandoned mines, jurisdictional ambiguity over responsibilities (Queensland Floods Commission of Inquiry, 2012), as well as competing priorities for funding, few jurisdictions have been willing to prioritise abandoned mines at a policy level. Only three out of seven jurisdictions in Australia have formal abandoned mine programs. They are Queensland, New South Wales and Tasmania. Very few jurisdictions have up-to-date inventories or a process to assess risks and prioritise sites at the jurisdiction-wide level.

An abandoned mine workshop (Bell, 2003) recommended Australia develop a national strategy for managing abandoned mines and in December 2010 a '*Strategic framework for managing abandoned mines in the minerals industry*' (MCMPR/MCA, 2010) was finalised. Abandoned mines are defined as:

... mines where mining leases or titles no longer exist, and responsibility for rehabilitation cannot be allocated to any individual, company or organisation responsible for the original mining activities (MCMPR/MCA 2010).

Such sites, with incomplete rehabilitation, are also called 'derelict', 'orphan', 'former' or 'legacy' mines. In Australia, abandoned mines have accumulated for over a

century, mainly, but not always, from times when mining environmental standards and community expectations were much lower than at present.

When sustainable development principles are applied to abandoned mine management, environmental and socio-economic impacts as well as opportunities for beneficial post-mining land uses must be considered. Furthermore, an understanding of the range of circumstances that have led to the occurrence of abandoned mines can provide useful context and knowledge to help inform current mining regulation and policy to reduce the likelihood of them developing in the future. A lack of current inventories on the magnitude and nature of impacts from abandoned mines makes it more difficult to make decisions at a strategic level on a state/territory wide basis. While states and the Northern Territory have responsibilities for abandoned mine liabilities, there are also national issues to consider where abandoned mines impact values of national significance (eg biodiversity).

The aim of this paper is to describe the key elements of leading practice abandoned mine programs and to apply these elements to Australia through the development of a maturity chart tool. This preliminary review will provide some insights into which aspects of the '*Strategic Framework for Managing Abandoned Mines in the Minerals Industry*' (MCMPR/MCA, 2010) are most important for developing an implementation plan to apply this framework across Australia. The concept of a maturity chart can support jurisdictions and plot where

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they are positioned at present, and where they want to be in the future. Minimum jurisdictional requirements can be identified and priorities developed with a consistent national approach. Implementation of the National Strategic Framework supported by this maturity chart could assist jurisdictions map a path toward the development of leading practice programs. Within these programs, individual priority sites will continue to require site-specific management plans according to the respective legislation and policies at the level of state and territory jurisdictions.

ABANDONED MINE MANAGEMENT – A GLOBAL PERSPECTIVE

This section comprises a review of global abandoned mine management. Examples of leading practices in Canada and the USA are presented, followed by a summary of the key outcomes of the global International Council for Mining and Metals (ICMM) and the International Union for the Conservation of Nature (IUCN) Legacy Mine Roundtable Forum in 2008. Finally, the conclusions of a Churchill Fellowship Study that investigated abandoned mine practices worldwide are described.

Abandoned mine management in Canada and the United States of America

The current framework of federal and provincial abandoned mine management programs in Canada was catalysed by a report by a multi-stakeholder advocacy group, presented to the Canadian federal government in January 2000 (MiningWatch Canada, 2012). The report identified that liabilities for abandoned mine sites were high – estimated at over C\$1 B for sites under federal jurisdiction, alone – and proposed a four-point plan to best address the problem. In the absence of complete and reliable data sets, the urgency for national and provincial inventories of sites was identified, followed by a need to verify the hazards posed by these sites through physical and chemical assessments. Thirdly, the report recommended that once the scale and nature of the problem were better understood, clean-up of the worst sites be funded and prioritised, along with research on how to best achieve this. Finally, it was recognised that inadequate bond requirements and/or bankruptcies had left the government with millions of dollars in clean-up costs, so it was recommended that a funding mechanism be developed to recover costs from industry.

