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Appendix C: Abandoned Mines Working Paper

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1 Introduction

The issue of abandoned mines is important because it represents many thousands of former mining sites that continue to pose a real or potential threat to human safety and health and/or environmental damage. In many areas this is considered a negative legacy of the mining industry and is important because it both demonstrates a lack of care and planning in past practice and adherence to regulations that were inadequate because of the lack of detailed understanding. In general the presence of abandoned mines negatively influences public perceptions of the industry. Generally, abandoned mines are sites where advanced exploration, mining or mine production ceased without rehabilitation having been implemented at all or completed. They are found in virtually all regions with a history of mining.

Historically, it was common practice to 'abandon' a mine site when mineral extraction was completed. The land was left unvegetated and exposed, while waste materials were left in piles or haphazardly dumped into mine cavities and pits. There was little concern for the environment and no thought of how mining might adversely affect the surrounding ecosystem for years to come. This can be compared with the current situation at many operational mine sites, where the need for rehabilitation is now taken for granted and companies and governments have established legal, financial and technical procedures intended to ensure that mine sites are returned to a socially useful state after operations cease.

In a survey of abandoned mines in Canada, WOM Geological Associates (2000) lists the following as the mining related elements that occurred to create the legacy of abandoned mines:

- Economic – unforeseen events that caused early closure or left companies bankrupt, such as a sudden drop in metal prices, insurmountable mining/milling difficulties, and infrastructure problems.
- Technical – prior to the introduction of drilling equipment in the 1930's and 1940's, mineral deposits were evaluated by numerous exploration shafts and test pits which were never back-filled.
- National security – several mines operated in Canada during the Second World War to produce strategic materials for the war effort. Some of these mines were immediately closed with the passage of the Lend-Lease Act of 1941, when the US joined the war effort. Little was done to rehabilitate these mines.

Other elements that contributed to the legacy of abandoned mines include:

- Regulation - few government mine reclamation policies and regulations existed until the latter part of the twentieth century. Nothing was in place to provide governments with financial security in the event a mining company going bankrupt and being unable to cover the costs of rehabilitation. Ineffective government enforcement, usually due to lack of capacity, also contributed to the number of abandoned mines. Governments control the permitting system and have a duty to keep updated records and ensure that operators do not abandon operations irresponsibly.

- Loss of mine data - information that was not well stored has been lost due to natural disaster or unscheduled closure. Records of underground workings and surface openings were lost making it impossible to know their locations and keep updated records.
- Political unrest - local political problems in some regions led to unscheduled closure of a number of mines. The Kilembe copper mine in Uganda was abandoned in the early eighties due to political unrest and the Bougainville mine in Papua New Guinea was abandoned in 1989 due to a landowner rebellion.
- Small scale mining – the uncontrolled occupation of mine sites by artisanal or illegal miners has occasionally lead to a site being abandoned.

Since abandonment is usually sudden and unplanned, governments are often left responsible for mine closure and rehabilitation. Clark *et al.* (2000) stated the following about abandoned mines: 'closure and rehabilitation costs must be directly or indirectly born by the State. As such the abandoned mines represent not only a major liability for the government but for the affected communities, adjacent areas and society at large: the latter must ultimately bear the financial burden of ensuring appropriate closure.'

It has been suggested that the way forward may be the development of a combined approach to funding. This could contain elements of contributions from inheritors of the liabilities of former operators, a specific levy on production from existing mines in a country, a higher levy on new mining projects in that country, allocation of part of mining royalties paid in that country to abandoned mines problems, allocation of part of existing direct foreign aid from former colonial powers, new funds expressly for this purpose or multi-lateral funds earmarked for environmental or social projects.

This Working Paper reviews the inventories for abandoned mines that were available to the working group and presents the physical, environmental and socio-economic considerations. The financial implications of abandoned mines and the various approaches used around the world to rehabilitate such mines are also discussed. Finally, information on the prioritisation of abandoned mines is presented. Recommendations are contained in the Large Volume Waste Main Report. The reader should note that the information contained in this Working Paper focuses particularly on North America (where the relevant literature is most readily available). This does not imply that abandoned mines are only a North American issue or that the solutions developed are applicable everywhere.

2 Inventories of Abandoned Mines

Land degradation from old mine workings is well known in almost all historical mining regions. Abandoned mines are sites where advanced exploration, mining or mine production has ceased without rehabilitation having been implemented at all or where it was not completed. Other terms commonly used to describe such mines include: inactive mines, orphaned mines and unattended mines. As will be seen in the proceeding sections, the definition of abandoned mines in different regions varies and is important in determining

their numbers. The Bureau of Land Management in Montana, US defines abandoned and inactive mines on Federal Lands as follows:[1]

- A mine is considered abandoned if there are no identifiable owners or operators for the facilities, or if the facilities have reverted to federal ownership.
- A mine is considered to be inactive if there is an identifiable owner or operator of the facility, but the facility is not currently operating and there are no approved authorisations or permits to operate.

