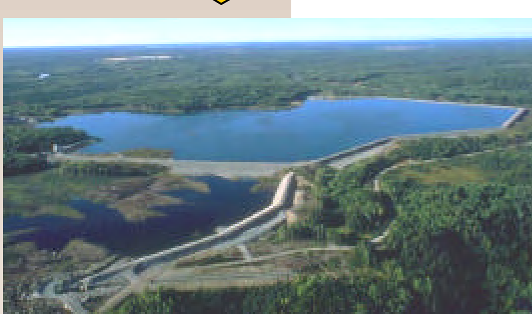
Acidic Drainage Research and Technology Gap Analysis

MEND Report 8.1

This work was prepared for MEND3 and sponsored by Natural Resources Canada, The Mining Association of Canada and Environment Canada

February 2002



Acidic Drainage Research and Technology Gap Analysis

Prepared for:

MEND3
and sponsored by
Natural Resources Canada,
The Mining Association of Canada and
Environment Canada

Prepared by:

SRK Consulting
Engineers and Scientists

in association with

SENES Consultants Limited

February, 2002

EXECUTIVE SUMMARY

Following the completion of the MEND and MEND 2000 programs, a new multi-stakeholder program called "MEND3" was initiated in 2001. The objective of MEND3 is to conduct carefully focused Canadian national and/or regional research that will improve environmental performance and stewardship for industry and civil society and reduce financial liability associated with acid rock drainage and metal leaching through a variety of techniques including prediction, pollution prevention and control. To launch MEND3, this project was commissioned to determine where research activities should be focused.

The findings of this study are based on input received through a questionnaire distributed by email and through the MEND web site, three workshops in Toronto, Yellowknife and Vancouver, and telephone conversations. In total, 94 individuals provided input. The questionnaire provided opinions on technology gaps, whereas the workshops and telephone conversations provided additional input on the challenges MEND3 may face.

The challenges identified included low commodity prices (which will limit funding from mining companies), government funding cuts as deficits are addressed, and pressure to demonstrate technology application to a much broader community than in the 1980s and 1990s.

Workshops participants identified the need to demonstrate the application of existing technologies through technology transfer programs such as compilation of high quality case studies to demonstrate long-term performance of technologies, sponsorship of technical meetings, partnership with other international programs, and development of broad information materials to strengthen the understanding of the issues by institutions and the general public.

The widest technology gaps lay in the prediction of the behaviour of underground mines, open pit mines and waste rock piles; application of blending of waste rock and/or tailings as a control measure; suitability of alternatives to conventional dry soil covers; application of low temperatures to ARD prevention and control; use of passive water treatment systems; and understanding of the chemistry of elements mobile under non-acidic conditions.

The benefits of research in these areas to meet MEND3's objective will be partly regional and specific to the phase of mine operation. Research on underground mines will have a national benefit, whereas open pit mines and large waste rock piles are primarily located in western Canada. Blending is applicable to proposed and operating mines where new facilities are being designed. The development of alternative cover materials will be beneficial primarily to the remediation of historic mine sites in eastern Canada with large tailings deposits. Research on the application of low temperatures will primarily benefit the diamond mines in Northwest Territories and Nunavut, but will also be applicable to the closure of historic mines in permafrost regions.

1CP008.01

ACIDIC DRAINAGE RESEARCH AND TECHNOLOGY GAP ANALYSIS

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ACIDIC DRAINAGE RESEARCH AND TECHNOLOGY GAP ANALYSIS

1. INTRODUCTION

1.1 Background

The Mine Environment Neutral Drainage (MEND) Program was initiated in 1989. Through its Federal, Provincial and mining industry partners, MEND sponsored leading research into ways of reducing the environmental impact and financial liabilities of acidic drainage from tailings and waste rock. One of the main objectives of the MEND program was to establish a toolbox of technologies to open, operate and decommission mine sites where acidic drainage must be considered, or is a hazard and risk in a predictable, affordable, timely and environmentally acceptable manner.

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 have been described as a model for cooperation of governments, industry and non-governmental organizations (NGOs) in technology development, implementation and monitoring.

Acidic drainage continues to be one of the most challenging environmental issues facing mining. MEND and its successor (MEND 2000) have made progress in this area. The potential liability to Canadian industry and governments due to acidic drainage has been significantly reduced but is still conservatively estimated to be in the range of several hundred million dollars.

In this vein, the Canadian stakeholders recommended that a renewed national ARD research initiative called “MEND3" be launched. The overall goals of MEND3 are to provide focus, technology transfer and leadership in ARD research on Canadian priority issues. It is a multi-stakeholder coordinated, focused Canadian ARD research initiative based on re-prioritized and augmented existing industry, government and university programs. MEND3 is intended to be a phased research program, carefully focused on prioritized Canadian national and/or regional needs. The first phase will be used to lay the initial groundwork for this potential multiyear program.

In August 2001, Steffen, Robertson and Kirsten (Canada) Inc. and SENES Consultants (SRK/SENES) were retained by The Mining Association of Canada (MAC), Environment Canada (EC) and Natural Resources Canada (NRCan), the current funding partners of MEND3, to complete a technology gap analysis report, with a view towards recommending the direction of future acidic drainage research in Canada over the next decade. The final report will outline the following:

- Past and ongoing research efforts;
- Gaps in ARD research and technology in Canada;
- Opportunities to advance ARD knowledge;
- A prioritized list of research projects for consideration; and
- Key areas of research that will help reduce liability to acidic drainage prevention and collection/treatment.