These conclusions were mirrored two years later when the Canadian Auditor-General undertook an audit of contaminated lands, including abandoned mines (Office of the Auditor General of Canada, 2002). Despite 13 years having passed since the Canadian government had recognised the need for a contaminated site clean-up program, it still lacked basic information about contaminated sites (eg the number of sites in existence, the hazards posed by these sites and the probable clean-up costs) and therefore had no means of ranking sites in order of risks to humans or the environment. The Auditor-General was also critical of the absence of ongoing funding for managing contaminated lands and identified the lack of central leadership as crucial, as it restricted the ability of managers to address higher-risk sites in a timely manner.

Following the federal Auditor-General report, each of the provincial Auditors-General embarked on similar audits. These were critical in gaining support for action at the highest levels of government. For example, the Quebec Auditor-General's report identified that the financial commitment required by the State to restore legacy sites was an estimated C\$264 M as of 31 March 2008 and that:

... the interventions seeking to ensure that mining companies comply with legal requirements during the various stages of a mine's life do not minimise the risk that the State may have to assume additional restoration costs (Office of the Auditor General of Canada, 2009).

Thus, this audit process highlighted the need for the province to implement a robust and strategically-planned abandoned mines program.

In the USA, the Abandoned Mine Lands (AML) program of the Bureau of Land Management (BLM) enhances public safety and improves water quality by reducing or eliminating the effects of past hard rock mining in the western United States (US Department of the Interior, 2012). The BLM and its 'Cooperative Conservation Partners' aim to mitigate hazards to protect public health and safety and to restore watersheds for natural resources, recreation, fish and wildlife. In the case of surface coal mines the Office of Surface Mining (US Department of the Interior, 2012) has a program for abandoned mine management.

The above two examples in Canada and the US indicate that mature abandoned mine programs require:

- central leadership, clear roles and responsibilities
- commitments to safety, health, environmental restoration, biodiversity and other uses
- complete inventories by jurisdictions to identify sites
- spatial data accessible to the public via a national mine land inventory
- physical and chemical characterisation of legacy sites
- a clear hierarchy of rehabilitation action based on systematic prioritisation
- appropriate allocation of resources so that the worst sites are prioritised
- establishment of funding mechanisms to recover costs and fund work
- evaluation of current regulatory policy to ensure intervention and amendments prevent future abandoned mine liabilities occurring
- cooperative partnerships with catchment and conservation groups and public land users.

International Union for Conservation of Nature/ International Council on Mining and Metals legacy mine roundtable forum

In March 2008, a legacy mine forum was co-convened by the IUCN-ICMM and the Eden Project Post-Mining Alliance in Toronto, Canada (Post-Mining Alliance, 2008). This forum emerged from a 2002 commitment by the ICMM and IUCN to convene a series of discussions titled '*Dialogue on Mining and Biodiversity*'. Participants were drawn from developed and developing countries and from government, industry and civil society to explore key obstacles to progress on regeneration of legacy sites. A questionnaire preceded this forum to help focus discussions on key challenges. A major concern of respondents was developing methodologies to more effectively deal with mine legacies (Whitbread-Abrutat, 2008). Respondents identified a need to improve understanding and trust-building among different groups in order to establish new relationships beyond conventional or ineffective approaches; however, to be successful, this would require responsibilities of each stakeholder to be better clarified. Respondents also rated the importance of exploring new funding options highly. The post-forum report recommendations were framed around the themes of funding, regulation, knowledge-sharing, partnership approaches and local community participation (IUCN-ICMM, 2008; Unger, 2008).

Churchill Fellowship study

In order to learn more from leading practice case studies overseas, a review of leading practice abandoned mine programs and post-mining land use was undertaken in six northern hemisphere programs for a Churchill Fellowship study (Unger, 2010). A summary of principal themes from four of these programs follows.