There are many references to environmental damage from such sites on a world-wide basis, however few systematic surveys and impact assessments have been carried out so the true scope of the problem is not known with any accuracy. No systematic world-wide inventory of abandoned mines exists, but their numbers run into millions if you include every shaft, adit and alluvial working (UNEP, 2000). Some regions like Canada, US, Australia and UK have attempted to produce abandoned mine inventories. The numbers of abandoned mines within these inventories are not always comparable because some surveys identify every mine feature as a 'site'.

The following section reviews available published and other information on abandoned mine inventories. Further information was obtained from a survey conducted by the UNEP in 1999 (these data were made available to the work group of MMSD). Information was also obtained through direct contact with individual State governments.

2.1 Australia

There is no nation-wide inventory of abandoned mines in Australia. It is the responsibility of the states and territorial governments. The different states are in the process of developing their own data collection and review systems for abandoned mines.[2] The New South Wales (NSW) Department of Mineral Resources has a database of about 500 abandoned mines but it is not a comprehensive list of all the sites.

As a result of the general lack of mining development between the 1940s and 1980s, the state of Victoria has few abandoned mine sites. However, there are good records of many older sites as a result of a long-term project to document historic mine sites. These records provide descriptions, interpretations and an assessment of the heritage status of around 2,000 sites. There is currently no co-ordinated programme to prioritise or address rehabilitation of these sites.[3]

In Western Australia (WA), the Department of Minerals and Energy is just developing its database of abandoned mines.[4] This is the first part of a process in identifying the outstanding risks and then prioritising each site as far as safety and environmental issues are

[1] See Management Bureau of Mines and Geology & Bureau of Land Management website at http://www.mbmg.mtech.edu/env-abldbms.htm/abldbms.htm

[2] Pers. comm. B. Gray, Land Access and Environment Section, Coal and Mineral Industries Division, Department of Industry, Science and Resources, Australia. 2001.

[3] Ibid.

[4] Ibid.

concerned. This Abandoned Mine Sites programme commenced in July 1999, with the objectives of accurately locating and describing abandoned mine sites in WA.[5] Priority in the inventory compilation is being given to high-risk sites, such as those close to population centres (within 10 km), main roads (within 1 km), areas of tourism activity, where the department has received complaints, and where accidents are known to have occurred. In the first one and a half years of the survey, a total of 23,000 hazards or potential hazards were inspected. This corresponded to about 40% of all high priority sites requiring inspection.[6] On average, each site of historic mineral production (of which there are about 2,000) converts to about 10 hazards or potential hazards in the database.

The Northern Territory has not yet undertaken an abandoned mines survey, but should commence in the next year, i.e. 2002.[7]

2.2 Canada

The Ontario Mining Act used the term 'abandoned mine' to describe sites where the proponent has ceased or suspended indefinitely advanced exploration, mining or production on the site. In Canada the details of abandoned mines inventory work vary widely. While more than 10,139 abandoned mines are on file, only about 60% have been physically assessed. This inventory includes sites recorded in federal government inventory records that are also listed in provincial/ territory inventories, some of which include trenches and test pits.

The quality of the inventories in Canada also varies greatly; some jurisdictions have created computer databases that are accessible to the public, others have only paper files and many abandoned mine sites have been recorded on the basis of library research only (WOM Geological Associates, 2000). Other provinces in Canada are shown to have inventories of abandoned mines but their numbers are not easily accessible. The provinces whose number of abandoned mines are known and are on file are shown below in Table C1.[8]

A multi-stakeholder process has been convened in Canada to develop a national approach to the problem of abandoned mines; the activities include developing an inventory, remediation expectations, ownership and liability issues and funding.[9]

2.3 United Kingdom

The recording of abandoned mines became a statutory requirement for England and Wales in 1870 (National Rivers Authority, 1994). Even with this statutory requirement in place, there is no total figure of abandoned mines available. One reason that prevents an accurate inventory in the UK is the change of mine names as old leases are combined and worked

[5] Pers. comm. D. Flint, Manager of Resource Assessment and Advice, Geological Survey of Western Australia. 2001.
[6] Ibid.
[7] Ibid.
[8] See http://www.miningwatch.ca/documents/Mackasey_abandoned_mines.pdf
[9] See http://www.mining.ca/english/publications/mmc2001.pdf

Table C1. Number of abandoned mines in Canada

Province	No. abandoned mines
Newfoundland and Labrador	36
Nova Scotia	300
New Brunswick	60
Quebec	1,000
Ontario	6,015
Saskatchewan	505
Alberta	2,100
British Columbia	< 20
Yukon Territory	120
Nunavut Territory	3
Northwest Territories	37

from one or several shafts. This is a major factor in Cornwall (Dines, 1956). There were no records of abandoned mines prior to 1872 (National Rivers Authority, 1994). The Mines and Quarries Inspectorate held only non-coal records and the data was not in a form easily accessible to the public. The British Coal Authority had a database of approximately 10,000 abandoned mine workings, i.e. Government owned mines, though this figure is believed to be an estimate as some of the mines may have been re-opened for commercial, recreational and educational purposes. It was also estimated that there were 1,700 abandoned metalliferous mine workings in the south-western region, whereas the British Geological Survey of abandoned mine data from the Metallogenic Map of Britain 1996 listed 155 abandoned mines.