1.2 Acknowledgements

This project was completed with the primary involvement of the following individuals:

- Stephen Day, SRK
- David Orava, SENES
- Gilles Tremblay, MEND Secretariat

SRK/SENES wish to express their appreciation to all individuals and organizations that provided input to this project.

2. METHODOLOGY

2.1 Overall Approach

The overall requirement of the project was to measure the gap between the status of technology and the ability to apply that technology effectively to manage acid rock drainage in the context of benefit to the natural environment, the industry and the public. Beneficial technologies with wide gaps are likely to be the best targets for further research. The definition of "beneficial" depends on individual perspective (for example, mining company, regulator, non-governmental organization), the stage of the mining cycle (for example, design and planning, operation, closure and post-closure) and geographic location in Canada.

To account for all of these variables, SRK/SENES considered it necessary to contact a large number of individuals in industry, government, non-governmental organizations, consultancies and research organizations. Since the late 1980s, knowledge of ARD and related issues has grown very rapidly, and the number of interested parties has grown at the same time. In order to ensure the involvement of as many individuals and organizations as possible, the following approach was designed:

- An "Invitation to Participate" and questionnaire was prepared and sent out by email using the MEND mailing list. The questionnaire was also posted on the MEND website.
- Three regional workshops were held.
- Selected individuals were contacted by phone.

Details of the above components are provided in the following sections.

2.2 Stakeholder Consultation

2.2.1 Invitation to Participate

The invitation was prepared to let interested parties know of the project and ask for their input. Initially, a thorough background paper was planned but this was replaced with a brief (three page) overview document because the project team felt that it was unlikely that a long document would be thoroughly read. The invitation is attached in Appendix A.

Interested parties were asked to contribute by completing a questionnaire and registering for a workshop.

The invitation and questionnaire were sent to 681 individuals on the MEND email list and posted on MEND's website. At least 75 other individuals who were not on the list were sent the invitation by SRK/SENES and the MEND Secretariat.

2.2.2 Questionnaire

A five-page questionnaire was designed primarily to evaluate perceptions of technology gaps in existing knowledge (Appendix B). Respondents were asked to rank individual technologies using the following four-gap measurements:

- Fundamental research has not been completed;
- Fundamental research has been completed;
- Application to mine sites has been investigated;
- Can be applied to design of mine waste facilities.

In the absence of personal knowledge, respondents were asked to indicate "No Opinion".

The instructions accompanying the questionnaire indicated that only one box was to be checked for each technology. As discussed in Section 3.2, some respondents choose to check multiple boxes while others indicated that they found the questionnaire to be unclear as to what was needed. In retrospect, the questionnaire could have been tested by a small group prior to the general mail out.

Respondents were asked to respond based on personal experience. The first page of the questionnaire collected background regional information to determine the basis of the experience. The following questions were asked:

- Location of the respondent's experience within Canada;
- Permafrost region (yes or no);
- Other country;
- Commodity (metal, non-metal, coal); and
- Mine stage (permitting, operation, closure).

The questionnaire could be returned in electronic format or faxed to a dedicated fax line. The questionnaire was posted on the MEND website and a deadline of September 7 was set for return of responses.

2.2.3 Workshops

Three one-day workshops were held in September 2001:

- Toronto (September 17);
- Yellowknife (September 24); and
- Vancouver (September 28).

The specific objective of the workshops was to provide open discussion on significant technology gaps and identify regional concerns. The standard agenda (Appendix C.1) for the workshops included:

- Opening remarks from one or two keynote speakers;
- Three minutes for each workshop participant to summarize opinions on technology gaps and research needs;
- An issues scan of areas identified by participants as the highest priority for research; and
- Identification of high priority research needs.

The standard agenda was used for the Vancouver and Toronto workshops. A different approach was adopted for the Yellowknife workshop because the number of participants was smaller. For this workshop, the agenda included:

- Opening presentation on MEND and MEND3;
- Brain-storming of specific features of Canada's northern regions ("the North");
- Identification of challenges and opportunities presented by the North; and
- Identification of research priorities.

Invitation to attend the workshops was open to all interested individuals. However, due to the timing of the announcement (late August and early September), the

SRK/SENES directly contacted numerous individuals. This approach also ensured that representatives of mining companies, government agencies, non-governmental organizations (NGOs), consultancies and academic institutions were present at the workshops. Organizations were asked to consolidate their input and send one representative to the meeting.

2.2.4 Follow-Up Telephone Calls

Following the receipt of completed questionnaires and completion of the workshops, the SRK/SENES identified approximately 30 individuals who were contacted by phone to comment on their perception of research gaps.

3. CONSULTATION SUMMARY

3.1 Distribution of Response Sources

Input from all sources totaled ninety-four. The breakdown by source was:

- Completed questionnaire only – 36.
- Completed questionnaire and attended workshop – 11.
- Attended workshop only – 31.
- Contacted by follow-up call only – 16.

The breakdown by organization group was:

- Mining Companies – 34.
- Consultancies – 28.
- Government Agencies – 13.
- Academic Institutions – 13.
- Non-government Organizations – 6.

The classification of individuals from whom input was obtained is provided in Appendix D.

3.2 Questionnaire

Forty-eight responses to the questionnaire were received representing 6% of those contacted by email or other means.