Crown contaminated sites program – British Columbia, Canada

A key factor in the transformation of the contaminated sites program (which incorporates abandoned/orphaned mines) in British Columbia were critical findings by the Auditor-General in 2002/2003 (in Unger, 2010), which highlighted shortfalls similar to the Quebec example above. Specifically, there was a lack of policy, roles and responsibilities were not defined, knowledge gaps were not being systematically addressed, there was no government-wide plan and ministries were unable to account for progress and liabilities. As a result, contaminated site programs were developed in 2004 to address policy development, data management and site inventory, site prioritisation and transparent public performance reporting of financial liabilities via a biennial report (Crown Contaminated Sites Program, 2012). A multi-disciplinary committee (the provincial contaminated sites committee) was established to help guide and prioritise restoration activities. Importantly, in order to prevent the creation of new abandoned mines, the regulatory authority (Ministry of Energy, Mines and Petroleum Resources, now Energy, Mines and Housing) aimed for full bonding of high-risk sites and a standardised spread sheet was developed to include post-closure acid rock drainage management (capital and operating costs) to minimise legacies reverting to the crown.

International construction exhibition (lakes) – regional regeneration project – the former East Germany (IBA-SEE)

A ten-year project to regenerate both the landscape and economy of the Lusatian region in Germany, IBA-SEE was completed in 2010. Unger (2010) presented ten principles for the development of post-mining landscapes from the 2009 conference where the project was showcased (IBA-SEE, 2009). They are:

1. developing iconic sites as examples for other projects
2. using resources effectively
3. fostering identity (link between industrial heritage and new landscapes)
4. the importance of the long-term planning perspective
5. shaping the process with strong leadership
6. allowing for creativity and innovation
7. generating pictures by visualisation of completed landscapes
8. ensuring transparency
9. building the organisational structure
10. the role of all levels of government collaborating to take responsibility.

The IBA-SEE project has successfully implemented a vision for the regeneration (IBA-SEE, 2009) of regional landscapes and economies via stabilisation of open cut pits, water management, landscape rehabilitation, conservation of mining heritage features together with new infrastructure to support land uses focused on tourism and associated enterprises.

National Orphan/Abandoned Mine Initiative – Canada

The National Orphan/Abandoned Mine Initiative (NOAMI) in Canada is led by a multi-stakeholder advisory panel (NOAMI, 2011). In 2002, NOAMI established five task groups to undertake in-depth analyses of issues and provide recommendations and advice to the advisory panel. The outcomes highlighted common issues across all jurisdictions that manage legacy site issues in Canada. These five task groups focused on the importance of information gathering/inventory, community involvement, legislative and institutional barriers to collaboration, funding approaches to abandoned mine rehabilitation and jurisdictional legislative reviews to facilitate leading practice abandoned mine rehabilitation (NOAMI, 2011). NOAMI have been very successful in attracting attention to abandoned mines issues in Canada and provides a useful model for Australia on how a single entity at a national level can support the rehabilitation of abandoned mines across jurisdictions.

The Eden Project – Post-Mining Alliance, Cornwall, England

The Eden Project in Cornwall, England is a charity and tourist attraction focused on education on sustainable development. Established within a reclaimed kaolinite pit Eden Project is an excellent example of successful rehabilitation of an abandoned mine site. In addition to the attraction, the Post-Mining Alliance was formed to communicate what has been learned from this project and other leading practice projects globally where socio-economic regeneration has been particularly successful. The Post-Mining Alliance (Pearman, 2009) observe that the key ingredients to successful regeneration projects include; the development of local solutions to fit local circumstances; leadership, vision and commitment; creative partnerships for funding, development and implementation, collaboration with 'unusual suspects'. These partnerships involved developing shared interests and community involvement and consultation at all stages to aid in developing shared responsibility and ownership. Finally, the uniqueness of the spectacle, along with good design were also key to success.

Other factors identified by Pearman (2009) as potentially being of location-specific relevance that contributed to the success of projects included: hybrid projects and multi-purpose sites; good location linked to transport; close to sizable population if visitor-dependent; links between heritage attractions in same region; government commitment to fund; and legislation (eg where biodiversity is a priority).