2.4 United States

There are a large number of abandoned mine sites all over the US. Most of these are legacies from as early as the 16th century, the beginning of the industrial age. One estimate is that there is over 557,650 abandoned hard rock mines in 32 states (Lyon *et al.*, 1993; Table C2). However, when the Western Governors' Association reported data obtained from 33 states on abandoned mines and inactive hard rock mines in 1991, it cautioned that "*The findings presented are not comparable among states because of the variability in definitions used by states, and variability in the type and quality of data available to states*" (USGAO, 1996). Most of these abandoned mines, which are located on private, state and public lands, were mined and abandoned prior to the existence of environmental regulations (1970s). This number excludes many sites in remote areas that have never been surveyed and others that have escaped official notice. It is further estimated that at least 50 billion tonnes of untreated and un-reclaimed mining wastes currently cover public and private lands. Not all abandoned mines in the US appear on any master map but there are a few states that have attempted to count them; others may only be noticed when a fatality occurs.

Table C2. Six classifications for abandoned mines in the US

Category	Type	Number of abandoned mines	%
Category 1	Reclaimed and/or benign	194,500	35
Category 2	Landscape Disturbance	231,900	41
Category 3	Safety Hazards	116,300	21
Category 4	Surface Water Contamination	14,400	2.6
Category 5	Groundwater Contamination	500	0.1
Category 6	Superfund	50	0.01

Source: Mineral Policy Center (in Lyon *et al.,*1993).

The four major land managing agencies in the US, the Bureau of Land Management, the Forest Service, the National Park Service, and the Fish and Wildlife Service, attempted to inventory the mine sites on the lands they managed. The National Park Service estimated about 4,000 sites, the Fish and Wildlife Service about 240 sites, and the Forest Service about 25,000 sites. However, the methodologies and assumptions used to develop the inventories differ. For example, some units within the National Park Service combined all the features associated with a mining operation such as tunnels, shafts and structures as one mine site. On the other hand, other units considered single features within a mining operation such as a tunnel, access roads and trails, historic buildings such as mills and company towns, tailings and waste rock piles, and abandoned machinery as a single site or abandoned mine.

The Bureau of Land Management has carried out a survey of abandoned mines in the last few years and estimates that there are about 9,200 abandoned mines on the 264 million acres of land that they manage. It is estimated that 25% of these pose physical safety hazards and approximately 5% may be causing significant environmental damage, primarily in the form of water pollution.[10]

Projections from the Arizona State Mine Inspector's Office inventory suggest that there are as many as 27,000 abandoned mine features in the State.[11] In Alaska, a preliminary field survey of abandoned mine sites in Chugach National Forest recreation areas found 200 sites with potential hazards which included abandoned explosives, rotten support timbers in adits, steep narrow and eroded access trails, partially caved and unstable adits, shafts concealed by vegetation, heavy loose rock build-up etc. In Wisconsin, a 1980 survey found 440 abandoned mines where uncontrolled erosion and sedimentation had affected water quality and plant growth. In other places like Pennsylvania, there are over 250,000 acres of abandoned coal mine lands. It is also estimated that there are approximately 17,000 to 20,000 abandoned mine sites in Utah.[12]

In 1992 and 1993, the United States Forest Service, the Bureau of Land Management, and the Montana Bureau of Mines and Geology entered into agreements to identify and

[10] See http://www.blm.gov/aml/faqs.htm#top
[11] See http://www.az.blm.gov/mines/mines.htm
[12] See http://www.blm.gov/utah/minerals/aml

characterise abandoned and inactive mines on or affecting public lands in Montana. Their database contained about 8,000 records.

The Division of Minerals in Nevada has a very active programme to secure abandoned shafts and openings. As of January 2001 they have identified 8,107 such openings and have secured 5,879 (72.5%) of them. This programme focuses on the physical hazards of these openings.[13] The Great Basin Mine Watch estimates that there are 15,000 abandoned mines in Nevada.[14]

2.5 South Africa

Due to a long history of mining, South Africa has many abandoned mines. These include 134 abandoned asbestos mines and 400 asbestos dumps that are still contributing to the constant flow of asbestos dust to the surrounding areas creating a health hazard.[15]

Abandoned mines in South Africa are controlled under the Water Amendment Act 58 of 1997. The Water Act came into effect in 1956. It protects water and limits effluent discharge by the industry. Before promulgation of the Water Act 54 in 1956, many mines were abandoned without implementation of adequate pollution control measures. The provision of pollution control measures at abandoned collieries, and the responsibility for costs to institute these measures, were established in an agreement called 'The Fanie Botha Accord' reached between the mining industry and the South African Government in 1976. The Fanie Botha Accord in summary states that:

- Pollution control measures, the maintenance of such measures and all costs pertaining to mines and works abandoned before July 1956, would be the responsibility of the State.
- In respect of mines or works abandoned subsequent to July 1956, where measures had been instituted to the satisfaction of the State, the State will take responsibility for the maintenance and betterment of the pollution control measures taken.
- Should mining or works at any stage be resumed at a previously abandoned mine, the company resuming the operations will be responsible for any existing pollution control measures on the portion which is to be reworked, and for any additional pollution control measures required in respect to the resumed operations (Dalton *et al.*, 1998).