3.2.1 Ranking of Technologies

Several respondents choose to check multiple boxes in the questionnaire. When contacted, a selection of these respondents indicated that fundamental research is lacking in many areas but that the technologies are being applied. As the intent of the questionnaire was to gauge opinion of the state-of-the-art rather than actual practice, the widest gap indicated by the response was used to analyse these responses. One questionnaire was discarded from analysis as all technologies were rated the same.

Most responses were by mining company staff (18) and consultants (13). The balance of responses was from academic institutions (9), government agencies (4) and non-governmental organizations (3).

The majority of responses were received from unspecified regions of Canada (16), British Columbia (10) and Ontario (8). No responses specific to the Maritime provinces or northern Canada were received. Most responses were from metal mining experience. Only one response was specifically from coal mine experience although eleven respondents indicated experience with both metal and coal mines.

The questionnaire responses were analysed by calculating a weighted average of the total number of responses (not including the "no response" category (Appendix B.2)). The scores assigned to each response were:

1. Can be applied to design of mine waste facilities.
2. Application to mine sites has been investigated.
3. Fundamental research has been completed.
4. Fundamental research has not been completed.

The weighted average score was calculated from:

$$(1.n_1 + 2.n_2 + 3.n_3 + 4.n_4)/(n_1 + n_2 + n_3 + n_4)$$

where n_x was the number of responses received for each response category.

The weighted scores ranged from 1.6 to 3.1, where a higher weighted score represents a wider gap. The highest possible score would have been 4.0. The list of technologies was then sorted by the weighted score and ranks assigned. Table 1 lists the ranks obtained. Technologies with a perceived wide gap have a low numbered rank. Narrow gaps have higher numbered ranks.

The top ranked areas (up to rank 12) with wide technology gaps indicated by the questionnaires were:

- Underground mine geochemistry and geochemical modelling;
- Blending of any type (tailings and/or waste rock);
- Open pit geochemistry and modelling;
- Waste rock geochemical modelling;
- Novel covers (de-sulphidized tailings, non-mining wastes);
- Permafrost; and
- Passive water treatment systems.

TABLE 1
Summary of Questionnaire Responses and Technology Gap Ranks

		Number of Responses from Questionnaires						
General Area	**Technology**	**Fundamental Research Has Not Been Completed**	**Fundamental Research has been Completed**	**Application to Mine Sites Has been Investigated**	**Can be Applied to Design of Mine Waste Facilities**	**No Opinion**	**Weighted Score**	**Overall Rank**
Prediction and Modelling	*Geochemical prediction methods (static geochemistry)*	5	5	7	17	5	1.9	*33*
	Geochemical prediction methods (kinetic geochemistry)	7	4	12	12	5	2.2	26
	Understanding of waste rock geochemistry	10	8	11	10	4	2.5	13
	Understanding of tailings geochemistry	7	6	14	10	6	2.3	23
	Understanding of underground mine geochemistry	13	7	4	5	14	3.0	**3**
	Understanding of open pit geochemistry	9	11	4	6	13	2.8	**12**
	Waste rock geochemical model	12	8	12	3	8	2.8	**12**
	Tailings geochemical models	6	7	11	6	12	2.4	18
	Underground mine geochemical model	9	7	1	3	23	3.1	**1**
	Open pit geochemical model (eg MINEWALL)	9	6	7	3	18	2.8	**12**
Prevention	Water covers for unoxidized waste rock	5	8	9	15	6	2.1	28
	Water covers for oxidized waste rock	7	8	12	10	6	2.3	23
	Water covers for unoxidized tailings	4	8	9	18	4	1.9	*33*
	Water covers for oxidized tailings	7	8	12	12	5	2.3	23
Control	Dry soil covers for waste rock (oxygen barrier)	5	9	11	9	9	2.3	23
	Dry soil covers for waste rock (hydrological barrier)	7	9	9	10	9	2.4	18
	Dry soil covers for tailings (oxygen barrier)	6	7	12	10	8	2.3	23
	Dry soil covers for tailings (hydrological barrier)	6	7	10	11	9	2.2	26
	Desulphidized tailings as a cover	12	6	6	6	13	2.8	**12**
	Use of non-mining wastes as covers	12	7	11	4	9	2.8	**12**
	Permafrost	7	4	5	3	23	2.8	**12**
	Blending or layering of waste rock	13	9	10	4	7	2.9	**5**
	Blending of tailings	12	5	6	5	15	2.9	**5**
	Blending of tailings and waste rock	16	5	6	5	10	3.0	**3**
	Segregation of waste rock (segregation methods)	2	7	11	15	8	1.9	*33*
	De-sulphidization of tailings	5	7	12	5	15	2.4	18
	Elevated water tables in tailings	7	6	9	8	7	2.4	18
	In-pit disposal of mine wastes	6	5	6	18	8	2.0	29
	Underground mine backfill	9	3	3	16	12	2.2	26
Treatment	*Conventional lime treatment*	2	5	6	25	4	1.6	*36*
	HDS Process	3	6	2	21	10	1.7	*35*
	Sludge stability	8	8	6	10	10	2.4	18
	Passive treatment systems	12	10	6	7	8	2.8	**12**
Monitoring	Monitoring Approaches	8	5	7	18	3	2.1	28
	Sampling Guidelines	5	5	6	18	5	1.9	*33*
	Chemical Analysis	4	6	4	20	5	1.8	*34*

Notes:
1. Bold indicates top ranks. Italic indicates bottom ranks

During the workshops, the need for water treatment technologies to achieve low concentrations in effluent for elements present at neutral or alkaline pH and for total dissolved solids (TDS) was also identified.

