

THE CANADIAN MINE ENVIRONMENT NEUTRAL DRAINAGE (MEND) INITIATIVE

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ABSTRACT

Acidic drainage has long been recognized as the largest environmental liability facing the Canadian mining industry, and to a lesser extent, the public through abandoned mines. The Mine Environment Neutral Drainage (MEND) Program was the first international multi-stakeholder initiative to develop scientifically-based technologies to reduce the effect of acidic drainage. A toolbox of technologies is now available to open, operate and decommission a mine property in an environmentally acceptable manner. This volunteer program established Canada as the recognized leader in research and development on acidic drainage. Through MEND, Canadian mining companies and the federal and provincial governments have reduced the liability due to acidic drainage by an estimated \$340 million, an impressive return on an investment of \$17.5 million over nine years.

The original MEND Program extended over a nine-year time frame ending in 1997; with technology transfer activities continuing to the end of year 2000 under the MEND 2000 program. MEND and MEND 2000 were described as a model way for governments, industry and non-governmental organizations (NGOs) to cooperate in technology development. This presentation will summarize the results that have been achieved, the lessons learned, and the opportunities for future actions. Case studies depicting Canadian full-scale applications of various technologies will be presented and discussed. Through these efforts a further reduction of the environmental liability associated with acidic drainage during mine life will be realized.

INTRODUCTION

One of the most significant environmental issues facing the global mining industry today is acidic drainage which affects all sectors of the industry including coal, precious metals (gold, silver), base metals (copper, nickel, zinc, lead), iron ore and uranium. Acidic drainage

is the result of a natural oxidation process whereby sulfur-bearing minerals oxidize upon exposure to oxygen and water. The net result is the generation of metal-laden effluents of low pH that can potentially cause damage to ecosystems in the downstream environment. Acidic drainage is caused not only by mining activities but also civil works. Remedial measures are currently in place at an international airport in Canada after construction of a runway exposed sulphide minerals which in turn resulted in acidic drainage. Road and pipeline construction are also periodic contributors.

Although the issue of acidic drainage is not new and has an extensive history spanning decades (and even centuries in Europe), it is not fully understood. In the past 10 years, changes in socio-economic expectations and heightened environmental awareness have made the management of waste an increasingly pressing issue in the mining industry (Price, 1995), with the result that the industry is one of the more intensively regulated and scrutinized of all industries. Extensive liabilities have been generated in countries such as Canada, the United States, Australia, Sweden and Germany by the inability to adequately deal with acidic drainage issues. Other countries such as Brazil, Peru and Argentina have recently discovered their own problems with acidic drainage. These liabilities are essentially the costs incurred by the property owner/manager during or after the life of the mine to ensure that the impact to the environment is minimized and consistent with environmental regulations. Costs typically include: the collection and treatment of acidic drainage; construction of engineered structures to contain mine wastes; relocation of mine wastes to containment areas; and rehabilitating the mine, mill and containment areas after operations have ceased. Some operations, at closure, may require treatment in perpetuity.

SCOPE OF THE PROBLEM

In the United States approximately 20,000 kilometers of streams and rivers have been impacted by acidic drainage, 85-90% of which receive acidic drainage from

abandoned mines (Skousen and Ziemkiewicz, 1995). Although there are no published estimates of total U.S. liability related to acidic drainage, some global examples may help to quantify the dimensions of the problem:

- The Leadville site, a Superfund site in Colorado, has an estimated liability of \$290 million due to the effects of acidic drainage over the 100-year life of the mine.
- The Summitville Mine, also in Colorado, has been declared a Superfund site by the Environmental Protection Agency (EPA) which estimated total rehabilitation costs at approximately ~ \$175 million.
- More than \$253 million dollars have been spent on Abandoned Mine Lands reclamation projects in Wyoming (Richmond, 1995).
- At an operating mine in Utah, U.S. regulators estimate liability at \$500-\$1,200 million (Murray et al., 1995).
- The Mineral Policy Center in the US has estimated that there are 557,000 abandoned mines in 32 states, and that it will cost between \$32 - \$72 billion to clean them up (Bryan, 1998).
- Liability estimates for Australia in 1997 and Sweden in 1994 were \$900 million and \$300 million respectively (Harries, 1997; Gustafsson, 1997).
- Ontario has more than 6000 historic inactive sites having an estimated rehabilitation cost of \$300 million dollars (CDN) (Cowan, 1999).
- The total Canadian liability has been estimated to be between \$2 and \$5 billion (CDN) (MEND 5.8e).