2.6 Other Countries

In Ireland the Environmental Protection Agency (EPA) has a list of 128 abandoned mines and most of these are very small or old and do not present any environmental problem. The Department of Natural Resources in Ireland identified five sites that are or have the potential to cause environmental problems.

[13] See http://www.minerals.state.nv.us

[14] See http://www.greatbasinminewatch.org

[15] See http://www.saep.org/subject/law_policy/ASBESTOS/Group_ProposalNJACOBS010515.htm

In Sweden, the EPA has a list of over 1,000 abandoned mines, of which only 70 are environmentally significant. In Japan, the national survey found 5,500 abandoned mines (UNEP, 2000). In Chile, a survey by the National Geology and Mining Service in 1989/1990 found that in northern and central Chile over 50% of the 665 tailings storage facilities studied had been abandoned without any cleanup or rehabilitation (Clark *et al.*, 2000).

From all the information above, it is clear that no country has a definitive abandoned mines list although globally the number probably may run into millions i.e. depending on the definition of an abandoned 'mine'. It is also clear that abandoned mines databases are a higher priority in developed countries. In most areas there is little or no co-ordinated information available to gauge the extent of the problem. In general abandoned mines may present physical hazards and/or create environmental impacts. This distinction has not been made in many of the inventories.

3 Issues Associated with Abandoned Mines

The issue of abandoned mines, with its the associated physical, environmental and public safety concerns, constantly emerges around the world as a reminder of the legacy that past mining operations created. While the safety hazards were historically appreciated by the public and media (though not always addressed), ongoing damage from such sites and the serious potential risks from the gradual deterioration of large abandoned mine features, such as tailings storage facilities and underground workings, were often ignored.

It was only during the latter half of the twentieth century that it was realised that some abandoned mines were a potential threat to the environment and needed to be assessed. Attempts have been made in many countries, especially in developed ones, to locate, study and rehabilitate abandoned mines sites. In some countries programmes exist to address the environmental, social and economic issues that surround abandoned mines. In addition, the impact of abandoned mines on the image of the industry can be detrimental to future developments.

In countries with a long mining history, the magnitude of the impacts from past mining is often considerable, as environmental regulation of mining activities has in most cases only been introduced relatively recently. Although the most important issues of abandoned mines are the physical hazards (safety of excavations and structures), and environmental contamination, public opinion, especially in the Western world, usually focuses initial opinions on visual impacts. However, as this is a qualitative, rather than quantitative, value this section will examine the physical, environmental and socio-economic concerns of abandoned mines. Because of the lack of data for developing countries the following sections are biased towards developed countries, and in particular, North America.

3.1 Physical Considerations

Some abandoned mines present only physical concerns. These concerns include public health and safety, visual impacts, stability issues and dust problems (the latter may also pose health impacts as will be discussed below). Accidents related to vertical openings or

deteriorating structures are the most common cause of death and injury in abandoned mines. Lethal concentrations of explosive and toxic gases like methane, carbon monoxide and hydrogen sulphide can accumulate in underground passages. It is also possible to encounter pockets of oxygen-depleted air in such workings. Rock falls and cave-ins from adits or pit walls can be a safety hazard. Unsafe structures include support timbers, ladders, cabins and other related features. These may seem safe but due to weathering they may easily crumble under a person's weight. Sometimes unused or misfired explosives are triggered. Many abandoned mines become flooded and shallow water can conceal other hazards like tunnels and sharp objects.

In order to warn the public about the hazards of abandoned mines, the State of Utah lists and discusses the following physical hazards on their website.[16]

- Mine shafts
- Explosives
- Highwalls
- Mines are not caves
- Abandoned mines are not ventilated
- Structures are dilapidated
- Animals live in abandoned mines
- Bad air
- Radioactivity
- Hazardous waste
- Water hazard

Many jurisdictions mostly in the US have safety programmes in place to educate the public about the physical dangers of abandoned mines. Posters and leaflets are distributed to raise awareness of these problems. These programmes also undertake special efforts to reclaim abandoned mines or to fence and post signs at shafts and other dangerous locations. A good example of such a programme is that of the Division of Minerals of the State of Nevada, US.[17] These materials (and those available from other programmes)[18] can be used to prepare training programmes that are suitable for a specific cultural setting though they can only be successful if the abandoned mines have been identified.

3.2 Environmental Considerations

Abandoned mines and associated features can have a detrimental effect on soils, water, plants and animals. The extent of the effects is not fully known because inventories are incomplete and some are still being evaluated (as was demonstrated in the preceding section). Generally, the common environmental consequences associated with abandoned mine sites include altered landscape, unused pits, shafts and adits, land no longer useable due to loss of soil or soil contamination, spoil heaps covering the land, abandoned tailings disposal facilities, contaminated aquatic sediments, subsidence, derelict works sites with compacted and polluted soil, burning coal waste dumps and workings and changes in vegetation.