Conversely, areas which had a narrow gap (i.e. the technology is well understood and can be applied to mine sites) included:

- Water treatment using conventional lime and HDS technologies;
- Monitoring;
- Methods for segregation of waste rock;
- Static geochemical prediction methods; and
- Water covers for unoxidized tailings.

3.3.2 Other Technologies

Space was provided on the questionnaire to allow respondents to indicate other technologies that were not specified on the form. A few common themes (i.e. mentioned repeatedly) were apparent:

- Long-term performance of technologies (dry covers, water covers);
- Understanding of waste rock pile hydrology;
- Underground mine hydrology;
- Behaviour of paste backfill;
- Synthetic covers;
- Treatment of effluents to low metal concentrations; and
- Scale-up of laboratory experiments.

Respondents who identified these areas indicated that the technologies are not well-developed (i.e. a wide gap).

All responses recorded on questionnaire forms are provided in Appendix B.3.

3.3 Workshops

3.3.1 Toronto

The workshop was attended by 15 representatives evenly split between major mining companies, consultancies, federal and provincial regulators, non-governmental organizations and university researchers. The workshop was chaired by Dave Orava (SENES).

Notes taken at the Toronto workshop are summarized in Appendix C.2. Some points concluded from the workshop were:

- **The MEND "toolbox" is acceptable and working**. There is a need to bring unproven technologies forward so that they can be available (if possible) for use.
  - There are definite gaps – specifically where technologies are not ready to be applied.
  - There is considerable need to improve communication/information management.
  - There is an expressed need to investigate the long-term performance of acidic drainage prevention and control technologies.
  - There is an expressed need to "audit" the performance of acidic drainage prevention and control technologies.

- **Monitoring data should be useful for decision-making.**
  - Monitoring should be highly focused.

- **Research should be focused toward specific applications**.

- **Use of funding must be efficient.**
  - There is an expressed need to address pollution prevention, and investigate the use of approaches other than (ROI) return-on-investment alone to select acidic drainage technologies.

A scan of issues identified the following concerns:

- **Overall Guiding Direction of MEND3.**
  - Prevention of ARD should be the focus.
  - Avoid duplication of efforts with other programs.
  - Integrate research from different fields.

- Multi-stakeholder perspectives involving communities and environmental effects.

- **Program Funding.**
  - Research funding is not readily available in mining companies.
  - MEND3 should work with other partners and programs.
  - Lower cost closure technologies are needed.

- **Research Focus.**
  - Passive treatment.
  - Re-consider NPV (Net Present Value) basis for costing of technologies.
  - Application of permafrost to mine waste management.
  - Behaviour and management of arsenic.
  - Behavior of low reactivity PAG (Potentially Acid Generating) wastes ("grey areas").
  - Use of mine wastes in other applications.
  - Long-term fate and environmental impacts of contaminants.
  - Use of alternate cover materials.
  - Behaviour of man-made materials (e.g. synthetic liners).

- **Communication and Information Management.**
  - Up-to-date information is not readily obtained.
  - Better ways of managing information are needed.
  - Success stories and challenging sites need to be communicated.
  - Information needs must reach the general public.

3.3.2 Yellowknife

The Yellowknife workshop was attended by seven individuals from mining companies (4), the Federal Government (1), the NWT Territorial Government (1) and consultancies (1).

The workshop was chaired by Stephen Day (SRK Consulting). Notes were collected through the meeting and projected on to a screen to allow participants to continually review findings. The notes are shown in Appendix C.3.

The workshop began with a review of critical features of the North (i.e. those that potentially could lead to different research requirements). Some examples included unique mineral deposits, climate, ecological systems, evolving regulatory regime, limited regional databases and lack of infrastructure. The features were then classified into "challenges" and "opportunities" for managing mine drainage. Participants felt strongly that the low temperatures are a significant, but not well understood opportunity.

Several research areas were then identified with the focus primarily on new operations rather than closure of old sites. Three areas were discussed in detail:

- Need for an "approved" thermal model to couple conventional permafrost modelling with geochemical effects.
- Prediction of the behaviour of low sulphide wastes.
- Sharing of technology.

Although not discussed in detail, education of public and regulators in a rapidly evolving regulatory environment came up throughout the discussions.

Lack of mechanisms to share technology was considered a major limitation to permitting and implementation of technologies.

3.3.3 Vancouver

The Vancouver workshop was attended by 18 representatives from mining companies (6), the Federal Government (2), B.C. Provincial Government (1), consultants (6) universities (2) and non-governmental organizations (1).

The workshop was chaired by Stephen Day (SRK Consulting). Meeting notes are summarized in Appendix C.4.

Comments provided by participants were grouped into six areas:

- **Fundamental Research Linked to Practical Application.**
    - Reactivity of sulphides, particularly at low concentrations.
    - Source and behavior of contaminants (under all pH conditions).

- **Predictions.**
    - Hydrology of waste rock.
    - Uncertainty in prediction of long-term chemistry for waste rock.
    - Classification of marginally PAG waste rock and tailings and delay to onset of ARD.