Considering the above data, the number of new mining projects currently under development plus existing mining projects in other countries not mentioned above (e.g. Europe, South America, South Africa), one might anticipate the total worldwide liability to be in the region of \$100 billion (US), or even beyond.

RESPONSE TO THE PROBLEM

Thirty years ago, rehabilitation was regarded primarily in terms of physical stabilization and the establishment of a self-sustaining vegetative cover. It was generally thought that the surface addition of alkalinity and the establishment of a vegetative cover would alleviate acidic drainage problems from these sites, and allow mining companies to abandon them without further liability. However, monitoring of the quality of the water draining

from revegetated acid-generating waste sites clearly showed in the years following, that acidic drainage remained a concern at many of these sites. In some cases, property owners were faced with the prospect of continuing to operate and maintain lime treatment plants indefinitely. There was need for a better understanding of processes involved, and for new remedial technology to be developed and demonstrated. What was done to try and resolve this issue?

In Canada there had been a tradition of institutional or collective approach to problem solving. From this mould, the National Uranium Tailings Program (NUTP) was cast in 1992. NUTP (1983-1988) was a program that focuses on developing predictive models to develop technology to reduce the liability for uranium mine tailings. The program was a Federal government initiative that had a fixed budget of \$9.5 million, was managed by a group of specialists, and had an advisory board from government and industry. Although some useful and innovative modelling methods were developed, no significant new disposal or management technology was developed. Also in terms of liability and environmental impact, acid generation from residual sulphides was clearly identified as the priority issue for uranium tailings in Ontario. This realization combined with the concerns by base metal and gold mining companies and government agencies led to the establishment of the Reactive Acid Tailings Stabilization (RATS) task force, which issued a report in 1988 which set out a 5-year research program that was to cost \$12.5 million. The program was subsequently called the Mine Environment Neutral Drainage (MEND) program with the realization that waste rock, mine adits and mine walls could also result in the generation of acidic drainage. This program had the following objectives:

- Provide a comprehensive, scientific, technical and economic basis for the mining industry and government agencies to predict with confidence the long-term management requirements for reactive tailings and waste rock.
- Establish techniques to enable the operation and closure of acid generating tailings and waste rock disposal areas in a predictable, affordable, timely and environmentally acceptable manner.

MEND was an unusual consortium driven primarily by the 130 volunteer representatives of the different participating agencies: regulators, NGO advisors, mining company managers and engineers, and federal and provincial government officials and scientists who freely contributed their time and expertise to the program. The program adopted an organizational structure that included a Board of Directors, a management committee and

several technical committees and a coordinating secretariat. Roles were simple. The Board of Directors provided vision and approval of yearly plans and budgets; the management committee provided "hands-on" management of the program; and the technical committees addressed technological issues and solutions. The Secretariat was essentially the "hub" of the organization and ensured coordination of the elements within, and external to MEND.

Over the succeeding ten years, the two levels of government, together with the Canadian mining industry, spent over \$17.5 million within the MEND program to find ways to reduce the estimated liabilities. Planned funding for MEND was divided equally among the three major partners: the mining industry, the federal government and five provincial governments. When MEND ended in December 1997, the federal government had contributed 37% of the funding, the provinces 24%, and industry 39%.

OTHER ASPECTS OF MEND'S SUCCESS

Aside from its technical successes, MEND has been described as a model for governments and industry to cooperate in technology development for advancing environmental management in the mining industry. Decisions on acidic drainage issues are now made based on sound science. The reasons for MEND's success include the following:

- The high return on the investment targeted and achieved, in terms of knowledge gained and environmental and technical awareness of the scope of the problem and credible scientific solutions.
- The partnership and improved mutual understanding developed between the two levels of government and the mining industry in search of solutions to a major environmental problem. Participation from non-governmental organizations was highly beneficial to the partnership.
- The small dedicated secretariat group which coordinated activities, managed the accounting, reporting and technology transfer, and was the "glue" which held the program together.
- The extensive peer review process that was both formal and informal, and resulted in enhanced credibility of the information base.
- The aggressive approach taken for transferring the knowledge gained during MEND.