Water is one of the resources most frequently polluted by abandoned mines. Water is also the main conduit by which impacts from abandoned mines extend beyond the immediate

[16] See http://www.dogm.nr.state.ut.us/mining/amr/
[17] http://minerals.state.nv.us/

site. Elevated concentrations of metals and increased levels of suspended sediment, acidity, hydrocarbons, and brine leaching can threaten surface and underground water quality and aquatic habitats. Probably the most common and also most significant problem at abandoned mines, especially ones that have sulphide mineralisation, is acid drainage.

Acid drainage occurs when surface or groundwater flows from or over abandoned mine features containing sulphide mineralisation. Discharge from adits or open pits, as well as surface flow over and seepage through sulphide rich waste rock and tailings can produce acid drainage. Acid drainage begins with the exposure of iron sulphide materials to air and water. The exposed, relatively insoluble sulphide materials are converted to soluble sulphuric acid and to iron compounds by oxidation. The sulphuric acid, in turn, dissolves other metals such as aluminium, copper, zinc, cadmium etc. Although these constituents can occur naturally in water in trace amounts, as a result of hydrologic and weathering processes, their concentration can increase substantially as a result of acid drainage. More details on acid drainage are found in the section on chemical stability in the Large Volume Waste Working Paper (Appendix A).

Abandoned mines may include disturbed lands and unprotected slopes that are susceptible to erosion. Uncontrolled surface drainage can remove soils and may make large areas unstable. For instance in Australia, large areas of dry land forest that were dug over in the gold rush in the 1860s have still not recovered. There is virtually no topsoil and only sparse vegetation and stunted trees cover the land.

Mercury from historic gold mining operations in the Nevada and California is a significant environmental problem. Large amounts of mercury still remain in the waste of the placer gold deposits that were mined in the Sierra Nevada foothills. The mercury can leach out of these deposits into the natural drainage in the area. As a result of this ongoing leaching of mercury, intermittent or long-term warnings are posted about the consumption of fish, which can accumulate mercury in the tissues and organs.[19]

Fish can travel long distances spreading mercury throughout the ecosystem. The WWF and the University of Para, Brazil have found fish with mercury levels up to 48 times the acceptable level for human consumption. These fish have been caught in the breeding lakes of Amazon North of Tefe, 2,500 km up the Amazon River from their normal habitat, the artisan gold mines in the State of Para. There is no economic way of cleaning these deposits and the mercury is expected to be a long-term problem.

The USGS is completing a five-year study of the environmental impacts of abandoned metal mines in two watersheds in the Western US. Extensive studies have been done in the Boulder River Watershed in Montana and the Upper Animas River in Colorado. Measurements of water quality throughout the watersheds and metal concentrations in fish and invertebrates have also been carried out. The results of these studies have been extensively reported.[20] Also, an account of the abandoned mine problems of Scotland, with

[18] See Office of Surface Mining web page at http://www.osmre.gov/keepout.htm
[19] See http://ca.water.usgs.gov/mercury/
[20] See http://amli.usgs.gov/amli/

more than 80 abandoned mine discharges causing pollution, has been done by Younger (2001).

3.3 Socio-Economic Considerations

The most important socio-economic concern caused by abandoned mines is the loss of employment and business activities in the community, due to the unscheduled closure. The other socio-economic considerations of abandoned mines mostly arise from both the physical and environmental considerations discussed in the preceding sections. These include the safety hazards caused by abandoned mines that usually result in the loss of lives.

The physical impacts of abandoned mines like slope stability, contamination of soils by acid drainage and other metals released from waste piles usually cause the loss of productive land. Disturbed lands and unprotected slopes are susceptible to erosion. Uncontrolled surface drainage and subsidence can remove soils and may make large areas unstable. Abandoned mines are often used for the dumping, both legally and illegally, of industrial and household waste, which adds to the problems with contamination.

Contamination of both the ground and surface waters by abandoned mines impacts on the aquatic systems. Contamination may be due to metal releases (involving elements such as mercury, lead, copper) resulting from processes such as acid mine drainage. Acid drainage from mines causes changes in the pH that either drives away or destroys the aquatic life. A manifestation of acid drainage is ochre, also known as 'yellow boy', an orange coloured slime caused by heavy metals precipitation. This slime coats the riverbeds often smothering aquatic life. In certain locations, the natural fish and invertebrate population of Welsh streams have suffered high mortalities due to mine water pollution, for example in the River Pelenna (National Rivers Authority, 1994). The dispersion of pollution that results in the migration of fish affects communities that depend on fishing for their livelihoods. There may also be imposition of restrictions on legitimate users of the waters who may find the water unsuitable for irrigation, livestock watering, industrial or portable water supply.

Another potential socio-economic impact from abandoned mines is dust from old waste disposal sites. This can be a nuisance and a health hazard if it contains certain minerals and heavy metals. Children playing on and around these sites may ingest dust that may also have health implications. Other concerns include windblown dust containing contaminants such as silica, asbestos fibres and chromium.