  - Scale-up of laboratory experiments.
  - Underground mine backfill.

- **Management of Wastes.**
  - Segregation of rock.
  - Blending of rock and rock/tailings.
  - Long-term cover performance.
  - Water cover stability.
  - Geotechnical containment.

- **Treatment.**
  - Sludge management.
  - Treatment of exotic elements.
  - Removal of low levels of metals.
  - TDS treatment.

- **Impacts.**
  - Metals cycling in the environment.

- **Technology Sharing.**
  - Case study dissemination.
  - Information exchange.
  - Manuals.

It was intended that participants would break into small working groups to further discuss each area. However, the participants chose to remain as a single group and two areas (technology transfer and prediction of the geochemical behaviour of waste rock) were selected for more discussion. This choice did not indicate that these were of higher priority but rather that they were of interest to the workshop participants.

The following additional comments on technology sharing were provided:

- Possible role of MEND to act as a clearing house of information using a website.

- Need for quality control and consistency of reporting of information on case studies.

- Need to improve quality of papers at conferences (i.e. ensure peer review).

- Use of students to pull together information from public consulting reports as theses.

The discussion on waste rock identified a multitude of poorly understand aspects including hydrology, thermal effects, geochemistry and the behaviour of weakly reactive rock types. Existing predictive tools provide very conservative water chemistry estimates. Further research was identified as a need to reduce prediction uncertainty. Follow-up case studies on predicted versus observed chemistry was suggested.

The overall consensus of the Vancouver workshop was that applied research, even on fundamentals, must be linked to practice, implementation, audit and improvement mechanisms.

3.3.4 Follow-Up Calls

Thirty individuals were called by phone and sixteen return calls were received. Comments provided during these calls are summarized below:

- **Water Quality Predictions.**
  - Better predictive techniques to understand the behaviour of acid generating materials are needed.
  - More applied experience is needed to quantify inputs into modelling, and thereby assist with decision-making based on the modelling.
  - Better methods are needed to predict water quality where dry covers (including synthetic geotextiles) are proposed.
  - Methods are needed to predict the long-term benefit of control technologies used on oxidized materials, including oxidized materials that have not yet generated acid.
  - The correlation between laboratory and field behaviour needs to be investigated.

- **Prevention and Control Technologies.**
  - Prevention of acidic drainage remains a high priority.
  - Acidic drainage prevention and control techniques are adequate for new mines.

  - Comments specifically on dry covers included:

    - Research is needed on the use of oxidized materials as covers or components of covers.
    - Design guides are needed for the construction of dry covers.
    - The long term performance (e.g. more than 100 years) of dry covers needs to be demonstrated.
    - The effects of vegetation and approaches to revegetation of dry covers need to be investigated.

- **The effects of acid rain on the performance of wet and dry covers need to be investigated.**

- **Research on the effects on groundwater of disposal of waste rock into open pits is needed.**

- **Drainage treatment.**
  - University-sponsored research on biological treatment processes needs to be continued.

Other general comments received echoed the discussions at the workshops, including the need for well-documented long-term monitoring of implemented technologies, and technology sharing.

3.4 Summary of Findings

3.4.1 General Comments

The level of response to the request for input to this project was not as strong as expected. If the MEND email list is an indication of number of individuals actively involved in this area, the 94 respondents probably represents a 15 to 20% response. The level of response is considered to have reflected:

- The timing of the invitation to participate which coincided with summer vacations, and autumn activities at mine sites.

- The general shortage of time available to many individuals actively involved in this field, and particularly those working at mining companies.

While the limitations of the questionnaire may have discouraged some potential respondents, the findings of the questionnaires were consistent with comments provided at the workshops. In addition, the input received from telephone conversations was consistent with that obtained form the questionnaires and the workshops, and therefore that a larger sampling of opinion is not likely to have resulted in substantial changes in the overall conclusions.

The workshops helped to identify non-technical needs, needs for the closing of technology gaps, and differences in regional foci. In eastern (and probably central) Canada, the main interest is in closure of acid-producing tailings deposits at historic sites and applied rather than fundamental research. In western (the Cordillera) and northern Canada, there is more interest in fundamental research on predicting the behaviour of waste rock as it pertains to designing and closure of mine site, though this research must have an application. Technologies for prevention are of more interest than control. In the west and north, metal leaching is a broader concern than ARD. A further concern in the North is the potential for application of the cold climatic conditions to management of reactive wastes.

The following sections summarize general themes identified during the consultation.

3.4.2 Technology Transfer and Education

A major non-technical theme was the need to find wide-ranging methods for technology transfer and information sharing. The main reason for this is that awareness of the issues surrounding ARD and metal leaching have grown, and mining companies are now routinely collecting the data needed to assess the performance of waste management facilities. This information is extremely useful to other sites for design of facilities and demonstration of performance of technologies to regulators and the public. Therefore, finding an approach for dissemination of case study information is a high priority.

Explanation of technology to the non-technical general public and regulatory agencies was also identified as a need to build the capacity of these groups to understand complex proposed remediation approaches for mine sites. Difficult scientific and engineering concepts need to be explained using familiar analogues and simplified language. This could possibly be achieved by preparing short briefing notes and videos, and providing training. The popularity of the MEND videos is an indication of the need for these types of materials.

3.4.3 Gaps in ARD Research and Technology

An overall comment was that the "MEND Toolbox" is useful, however it is incomplete. Technology gaps need to be filled.