Australian programs

In Australia, most abandoned mines are the responsibility of the state and territory governments. A summary of the strengths of each of the programs is provided later in this paper. This section provides an overview of key milestones in the development of a national strategy for abandoned mines in Australia over the last decade, namely, the 2003 Australian Centre for Mining Environmental Research (ACMER) workshop and the establishment of the Abandoned Mine Working Group, which convened from 2006 to 2011 and which developed the 'Strategic Framework for Managing Abandoned Mines in the Minerals Industry' (MCMRP/MCA, 2010).

Australian Centre for Mining Environmental Research abandoned mine workshop, 2003

In November 2003, an abandoned mine forum was held in Brisbane by ACMER (Bell, 2003). The forum addressed the following themes:

- looking forward with the benefit of hindsight
- stakeholder perspectives and perceptions
- risk identification and management
- innovative approaches for remediation and funding.

The workshop identified a need to develop an overall framework for addressing abandoned mines issues in Australia and it was recognised that the Canadian NOAMI model provided a useful approach. The workshop concluded that the development of a management strategy, incorporating a consistent risk assessment approach, partnerships, adding value, synthesis of information and identification of knowledge gaps is critical. Additionally, funding opportunities including royalties, bonds, incentives addressing liabilities and legislative issues (addressing liability and duty of care) are important. Engagement with considered industry was essential. Finally, the workshop forum recommended that a summary paper be prepared to map the way forward to improve information sharing and that this should involve the Ministerial Council for Mineral and Petroleum Resources (MCMPR is now part of the Standing Council on Energy and Resources under the Council of Australian Governments).

Abandoned Mines Working Group, 2006 - 2011

The Abandoned Mines Working Group was formed in 2006 and collaborated until 2010 under the MCMPR. The group comprised abandoned mine managers from within most state governments (not all jurisdictions had formal abandoned mine programs) and representation from the Minerals Council of Australia (MCA). The working group developed a 'Strategic Framework for Managing Abandoned Mines in the Minerals Industry' (hereafter referred to as the 'Strategic Framework') which was released in December 2010. The Strategic Framework (MCMPR/MCA 2010) aimed to 'encourage a strategic approach to abandoned mines management, which promotes efficiency, sustainability, innovation and consideration of the unique assets and community values for each mine' and provides a great first move toward addressing abandoned mines issues in Australia collectively at the national level. Chapter titles 1 - 5 are included in Table 2.

QUANTIFICATION OF ABANDONED MINE LEGACIES

A key first step in evaluating the impact of abandoned mines is the development of an inventory describing the number of mines and their characteristics. To date, there has not been a national inventory of abandoned mines prepared in Australia of suitable quality. The need for such a data set is recognised as critical to assessing Australia's mining legacy through analysing cumulative impacts, estimating rehabilitation costs and prioritising abandoned mines for rehabilitation.

The total number of abandoned mine records within Australia is 52 534 (Figure 1), although it is recognised that this is likely to be an underestimate because many of the state data sets are incomplete. Figure 1 represents the first draft of a national abandoned mine map based on publically-available information, and further correspondence with each jurisdiction is required to address some of the uncertainty in the data sets. The recorded numbers of abandoned mines in the Australian states vary by an order of magnitude (for example, Queensland has 15380 and New South Wales (NSW) has 410 records, respectively). A major reason for this difference may well be due to definition and scale, but the lower number recorded for NSW may also be because, as is the case elsewhere, there is no resourced program in place for the capture of such data and the subsequent development of an appropriate database.

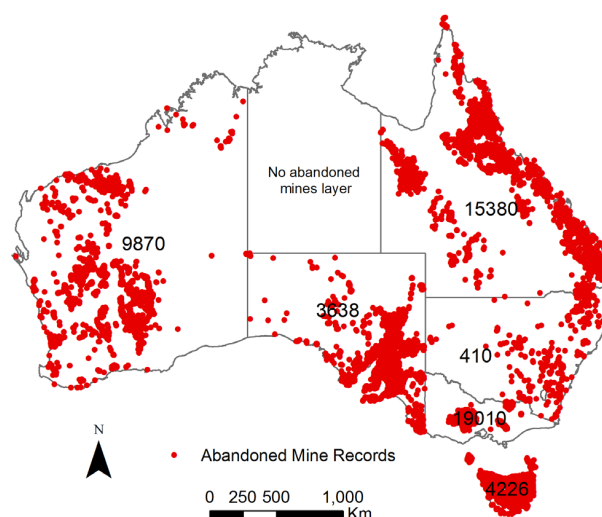


FIG 1 - Abandoned mines records for each state, as of July 2011 (for some states/territories, the records are incomplete).