Mines abandoned by a company may become a target for legal or illegal mining by small-scale miners. In some cases this involves the expansion of the previous mine workings while in others it is the reworking of the waste materials to extract whatever metal was left. While this might have the advantage of providing jobs and revenue for people who have lost their jobs due to the unscheduled mine closure, it may also have adverse effects. Most of these miners have no formal training, although they may have gained some experience at other mining operations. In some cases the miners could use dangerous processing chemicals to extract metals (such as the mercury used in gold extraction) and this could have impacts on both their health and the environment. This uncontrolled mining can lead to impacts on the ecosystems and water resources. Abandoned mines will continue to have an impact on both the environment and the communities in which they exist unless good mine closure

practices are implemented. These issues are discussed in the Mine Closure Working Paper (Appendix B).

3.4 Financial Implications

Funds are required for the rehabilitation of abandoned mine sites. The question when dealing with abandoned mines is: who provides these funds, what mechanisms exist in various jurisdictions to raise these funds and who is ultimately responsible for the rehabilitation work and the long-term care of the sites? In some cases governments are forced to take on the task of rehabilitating abandoned mines when there are no identifiable owners or if the owners have no funds to pay for rehabilitation. In some countries legislation may be designed to fund the rehabilitation of abandoned mines. The costs are affected by the lack of agreed criteria as to what conditions need to be remediated and what the goals of rehabilitation should be.

Mine closure legislation can enable the regulating authority to control and prevent operating mines from becoming abandoned mines by setting up funds for rehabilitation. This issue is further discussed in the Working Paper on Mine Closure. Other concepts such as the polluter pays principle will be discussed together with the roles of governments in establishing these environmental policies. Finally, the involvement of third parties in abandoned mines rehabilitation, which sometimes involve liability issues that can discourage potential efforts to reclaim them will also be analysed.

The cost estimates to rehabilitate abandoned mine lands are very uncertain. Lyon *et al*. (1993) estimated US$ 32.7-71.5 billion to reclaim the 557,650 abandoned mines they listed in the USA. The biggest cost range was associated with the 14,400 mines listed under Category 4 - surface water contamination that was estimated to be US$ 14.4-43.2 billion. Clark *et al.* (2000) indicated that the Canadian Institute for Environmental Law and Policy estimated in 1999 that it would cost more than C$3 billion to rehabilitate the 5,000 plus abandoned mines in Ontario.

As noted above, abandoned mines are found in many places all over the world where there have been historical mining activities and their rehabilitation is expensive. Clearly, society previously received both the benefits and the negative impacts from these activities but the question is who should pay for the rehabilitation of these areas. One opinion is that the government should pay for rehabilitation, while another is that the previous owners (or their heirs) should be held responsible for such clean-up actions (i.e. the polluter pays principle in its purest form). An issue with the latter option is that for most abandoned mines the previous owners are no longer viable companies, cannot be located, or an individual owner may have died and it is therefore impossible to recover any costs. Another issue is that some sites are located in areas with many older abandoned mines making it uncertain who is responsible for the pollution.

There are those who feel that the present mining industry should contribute to a fund that can pay for the rehabilitation of the abandoned mines. This approach is part of the US Surface Mining Control and Reclamation Act of 1977 (SMCRA). The Office of Surface Mining has been established to regulate coal mine activities under this law. Inter alia, the law provides for the restoration of lands mined and abandoned or left inadequately restored

before August 3, 1977. Production fees of 35 cents per ton of surface mined coal, 15 cents per ton of coal mined underground and 10 cents per ton of lignite are collected from coal producers at all active mining operations. These fees are deposited in the Abandoned Mine Reclamation Fund, which is used to pay the reclamation costs of Abandoned Mine Land (AML) projects.[21] There is an agreement within the programme that one half of the collected funds will be returned to the States that produce coal. Unfortunately these amounts have not been paid to the States as most of it has been diverted to other social programmes unrelated to abandoned mines cleanup.[22] It must be noted that states where there is no coal production, such as Nevada, do not get any funding for abandoned mines rehabilitation work under this program.

The AML fund works well for most coal producing states. For example, in the State of Wyoming (an arid state for the most part) all abandoned coal mine sites have been rehabilitated, though this is not the case in most of the Eastern US States such as West Virginia. The total amount already spent, and estimated to be spent, on rehabilitation of abandoned coal mine lands in the USA is estimated at US$ 7.556 billion (Table C3). A large sum of money that is due to the various states for coal mine reclamation remains in the Office of Surface Mining. The previous and present administrations have not released these funds to the states resulting in high remaining liabilities.

Clark *et al.* (2000) indicated that similar programmes are in place in Canada and India.

Whilst a programme based on fees collected from operating mines to rehabilitate abandoned mines has been proposed for hard rock mines in the US, no formal legislation has been passed to implement it. The various programmes in the US and Canada have spent tens of millions of dollars during the last 5 to 10 years in the rehabilitation of abandoned mine sites and much remains to be done.

Various mechanisms can be used to pay for rehabilitation of abandoned mines. The approach used for coal mines in the US has been described above. Tasmania established a Trust Fund, as part of the Mineral Resources Development Act of 1995, for the rehabilitation of abandoned mines (Tasmanian Geological Survey, 1998). This Trust Fund can be used to clean up mines after they have been ranked according to priority (see discussion in next section). The aims of rehabilitation are:

- Remove risks to health and safety;
- Stabilise the site and reduce or remove impact of erosion and mass movement;
- Where feasible maintain or increase the biological diversity of species in the vicinity to pre-mining levels;
- Remove or ameliorate sources of site contamination;
- Remove features limiting the beneficial use of the site and its surroundings; and,

Improve the visual amenity of the site and its surroundings.