Some of the larger technology gaps commonly identified included:

- The knowledge of underground mine and open pit hydrology and geochemistry and the ability to predict effluent chemistry.
- Characterization and prediction of waste rock effluent chemistry, including
  - Waste rock hydrology and hydrogeology; and
  - Behaviour of weakly reactive and marginally potentially acid generating ("grey zone") waste rock..
- Blending of waste rock and/or tailings for hydrological or geochemical reasons.
- Availability of alternatives to soils as cover materials for reactive tailings.
- Understanding of the long-term performance of all technologies (though particularly dry covers).
- Application of cold climates to managing of reactive wastes.
- Ability to characterize, predict and manage the behaviour of chemical elements occurring in non-acidic drainage (for example, arsenic, antimony, cadmium, molybdenum, selenium, zinc).

4. DISCUSSION OF MEND3 APPROACH

4.1 Challenges

The original MEND program was started in the late 1980's against a backdrop of a financially-strong mining industry. As a result, junior, intermediate and major mining companies were able to provide direct funding of projects and programs, and in-direct support through the volunteer efforts of their employees. Provincial and federal government departments were also a source of strong funding for MEND.

At that time, awareness of acid rock drainage (ARD) and related issues were confined to a relatively small group of major mining company research staff, consultants, regulators and academics. The main focus was management of conventional ARD from tailings impoundments.

In the early 2000's, a significantly different environment exists. Major challenges are:

- **Commodity prices are at sustained historical lows**. Several commodities are simultaneously at low values whereas in the past falling prices for one commodity were often matched by high prices for another. Therefore, funding from mine companies will be limited until prices improve. This will limit direct funding and in-direct funding through volunteers. Nonetheless, awareness of environmental liabilities and responsibilities has increased and industry will continue to be involved in ARD research programs

- **All levels of governments are addressing deficits accumulated during the 1980s and 1990s**. This has resulted in reduced funding. Governments will probably continue to provide funding but through different avenues and with greater competition from other research sectors.

- **Awareness (though not necessarily knowledge) of ARD has grown substantially in industry, government, universities, NGOs and the general public**. This has brought pressure in terms of the need to demonstrate the long-term success of technologies and explain the application of technologies to a broader audience.

- **Wider concern about and knowledge of low level, cumulative effects and metal fate in the environment has shifted concern from conventional ARD containing elements like copper and zinc to non-acidic and alkaline drainage containing unusual elements (for example, selenium, antimony).** Traditionally, MEND was focused on "mine property" issues and other agencies were responsible for downstream impacts. A stronger link is needed between which contaminants are released on the property and what this means for fate in the downstream environment.

- **ARD is now linked to broader issues such as environmental assessment, permitting, closure planning, risk assessments, and other investigations and assessments of the potential impacts of metals and the environment**. Waste management needs to re-consider basic issues such as mining and waste disposal method.

4.2 Opportunities for Partnerships

A number of international programs parallel MEND's goals to some degree and may be suitable partners for future research efforts.

Sweden's MiMi (Mitigation of Environmental Impact from Mining Waste) was started in 1997 and has similar objectives to the MEND program (Höglund 2000). The 1997-2000 MiMi program had funding of US$4.8 million from a federal investment fund. A similar funding level is planned for 2001 to 2003. A research plan was issued in February 2001. The research plan indicates that MiMi will be focusing on source control through selective management of different types of waste streams, optimizing soil and water covers, alternative disposal approaches (e.g. co-disposal of waste rock and tailings), biological barrier technologies (e.g. passive treatment) and far-field natural attenuation.

Australia's AMIRA (Australian Mineral Industries Research Association) has been in existence since 1959 (Greenhill 2000) and has a much broader scope than MEND. In 2000, two projects were described on investigating the Net Acid Generation (NAG) procedure, and review of waste management technologies. The former project is currently listed in AMIRA's website http://www.amira.com.au). The latter was a one year project.

The industry-sponsored **INAP (International Network on Acid Prevention)** was officially launched in 1998 (Brehaut 2000). The overall goals of INAP are similar to MEND (i.e. reduction of liabilities associated with mine materials) although the emphasis is on sharing information between the fourteen member companies. INAP also has an international-focus. The INAP website (http://www.inap.com.au) lists nine active projects primarily in Australia and Southeast Asia but access is limited to password holders.

The USA's ADTI (Acid Drainage Technology Initiative) was started in 1995 to develop technologies for the coal industry. It was expanded to the metal mining industry in 1999 (Hornberger et al 2000). The ADTI website link for the metal mining sector (http://www.mt.blm.gov/bdo/adti/) has not been updated since 1999. ADTI's approach is to compile research needs and encourage mining companies to conduct research in the context of these needs.

The **Metals in the Environment (MITE) Research Network** was created in 1998. With a Secretariat based at the Canadian Network of Toxicology Centres, MITE-RN draws on the research capacity of 12 universities and three government departments. It focuses on the sources of metals in the environment, processes by which metals move and transform within the environment, and impacts of metals on ecosystems and human health. The five-year funding for the Network is about $7 million, which includes $3.5 million from the Natural Sciences and Engineering Research Council (NSERC) for 1999-2004; $2.25 million from The Mining Association of Canada and Ontario Power Generation Inc.; and in-kind contributions from the federal government partners. MITE's website (http://www.mite-rn.org/index.html) lists the current projects and the research teams.