A significant issue associated with utilising these data sets at a national level is the lack of consistency and the ambiguity in the category definitions describing mine characteristics (Table 1). Spatial data quality is a key problem that may affect the ability to utilise data and have confidence in the results (Aspinall and Pearson, 1996). A lack of consistency makes it difficult to combine data from different sources and will result in state-dependent bias when processed. Inconsistency includes a range of naming conventions as well as a range of quantitative measures. In order to combine data sets the classification/categorisation method needs to be explicitly defined within the meta data. Incompleteness and bias is often the result of the development of abandoned mine data sets for specific purposes unrelated to quantifying impacts. For example, the abandoned mine data set in some states was primarily developed to document potential resources for future extraction (eg Queensland) while in other states it was developed for safety concerns due to the risk of injury or subsidence from underground shafts (eg Victoria). In order to understand the cumulative environmental and socio-economic impacts and potential opportunities of abandoned mines in Australia, there is a need to have spatially-accurate data across jurisdictional boundaries which describes many facets but in particular, the area of disturbance, commodity type and the mine features present (eg pits, waste dumps, shafts, tailings storage facilities).

CONCEPTUAL MODEL OF A MATURE PROGRAM

Maturity chart concept

In order to successfully operate an abandoned mine program it is important to address its multi-faceted nature; from funding to legislation to communicating with stakeholders. Each component of an abandoned mine program needs to progress through maturity phases to achieve leading practice planning and implementation of rehabilitation. These phases can be considered through the development of a maturity chart tool (Westrum, 1993; Hudson, 2007). The purpose of a maturity chart is to map the development of an integrated, systems-based approach to abandoned mine management. It allows strengths and weaknesses to be identified in the current approaches to abandoned mine management taken by each jurisdiction and the evaluation of this against

TABLE 1

Summary of abandoned mine mapping in Australia by state and the information present within each database.

State	Location	Commodity	Mine type	Size – commodity	Size – physical	Start date	Close data	Processing method	Lease boundary
Qld	Present	Present	Absent	Present	Absent	Absent	Absent	Absent	Absent
SA	Present	Present	Present	Absent	Absent	Absent	Absent	Absent	Present
NSW	Incomplete	Incomplete	Incomplete	Absent	Absent	Absent	Absent	Absent	Absent
Tas	Present	Present	Present	Absent	Absent	Absent	Absent	Absent	Absent
WA	Present	Incomplete ^a	Absent ^a	Absent	Absent ^a	Incomplete	Incomplete	Absent	Absent
Vic	incomplete	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
NT	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a
Example or further info	Longitude, latitude	Gold, zinc	Under-ground, open pit	100 t	4 km × 5 km footprint	When mine opened	When mine closed	Cyanide leach	Spatial data describe lease boundary

a. The information was present in the Western Australian abandoned mine data set (WABMINE).

current international leading practice. Finally, it provides an indication of step-wise improvements that could be taken by each jurisdiction on their path to maturity. The maturity chart approach for risk management has been successfully used around the world to evaluate safety, environmental and socio-economic maturity.

Against this background and context, an abandoned mine maturity chart has been developed for the Australian context. From the information provided by this review of abandoned mines programs at both global and Australian levels,

categories of leading practice components that need to be undertaken has been identified. Fourteen key characteristics have been derived to define the maturity elements of programs. Figure 2 provides a conceptual flow chart of how these mature program elements relate to each other. These elements have been incorporated into a maturity chart in Tables 2 and 3.