[21] http://www.osm.gov

[22] http://www.westgov.org

Table C3. Summary of Abandoned Mine Lands Programme for the Office of Surface Mining in the US; Abandoned Mine Land Inventory System - Priority 1 and 2 Sites

State/Tribe	Completed	Funded	Un-funded	Total
Alaska	5	0	38	43
Alabama	21	5	40	65
Arkansas	15	1	14	30
Colorado	9	4	25	38
Crow	2	0	0	2
Hopi	0.4	0	0	0.4
Iowa	22	1	23	46
Illinois	35	12	29	76
Indiana	35	1	11	47
Kansas	10	1	60	71
Kentucky	218	49	302	569
Maryland	16	2	16	34
Missouri	37	0	38	75
Montana	17	0	0	17
Navajo	0.6	0	0	0.6
North Dakota	22	0	41	63
New Mexico	6	0	4	10
Ohio	63	8	93	164
Oklahoma	17	1	91	109
Pennsylvania	281	70	4,584	4,935
Tennessee	1	0	0	1
Texas	6	0	6	12
Utah	8	1	25	33
Virginia	50	6	108	164
West Virginia	217	14	626	857
Wyoming	92	0	0	92
Totals	1,206	176	6,174	7,556

Another approach is to provide incentives for active mining companies to participate in the rehabilitation of abandoned mines. These mines usually have the equipment available to perform much of the work. Environmental legislation may not provide this incentive, as is the case in the US. Anybody who becomes involved with construction (or earthmoving) activities at a contaminated site can be held responsible for the complete cleanup of the site to specific criteria, e.g. water quality criteria under the Clean Water Act. Making an improvement to the site conditions may not be sufficient to remove this responsibility. Such laws are seen as deterrents to the overall rehabilitation of abandoned mines. Specific legislative initiatives have been proposed to overcome this, however nothing is currently in place.

It is recognised that the mining industry has a poor reputation in many parts of the world and that there is always suspicion that the industry would not do something to improve the

conditions in an area unless there are clear financial incentives. Some companies have agreed to rehabilitate old sites within their lease as one of the conditions for receiving an exploration or mining licence (Box C1).

Box C1. Coeur Rochester's Nevada Packard Project

The Nevada Packard Project is located approximately 17 miles northeast of the town of Lovelock in Northern Nevada. It will consist of a small satellite open pit mine near the Coeur Rochester Mine. The Coeur Rochester is a silver and gold open pit mine that commenced operations in 1986.

The Nevada Packard Project is located in the historic Rochester mining district; an area that has been extensively mined in the past, resulting in numerous small waste stockpiles and borrow pits, as well as adits and shafts. Parallel with the Nevada Packard Project development, Coeur is proposing to reclaim approximately 63 acres of older abandoned mining disturbances created by previous operators located within the project boundary. In return, the authorities have agreed to expedite the permitting process and allow the company to carry out an environmental audit rather than an environmental impact assessment.

The rehabilitation includes the following:

- A nine-acre heap leach pad will be recontoured to a 2.5:1 slope and reclaimed in place using suitable growth media and revegetated cover;
- Water wells would be plugged to Nevada Division of Environmental Protection standards;
- The historic tailings located within the project area will be covered with waste rock and overburden, recontoured to a 3:1 slope and then revegetated;
- The drainage in the area of the historic tailings will be modified, if necessary, to minimize erosion;
- The historic tailings outside the project area will be covered with waste rock and overburden and regraded to a 2.5:1 slope to minimize erosion.
- Any pre-Coeur exploration roads outside the open pit will be reclaimed, with the exception of some older roads and those required for public access as part of the post-mining land use.

Following rehabilitation all previously existing and new surface disturbance would be recontoured and revegetated except for approximately 47 acres of the open pit. This remaining open pit will be partially backfilled.

Many abandoned mines occur in areas of extensive mineralisation, which means that natural runoff may contain elevated metal levels. Baseline water analyses are not always available for these areas and it is therefore very difficult to determine what the discharge criteria must be after rehabilitation. Using the watershed approach (described below) one can set targets for improvement of conditions. This requires co-operation between regulatory agencies and community groups. It is conceivable that other funding sources may be located when such

multi-stakeholder groups are formed. One such group that is actively involved in abandoned mines issues is the Animas River Stakeholder Group in Colorado.[23]

There is a clear question as to whether the present operators should be held responsible for the 'sins' of their predecessors; this is a question of national culture and priorities. Most of the past mining operations were conducted prior to a full understanding of the potential environmental impacts and before any environmental regulations existed. In many cases these operations were seen as contributing to the development of a region and specific groups in society. It must also be noted that most of these mines operated in full compliance with the regulations of the day.

The Polluter Pays Principle is well established for the cleanup of environmental impacts. Using this approach it is important to try and locate the responsible parties when abandoned mines are rehabilitated. This is routinely done when abandoned mines are rehabilitated and all the federal and state groups will undertake these searches for the responsible party. It must be noted though that in most cases there are no responsible parties still alive, or in business, and the cost for rehabilitating the abandoned mines must then revert to the government.