The **Toxicological Investigations of Mining Effluents (TIME) Network** program was created in 2000 to address toxicological issues related to the proposed Metal Mining Effluent Regulations. Projects focus on the proposed requirement for non-acutely lethal effluents. The program is funded by The Mining Association of Canada, Environment Canada and Natural Resources Canada (NRCan) with the Secretariat located at NRCan/CANMET. Program information and documents are posted on the TIME website (http://envirolab.nrcan.gc.ca/time/time-e.htm).

4.3 Facilitating Technology Transfer

MEND3 can play a major role in the long-term management and dissemination of information collected by mining companies in Canada as they apply technologies, monitor performance and evaluate success or failure. The information needs to reach not only other mining companies but other stakeholders, including First Nations, NGOs and government representatives. It was suggested at the Vancouver workshop that MEND3 could serve as a manager of national acidic drainage information.

Some specific areas are:

- The long term performance of prevention and control technologies, for example:
    - The performance of dry covers, and factors that can affect their performance (i.e. What effect do tree roots have on cover performance? Is there a need to defoliate dry covers? What is the service life of a geotextile cover?).
    - The performance of water covers over time, and with climate change, extended drought, etc.
- Use of low temperatures in permafrost regions as this has been proposed or is being attempted at several mines in the North.
- The potential effects on receiving groundwater and receiving surface waters and aquatic life.

Case studies are a possible means to distribute information and are desirable because they are written to present the results of a specific relevant study. MEND has already attempted to compile case studies and post them on its website. This has met with limited success. Problems have been encountered with obtaining the write-ups and then having the studies updated. These problems reflect the limited resources available for preparation of the case studies, and probably in some cases confidentiality concerns. The case studies also tended to selectively present data that supports the technology being applied. This limited the usefulness of the case study because reasons for weak or failing performance cannot be assessed.

There is a wealth of information submitted to support mine permit applications and requirements of permits. The data are up-to-date and are often collected and interpreted on behalf of mining companies by experienced consultants. The reports often do not provide the final result and in some cases are only progress data listings. Other practitioners may be able to apply the ongoing data to support other projects or use the information obtained as inputs for models. The most time consuming step is often to determine that the data even exist, and then to obtain the report.

Participants in the workshops discussed a variety of different approaches to disseminate this type of information.

- Maintain a website with lists of new journal articles, and provincial and territorial library contact information for compliance reports.
- Provide direct on-line access to electronic documents through the MEND website.
- Sponsor master's level graduate students to compile case histories for the website

The data itself may be of little use if certain background information is not provided and the data quality is unknown. There is a need to vet reports and obtain supporting background information. For example, a seepage monitoring report for a waste rock disposal facility has little value without background information on the local climate, geology and geochemistry of the rock. Likewise, specific variables needed for decision making could be identified and specifically collected by MEND3.

In the past, case histories have tended to be presented in the style of scientific papers. An alternate approach could be to develop a tabular template that clearly separates different types of background information (e.g. geology, geochemistry, climatology, hydrology), control technology application and monitoring results. This would show clearly what type of information is required to support the case study and what information is missing. It would also allow users to rapidly sort case studies without having to read a whole report.

MEND3 could, from time-to-time, do a thorough review of technology application at a specific site.

4.4 Greatest Opportunities for Reduction of Liabilities

MEND3 indicated that an objective of this gap and opportunities analysis was to identify technology development that could lead to the greatest effective improvement in environmental conditions at mine sites as the MEND3 program moves forward.

To achieve this overall goal, further research should be applicable on a national basis, or should be applicable to a significant sector of the mining industry. The findings on technology gaps from the consultation were considered in this context.

The widest technology gaps were for:

- Underground mine geochemistry and geochemical modelling;
- Blending of any type (tailings and/or waste rock);
- Open pit geochemistry and modelling;
- Waste rock geochemical modelling (including waste rock hydrology and the behaviour of low reactivity wastes);
- Novel covers (de-sulphidized tailings, non-mining wastes);
- Permafrost; and
- Passive treatment systems.

The wide gaps for prediction of the chemistry of drainage from waste rock, underground mines and open pit mines partially reflects MEND's past emphasis on tailings, which has resulted in predictive models (such as RATAP) and significant reductions in the environmental impacts of tailings deposits. Geochemical predictions can currently be made for mines and waste rock but they are typically excessively conservative resulting in negative perception of the benefits of control and prevention technologies, possibly unnecessary contingency planning and high security deposits to cover uncertainties. More reliable prediction models for mine workings and waste rock would benefit all types of mines throughout Canada, though the primary benefit would be in western Canada at underground mines in mountainous areas and the large open pit copper mines. This research would include coupled investigations of geochemistry, hydrology and limnology.

Development of blending of tailings and/or waste rock as a control technology has not occurred partly due to the limitations of waste rock modelling, which cannot currently predict the behaviour of heterogeneous mixtures due to the complexity of flow and chemical interactions in mixed waste rock and tailings. Blending potentially represents a walk-away technology without the long term physical stability concerns of water and soil covers. In general, blending can only be implemented for new facilities at proposed mines and operating mines. Most of the current environmental liability in Canada is associated with historic mine sites. Research on blending would benefit proposed and operating mines.