Partly due to MEND, new mines are often able to acquire operating permits faster and more efficiently than before since there are now accepted acidic drainage prevention techniques. As an example, the Louvicourt mine in northern Québec adopted MEND subaqueous tailings disposal technology and has been able to progress from the exploration phase to an operating mine within 5 years, with a reduced liability of approximately \$10 million for the tailings impoundment. Similar impacts are reported for existing sites in the process of decommissioning. MEND has also fostered working relationships with environmental groups, ensuring that they are an integral part of the process.

MEND 2000

When MEND ended on December 31, 1997, the partners agreed that additional cooperative work was needed to further reduce the acidic drainage liability and to confirm field results of MEND-developed technologies. Increased technology transfer was also emphasized.

This resulted in MEND 2000, a three-year program that officially ended in December 2000. The program was funded equally by the Mining Association of Canada (MAC) and Natural Resources Canada (CANMET), a department of the Canadian government.

The MEND 2000 organizational structure included a Steering Committee that set the objectives, provided strategic direction and managed the overall program. Except for the Secretariat at CANMET, all members and stakeholders were volunteers from the mining industry, NGOs, and federal and provincial government departments. Many of these individuals were participants in the MEND program.

The importance of technology transfer became evident as MEND progressed and was regarded as the most important function for MEND 2000. All research results must be effectively communicated to industry, government agencies and the public if the program was to continue to achieve the desired results.

MEND3

In 2000, members of the MEND 2000 Steering Committee, together with their representative constituencies, reviewed the current and future needs of Canadian stakeholders in addressing acid rock drainage.

It ultimately recommended that a renewed national ARD research initiative called "MEND3" be launched in 2001.

The overall mission of MEND3 is to provide leadership in ARD research on Canadian priority issues, within an international context. It is a multi-stakeholder coordinated, focused Canadian ARD research initiative based on re-prioritized and augmented existing industry, government and university programs. It is intended to be a phased research program, carefully focused on prioritized Canadian national and/or regional needs, with modest administration costs. It is a proactive program that will maximize value from scarce resources, involve many stakeholders and provide a regional link to international efforts. This program will provide a national focus. The year 2001 will be used to lay the initial groundwork for a multiyear program.

MAJOR ELEMENTS AND RESULTS OF THE CANADIAN RESEARCH

MEND organized its work into four technical areas: prediction, prevention and control, treatment and monitoring. The four technical committees were also involved in technology transfer and international activities.

Over 200 projects were completed. Some of the key technical results and observations include the following.

Prediction and Modelling

Field studies of several waste rock piles provided important understanding for development of prediction techniques. One of the most important observations was that waste rock piles accumulate extensive quantities of oxidation products and acidity that can be released to the environment in the future (MEND 1.14.3; MEND 1.41.4).

Geochemical and physical characteristics of a waste rock pile, from its origin in underground workings to its disassembly and placement underwater in a nearby lake was completed. This study on Eskay provided qualitative and quantitative information on mass transport and water infiltration within a waste rock pile. Geochemical processes were dependent on physical factors such as channeling or stratification within the dump (MEND 1.44.1).

Laboratory and field prediction tests for waste rock and tailings have been investigated and further developed. These tests include static and kinetic tests, mineralogical evaluations and oxygen consumption

methods.

An "Acid Rock Drainage Prediction Manual" for the application of chemical evaluation procedures for the prediction of acid generation from mining wastes was produced (MEND 1.16.1b).

Advances in the prediction of drainage quality for waste rock, tailings and open pit mines have been made. A tailings model (RATAP) was distributed and a geochemical pit lake model was developed (MINEWALL). A critical review of geochemical processes and geochemical models adaptable for prediction of acidic drainage was completed (MEND 1.42.1).

Models that will predict the performance of dry and wet covers on tailings and waste rock piles are available (WATAIL, SOILCOVER).

Prevention

Prevention has been determined to be the best strategy. Once sulphide minerals start to react and produce contaminated runoff, the reaction is self-perpetuating. Also, at some mine sites, acidic drainage was observed many years after the waste pile had been established. With many old mine sites, there may be no "walk-away" solution;

In Canada, the use of water covers and underwater disposal are being confirmed as the preferred prevention technology for unoxidized sulphide-containing wastes. A total of 25 reports and/or scientific papers have been prepared on subaqueous disposal (MEND 2.11). A generic design guide was developed (MEND 2.11.9). The guide outlines the factors involved in achieving physically stable tailings, and discusses the chemical parameters and constraints that need to be considered in the design of both impoundments, and operating and closure plans. Water covers have been applied at many sites, but are not universally applicable. Related issues such as the ability to maintain a water cover over the long-term, (structures) and locality and site-specific potential risks due to seismic events, severe storm events, etc. can negate the use of this technology.