There are very complex legal issues associated with historical mines, some of which are now abandoned. Some of these mines were operated under emergency conditions in Canada and the US during the Second World War to provide materials for the war efforts. Some uranium mines were operated under similar conditions during the cold war era. The UK also had mines operated under martial regulations in both World Wars. Typically the government is expected to take responsibility for environmental damages associated with these facilities though in some cases they are often neglected

The costs of rehabilitating abandoned mines may be recovered over time if the area can be used for future commercial activity. For example, some abandoned mine areas may become tourist sites with important spin-offs for the communities; an example is the Gold Reef City theme park in Johannesburg. Mining heritage sites can become popular tourist attractions. These opportunities may become more significant if the mine has unique features, e.g. discharge of geothermal water from an adit.

3.5 Ranking and Prioritisation

Today, to avoid the problems associated with abandoned mines, mining companies in many regions are required to provide a fully bonded rehabilitation programme before they are granted a licence. However, these bonds are not always adequate as the cost of waste treatment may not be included in the bond or when corporate guarantees that constitute part of the bonding requirements become worthless when a company declares bankruptcy.

If done at all, the task of rehabilitating abandoned mines, is usually taken on by governments. The role of government with respect to abandoned mines should first be to protect the safety and health of its citizens. Therefore, the activities associated with securing shafts and other facilities that pose hazards must receive the highest priority. One could

[23] See http://www.waterinfo.org/arsg

argue that a good inventory should form the basis for this work. Not only should such an inventory contain all the sites but they should also be investigated so that their features can be understood. The priority of most governments is to accomplish this near population centres and near roads where people will have the easiest access. This becomes especially a problem near fast-growing cities such as Las Vegas. The Nevada Division of Minerals describes their special efforts in this regard on their website.[24]

Regions have different ranking/prioritisation criteria for the rehabilitation of abandoned mines. Typically, criteria used in the prioritisation focus first on public safety and then the environment. In some regions, legislation dictates which criterion should be used, especially in cases where government funding is involved. For instance in the US under the Office of Surface Mining rules there are 'high priority' sites that pose a threat to health, safety and general welfare of people. These are the only problems that the law requires to be inventoried under this category. Thirteen states now do their own emergency abandoned mine land rehabilitation. Abandoned mine land problems impacting the environment do not have to be inventoried if rehabilitation is not funded.

Pioneer Technical Services (1994) describes a risk-based methodology for the prioritisation of abandoned mine sites in Montana; these include both coal and hard rock. The methodology is modelled after the USEPA's Hazard Ranking System used for sites containing hazardous waste. Site-specific criteria for evaluation include:

- The extent of actual releases and the potential to release hazardous constituents from the site into the environment;
- The quantity, toxicity, and concentrations of hazardous constituents in waste materials at the site; and,
- The degree of risk to human health and the environment posed by those hazardous constituents.

A scoring system is developed and is intended as a preliminary screening and prioritisation mechanism. Four pathways or routes of exposure are evaluated: groundwater, surface water, air and direct contact (soil exposure). The ranking of the sites is done based on available data and a site visit; no extended investigations are carried out.

The Bureau of Land Management in the US embraces the watershed approach for the rehabilitation of abandoned mines. This approach includes the following:[25]

- It is an interagency/interdepartmental effort that focuses on co-operation among land managers and science bureaus. It allows the demonstration of 'good faith' effort at a reasonable level of effort and expense over the near future, with full awareness of the potential burden of such cleanup on the public;
- It establishes an interagency group that will co-ordinate the Federal efforts to prioritise in each watershed the specific water bodies that are affected by discharges from abandoned mines;

[24] See http://www.minerals.state.nv.us

[25] See http://www.blm.gov/aml/watersol.htm#top

- It allows cleanup to proceed on a risk-based priority, addressing priority sites first; and
- It requires the Federal land managers to utilise appropriate management and control practices based on the identified risk on the specific site.

The Tasmanian Geological Survey (1998) presents a process for selecting and prioritising abandoned mine sites. The overall approach is similar to others in that safety and health of the public is the first priority. Clear guidance is given on how to apply the process.

WOM Geological Associates (2000) describe the prioritisation methods used by two agencies. Department of Indian Affairs and Northern Development uses what is referred to as the 'Northern Environment Risk Assessment Strategy' which considers four factors: legal environmental liabilities, human health concerns including food chain and physical hazards, land claim obligations, and public concerns. The Ontario Ministry for Northern Development and Mines has an 'Abandoned Mine Hazard Ranking System' that considers public safety, public health, environmental, social and economic issues.

From the different prioritisation systems discussed above, it is noted that the criteria for the rehabilitation of abandoned mines, especially in the developed regions, is quite similar with most considering public health and safety first. This has the disadvantage that environmental impacts, especially to limited water resources, are usually ignored.

Conclusions and Recommendations

See the *Mining for the Future Main Report* for general discussion and recommendations.

References

See separate References for the Main Report and Appendices.