Each of the 14 elements within the maturity chart needs to be ranked in terms of how an abandoned mine program is performing. Each management category can be described

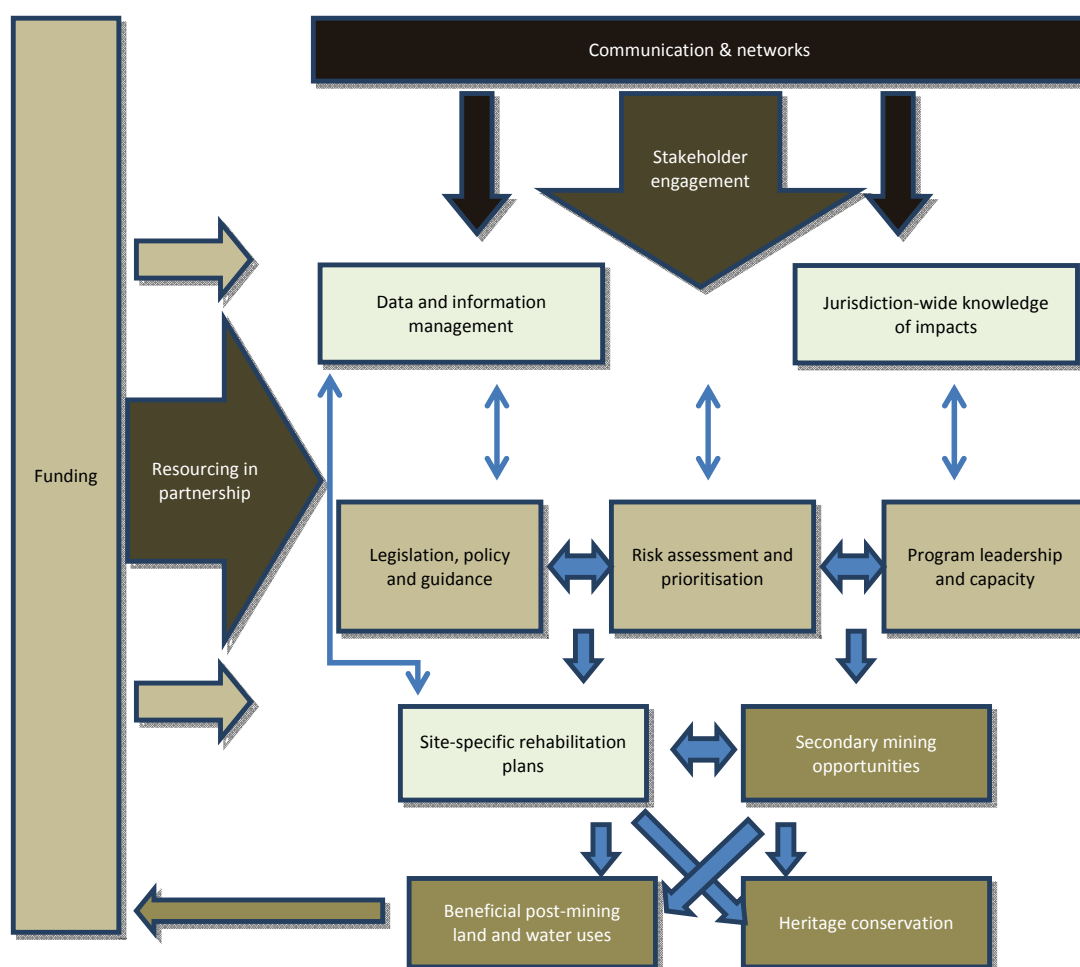


FIG 2 - Elements of a mature abandoned mine program as a conceptual flow chart.

TABLE 2
Elements of a mature abandoned mine program integrated with strategic framework.

	Strategic framework	Mature program conceptual model
1	Chapter 2: data collection and management	Data/information management
2		Jurisdiction-wide knowledge of health, safety, environment, and socio-economic impacts
3		Site specific rehabilitation and management plans for high risk sites
4	Chapter 3: risk assessment and management	Leadership, legislation, policy and guidance to address AMs
5		Legislation, policy and guidance to prevent new AMs
6		Risk assessment and prioritisation of programs
7		Abandoned mine program leadership and capacity/skills
8		Funding; sources, mechanisms and resources
9	Chapter 1: valuing abandoned mines	Focus on beneficial post-mining land/water uses
10		Heritage conservation – Indigenous, cultural and industrial
11		Secondary mining opportunities
12	Chapter 4: resourcing and partnership opportunities	Resourcing in partnership
13		Stakeholder engagement at jurisdiction level
14	Chapter 5: information sharing and 'leading practice'	Communication and networks

TABLE 3
Example of maturity chart contents for Item 1 data information/management of Table 2.