However, under suitable conditions, the present state of knowledge is sufficient to allow for the responsible design, operation and closure of waste management facilities using water covers.

Underwater disposal of mine wastes (tailings and waste rock) in man-made lakes is presently an option favored by the mining industry to prevent the formation of acidic drainage. At the Louvicourt Mine (Québec) fresh, sulphide-rich tailings have been

deposited in a man-made impoundment since 1994. Laboratory and pilot-scale field tests to parallel the full-scale operation and evaluate closeout scenarios were completed (MEND 2.12.1).

The use of water covers to flood existing oxidized tailings can also be a cost effective, long lasting method for prevention of acid generation. Both the Quirke (Ontario) and Solbec (Québec) tailings sites were subjects of MEND field and laboratory investigations (MEND 2.13.1 (Quirke); MEND 2.13.2 (Solbec)). These sites were decommissioned with water covers and are presently being monitored. Where mining wastes are significantly oxidized, laboratory results have shown that the addition of a thin sand or organic-rich layer over the sulphide-rich materials can prevent or retard diffusion of soluble oxidation products into the water column.

Control

Dry covers are an alternative where flooding is not possible or feasible. MEND has extensively investigated multilayer earth covers for tailings and waste rock (e.g. Waite Amulet and Les Terrains Aurifères (tailings) and Heath Steele (waste rock): 3-layer systems). These type of covers use the capillary barrier concept and although they are effective, they are also costly to install.

Innovative "dry" cover research is indicating that a range of materials, including low cost waste materials from other industries (crude compost, lime stabilized sewage sludge, paper mill sludge) may provide excellent potential for generating oxygen-reducing surface barriers. This technology would see the application of one waste to solve a problem of other wastes.

Non acid-generating tailings can be used as the fine layer in composite moisture-retaining surface barriers. Laboratory studies have confirmed that sulphide-free fine tailings offers some promising characteristics as cover materials (MEND 2.22.2). Barrick's tailings site in Northwest Québec, Les Terrains Aurifères, is the first full-scale demonstration project of using tailings in a cover system (MEND 2.22.4). A second site, Québec crown-owned Lorraine, has also been rehabilitated using the same closure technique.

The first full-scale application in Canada of a geomembrane liner for close-out was completed in 1999 at Mine Poirier in Northwest Québec. Performance monitoring of the close-out scenario is ongoing.

Disposal Technologies

Several other disposal technologies that will reduce acid generation and have been investigated include:

Permafrost in northern environments. Permafrost covers approximately 40% of Canada, and cold conditions inhibit oxidation. Predictive methods have been researched. Although acid generation is common in cold environments, it occurs when exposed sulphides are warmed to temperatures above freezing (MEND 1.61.1-3, 1.62.2)

Blending and segregation (or layering). Technology is defined as the mixing of at least two rock waste types with varying acid generation potential, neutralization potential and metal content to produce a pile that has seepage water quality acceptable for discharge without additional measures (MEND 2.37.1, 2.37.3).

Elevated water table in tailings. This technique offers a method of inhibiting the oxidation of sulphides through the effective saturation of pore spaces. It may be applied as one component of a multi-component reclamation strategy (MEND 2.17.1).

In-pit disposal following mining. Mined-out pits can provide a geochemically stable environment for wastes and can be a focal point in mine rehabilitation. The addition of buffering material may be required (MEND 2.36.1).

Depyritized tailings as cover materials. Laboratory and field tests are showing that depyritized tailings have excellent potential as covers. Economic analyses have indicated that hydraulic placement will be necessary to be cost effective (MEND 2.22.3).

Lime Treatment

Studies conducted to date support the view that sludges will remain stable if properly disposed. Concerns had been raised with regard to the long-term chemical stability and the potential liability arising from dissolution of heavy metals contained in the sludge (MEND 3.42.2). Other findings include:

- Optimum conditions will depend on site-specific factors e.g. pH, metal loading chemistry.
- Modifications to the treatment process (e.g., lime slaking, pH adjustment, mixing, aeration, flocculent addition) can influence operating costs, sludge volumes, and metal release rates.
- The method of disposal of the sludge will affect its long-term stability: aging can promote recrystallization which improves sludge stability.

- Codisposal of sludges with other mining wastes requires further study.
- Leach test protocols need to be developed specifically for lime treatment sludges.

The status of chemical treatment and sludge management practices was summarized in a reference document (MEND 3.32.1).

Passive Treatment

In Canada, experience indicates that passive systems do have specific applications for acid mine drainage (AMD) treatment. These applications range from complete systems for treating small seeps to secondary treatment systems such as effluent polishing ponds. Alone, they cannot be relied upon to consistently meet AMD discharge standards. Large-scale passive systems capable of handling the low winter temperatures, high metal loads, and fluctuations in flow rates associated with the spring freshet have yet to be implemented.

The status of passive systems for treatment of acidic drainage was summarized in a reference document (MEND 3.14.1).

Monitoring

Several guides are available to assist in the development of acidic drainage monitoring programs. An important MEND deliverable is MEND 4.5.4, *Guideline Document for Monitoring Acid Mine Drainage*. This document is designed to serve as a single source introductory guide to a wide range of AMD monitoring concerns, while also providing users with information on literature sources for site-specific concerns and emerging monitoring techniques. Monitoring requirements are addressed for both source and receiving environments, with receiving environment concerns restricted to freshwater systems.

Other guideline documents include a field sampling manual (MEND 4.1.1) that presents an approach to assist people in selecting the appropriate methodologies for the sampling of tailings solids, liquids and pore gas. A comprehensive list and description of sampling techniques, and a guide to waste rock sampling program design for the exploration, operation and closure phases of a mining project is produced in MEND 4.5.1-1. Available sampling techniques for waste rock is given in MEND 4.5.1-2.

At the conclusion of the MEND program, a "tool box" of technologies has been developed to assist the mining

industry in addressing its various concerns related to acidic drainage, and in significantly reducing its estimated liability. A particularly important outcome has been the development of a common understanding among participants, inasmuch as it has allowed operators to take actions with greater confidence and to gain multi-stakeholder acceptance more rapidly.

TECHNOLOGY TRANSFER

Technology transfer activities have been significantly expanded in recent years and this will continue for the duration of MEND3. The dissemination of information on developed technologies to the partners and the public is a major function of the program. A MEND 2000 Internet site (<http://mend2000.nrcan.gc.ca>) has been established and is regularly updated with current information on technology developments. Report summaries, the MEND publication list, information on liabilities, case studies, and conference and workshop announcements are provided. Further, MEND hosts several workshops per year on key areas of technology at various locations across Canada. These workshops have been the vehicle of choice to transfer the available information to the users and they have been quite successful in accomplishing this goal. Proceedings for the workshops on chemical treatment, economic evaluations, case studies of Canadian Technologies, monitoring, in-pit disposal, dry covers, research work in Canada, and risk assessment and management are available from the MEND Secretariat.

MEND participated in the organization of several International Conferences on the Abatement of Acid Rock Drainage (ICARDs) held in 1991 (2nd Montreal), 1994 (3rd Pittsburgh), 1997 (4th Vancouver), and 2000 (5th Denver).

Technology transfer will include information and analysis of projects not necessarily initiated under MEND (e.g Poirier) as well as an exchange of technology information with international organizations involved in research on acidic drainage. This includes foreign government institutes and other research initiatives such as the International Network on Acid Prevention (INAP), the Mitigation of the Environment Impact from Mining Waste (MiMi - Sweden), and the Acid Drainage Technology Initiative (ADTI - USA).

Other technology transfer initiatives include:

- MEND videos are available in English, French, Spanish and Portuguese, and describe technological advances relating to the prediction, prevention and

treatment of acidic drainage from mine sites. These videos are available free of charge and can be ordered directly through the Internet.

- The MEND Manual that summarizes all of the MEND and MEND-associated work on acidic drainage from mine wastes and openings.
- The Proceedings of the 4th International Conference on Acid Rock Drainage are available on CD-ROM.
- About 200 reports completed during MEND and MEND 2000.
- A selection of over 110 MEND reports on two CD-ROMs.
- National case studies on acidic drainage technologies.