		Vulnerable (1)	Reactive (2)	Compliant (3)	Proactive (4)	Resilient (5)
1	Data/ information management	<ul style="list-style-type: none"> No inventory No estimate for liability to state/NT Absence of a knowledge base upon which to apply risk assessment for decision-making 	<ul style="list-style-type: none"> Data exists on those sites, which have come to the attention of governments by communities, land owners or other stakeholders 	<ul style="list-style-type: none"> State/NT-wide database exists An estimate for liability can be determined Data cannot be compared across jurisdictional boundaries; definitions and size classifications as well as historic information availability varies from site to site Part of an abandoned mine manager's role to also manage database 	<ul style="list-style-type: none"> State/NT-wide database exist of all abandoned mine features so it is possible to delineate risks by feature as well as by site Full liability estimate made Spatial data bases publicly accessible, regular review and update of data Personnel dedicated to data/information management Data for priority sites relatively current Data of sufficiently high quality with the appropriate meta data 	<ul style="list-style-type: none"> High quality state/NT-wide database exist of all abandoned mine features with the appropriate meta data based on ISO standards It is possible to delineate risks by feature as well as by site inventory, regularly updated Full liability estimated updated regularly Data set compatible across jurisdictional boundaries; alignment of database components so comparisons can be made with other states as well as risk assessment undertaken on national values Regular collaboration across Australia on data sets and information management Detailed data sets on priority sties. Sufficient data on other sites for decision-making

against five levels of maturity, ranging from vulnerable and reactive to accepting, proactive and resilient. These five phases have been adapted from the Minerals Industry Risk Management (MIRM) maturity chart, which is a version of the Hudson Ladder (Department of Resources, Energy and Tourism, 2008b; Hudson, 2001). The Australian states and territories are not yet ranked against the categories presented in the maturity chart (Table 2). The evaluation by each jurisdiction of performance for each management category is a key first step to systematically addressing abandoned mine management issues.

The maturity chart has been developed while considering the structure of the Strategic Framework (MCMPR/MCA, 2010) to align the chart with this milestone document and

to support the development of an 'Implementation Plan' to help transform the Strategic Framework into action. Once the maturity chart assessment has been used to highlight areas of strength and conversely areas of poor performance, planning can then focus on the next step to move programs toward leading practice. An example of how the maturity chart will be completed is shown in Table 3 for the first line of the chart 1 data/information management.

This implementation plan could include the development of appropriate support tools to assist knowledge sharing and progression of abandoned mine programs along the path to maturity. Finally, in order for an implementation plan to be effective, support from all levels of government is critical. As a precedent of support at the Commonwealth government

level, the implementation plan for a National Mine Safety Framework is an example of such a process (Department of Resources, Energy and Tourism, 2008a).

CONCLUSIONS

With more than 50 000 abandoned mines in Australia, a mining boom and a focus on approvals of new mining projects, the effective management of these sites requires a strategic national focus. This paper set out to describe the key issues that abandoned mine programs need to address in Australia in order to achieve this. The findings of the global and Australian review can provide guidance to jurisdictions and stakeholders involved in the development of abandoned mine programs and could be applied to the development of an Implementation Plan for the Strategic Framework (MCMPR/MCA, 2010). Key to systematically implementing solutions to the issues outlined in the review is the use of a maturity chart. In taking the next step of assessing jurisdiction development against this chart, a pathway would be mapped to provide long-term guidance. The goal is for Australian programs to progressively move towards mature programs consistent with international benchmarks for leading practice in other developed countries and thus, over time, to greatly reduce national liabilities.

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