NEW IDEAS

In 1992, MEND formed a Task Force to solicit and nurture innovative new ideas. An additional goal was established to encourage researchers from outside the general area of mining environment to becoming involved in acidic drainage research. The resulting technology would need to be reliable, inexpensive, permanent, and widely applicable. An innovator had to demonstrate the relevance of their idea at the concept level, which would then be the basis for proceeding to a more detailed development project. Up to \$10,000 was provided for the review and the development of a concept. Although most of the new ideas were innovative and applicable and provided useful information, they did not achieve the objective of providing a solution to the problem of acidic drainage. At least three had potential applications (sprayed polyurethane, modified clay and permafrost) and three yielded useful state-of- art reviews (U.S. research, foam flotation and Japanese technology).

MEND MANUAL

More than 200 technology-based reports were generated from the MEND and MEND 2000 programs. These reports represent a comprehensive source of information, however, it is not practical for users to have on hand or assimilate all the detailed information. This manual is intended to serve as a single source reference to the diverse and complex research undertaken by the MEND Program from 1988 to 2000, and selected complementary work completed outside of MEND. This

manual includes an introductory volume (Volume 1) and five technical volumes which address acidic drainage issues: sampling and analyses; prediction; prevention and control; treatment; and monitoring (MEND 5.4.2).

The objective of the manual was to summarize work completed by MEND in a format that would provide practitioners in Canadian industry and government with a manageable document. The document is not a "How to" manual. It is a set of comprehensive working references for the sampling and analyses, prediction, prevention, control, treatment and monitoring of acidic drainage. The document provides information on chemistry, engineering, economics, case studies and scientific data for mine and mill operators, engineering design and environmental staff, consulting engineers, universities and governments. The MEND Manual describes the MEND-developed technologies and their applicability in terms of cost, site suitability and environmental implications.

Many acidic drainage related decisions are subject to a range of considerations including but not limited to the technical basis, the regulatory framework, costs and risks. The MEND Manual, and the majority of the MEND reports referred to in the manual, focused on acidic drainage technical subjects. For the benefit of manual users, the manual includes references to non-MEND documents that address issues such the management of tailings disposal facilities, treated effluent quality and effluent toxicity requirements, environmental management systems, and risk assessment. Readers may find it best to use the manual as a key reference document that allows follow-up with listed references in areas of interest.

Acidic drainage is a technically complex area and one that typically requires the involvement of experts from numerous technical disciplines. Site-specific factors and conditions add to this complexity, and often necessitate site-specific research. As such, acidic drainage technologies are not universally applicable. Research to date, and the application of the new technologies, have provided some practical experience in their application. In this light, the discussions in the manual also note aspects to consider when evaluating the potential use of these technologies.

CONCLUSIONS

The successes of MEND have come through the sharing of experiences, the thorough evaluation of technologies and their incremental improvement. The

major achievement of the program has been the use of water covers. Canadian industry reports that a significant reduction in liability is confidently predicted. An evaluation of MEND (MEND 5.9) concluded that the estimated liability had been reduced by \$340 million for five Canadian mine sites alone. It is also acknowledged that the reduction in liability is significantly higher than this quoted value, with a minimum of \$1 billion commonly accepted. The same study concluded that:

- There is now a much greater common understanding of acidic drainage issues and solutions;
- The research has led to less negative environmental impact;
- There is increased diligence by regulators, industry and the public;
- MEND has been recognized as a model for industry-government cooperation; and
- The work should continue with strong international connections.

As a result of MEND, the knowledge base on acidic drainage has grown considerably to include a fundamental understanding about the acid generation process and factors that affect it, and about measures that can be taken to prevent and control acid generation, or treat acid drainage should it occur. MEND focused the acidic drainage effort, and developed a toolbox of technologies that is available to all stakeholders. Technologies are now in place to open, operate and decommission a mine property in an environmentally acceptable manner, both in the short and long term. This can have a major impact on new mine financing and development. Moreover, mining companies and consultants have acquired a great deal more capability to deal with water contamination from mine wastes, including acid generation. And while the knowledge base can be generally described as reasonable and adequate, there is a need for additional research to: add to the present state of understanding, confirm the performance of technologies through large scale applications and long term data; and continue the search for more efficient and affordable technologies. As such, readers are encouraged to think of acidic drainage as a work in progress where future research is likely to add to the present state of knowledge.

MEND is thus a good example of a successful, multi-stakeholder initiative addressing a technical issue of national importance, and has been a model for cooperation among industry, various levels of government and NGOs. The program has significantly advanced environmental management practices and thus

contributed to the long-term sustainability of the mining industry.

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