Development of alternate cover materials would primarily benefit mines in areas lacking significant nearby deposits of soils with low permeability. Large numbers of historic mine sites in the shield regions of eastern Canada would benefit from this research. These mines have deposits of acidic tailings but conventional soil covers are feasible due to the thin soil deposits. Alternate cover materials could include municipal wastes.

Finally, application of permafrost, or natural cold conditions as a control technology is at an early stage. The Northwest Territories and Nunavut are the only regions of Canada currently seeing significant development of new mines and these mines are in regions of continuous permafrost. Other proposed diamond mines are also in regions with some degree of permafrost (northern Saskatchewan and Ontario). Low temperature technologies can also be applied to closure of mines in the far north by using natural or induced low temperatures. Research in this area would primarily benefit opening of new diamond mines, with a secondary benefit to closure planning for historic sites.

Water covers received low weighted scores because the technology is thought to be well-developed. However, given the interest in long term performance of other technologies, SRK/SENES believes that the scores should be higher to reflect geotechnical (i.e. containment), climatological (i.e. climate change) and water quality related uncertainties. Using covers on oxidized materials is also not well understood due to the development of reducing conditions that tends to de-stabilize oxide products.

5. CONCLUSIONS

This study was based on consultation of stakeholders in the mining industry representing mining companies, federal and provincial governments, consultants, academics and members of non-governmental organizations. Input was received through the use of a questionnaire, three workshops and telephone interviews.

It was concluded based on the input received that technology gaps are greatest for prediction of the behaviour of underground mines, open pit mines and waste rock piles (particular less reactive "grey zone" wastes), the application of blending of waste rock and/or tailings, the availability of alternative covers to conventional soil covers (primarily for tailings deposits), the application of low temperatures (i.e. permafrost) to prevention and control of ARD, and passive water treatment systems. Understanding of the behaviour of elements mobile under non-acidic conditions was identified as a significant uncertainty.

The best developed major technologies were believed to be conventional water treatment technologies and water covers. Static testing methods were also considered to be well-developed.

Continuing technology transfer was determined to be a major need to ensure that results of long-term monitoring of technology performance are widely available. In addition, technology needs to be explained to non-technical audiences.

This report, **1CP008.01, Acidic Drainage Research and Technology Gap Analysis**, has been prepared by:

STEFFEN, ROBERTSON AND KIRSTEN (CANADA) INC.

Stephen Day, M.Sc., P.Geo.
Project Manager

and;

SENES CONSULTANTS LIMITED

David Orava, M.Eng., P.Eng.
Senior Mining Engineer

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APPENDIX A
Invitation to Participate

Invitation to Participate

MEND3

Acidic Drainage Technologies Gap Analysis and Opportunities Study

MEND3 is embarking on a project to identify areas for future research in acidic and metal-rich drainage to build on research done in the last decade[1].

The focus of the project will be a "**gap analysis**". The project will identify gaps between needed and actual knowledge of the various aspects of mine drainage management. Research needs will be assessed based on widths of the gaps. Research plans will then be developed.

As part of this project, MEND3 is seeking input from interested parties through the use of a focussed questionnaire on the MEND website, selected follow-up interviews, plus consultative workshops to be held in Toronto, Yellowknife and Vancouver. You are invited to contribute by:

- Filling out the questionnaire.
- Attending the workshops.

Contribute at Workshops!

Location	Tentative Date
Toronto	September 17, 2001
Yellowknife	September 24, 2001
Vancouver	September 28, 2001

Email to MEND3@srk.com or fax to 1-801-697-3021 to request participation.

State MEND3 WORKSHOP in the Subject Line

Indicate your name, title, affiliation and mining sector (operator, consultant, academic, regulatory, NGO, other).

Please note, space is limited,

Details will be provided when the attendance list is confirmed.

The MEND3 Program and the project are described below. Some background information on the present state of knowledge in acid drainage is also provided for your reference.

What is the MEND3 Program?

MEND3 is a multi-stakeholder coordinated, focused Canadian national acidic drainage research initiative based on re-prioritized and augmented existing industry, government and university programs.

In 2000, the MEND 2000 Steering Committee and its representative constituencies reviewed the current and future needs of Canadian stakeholders in addressing acid rock drainage, and

[1] This project is being completed on behalf of MEND3 by SRK Consulting (Vancouver, BC) and SENES Consultants Limited (Toronto, Ontario).

recommended that a renewed national ARD research initiative called "MEND3" be launched in 2001 with an overall mission to provide leadership in acidic drainage research on Canadian priority issues, within an international context.

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 also 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.

Find out more about MEND and acidic drainage at the MEND website:

http://mend2000.nrcan.gc.ca

Gap Analysis Method

The Acidic Drainage Technologies Gap Analysis and Opportunities Study will identify and evaluate gaps in acidic drainage research and technology, through an assessment of past and ongoing research efforts, opportunities for advancement of acidic drainage knowledge, and the development of a prioritized list of research projects for consideration.

A context will be needed against which to measure past and ongoing research, and future technology development needs.

> ***Mine drainage chemistry issues are site-specific due to the characteristics of ore and waste materials, climatic effects, hydrological regime, local topography, local land use, and statutes, policies and guidelines in different jurisdictions.***

The gap analysis will need to classify research and technology needs based on common broad regional issues, and identify major technology needs versus needs that are significant but only to a small sector of the industry. In this context, the gap between needs and technology development can be classified using the following four general levels:

1. Fundamental mechanisms and processes are not known, and where no research has been completed to date (widest gap);

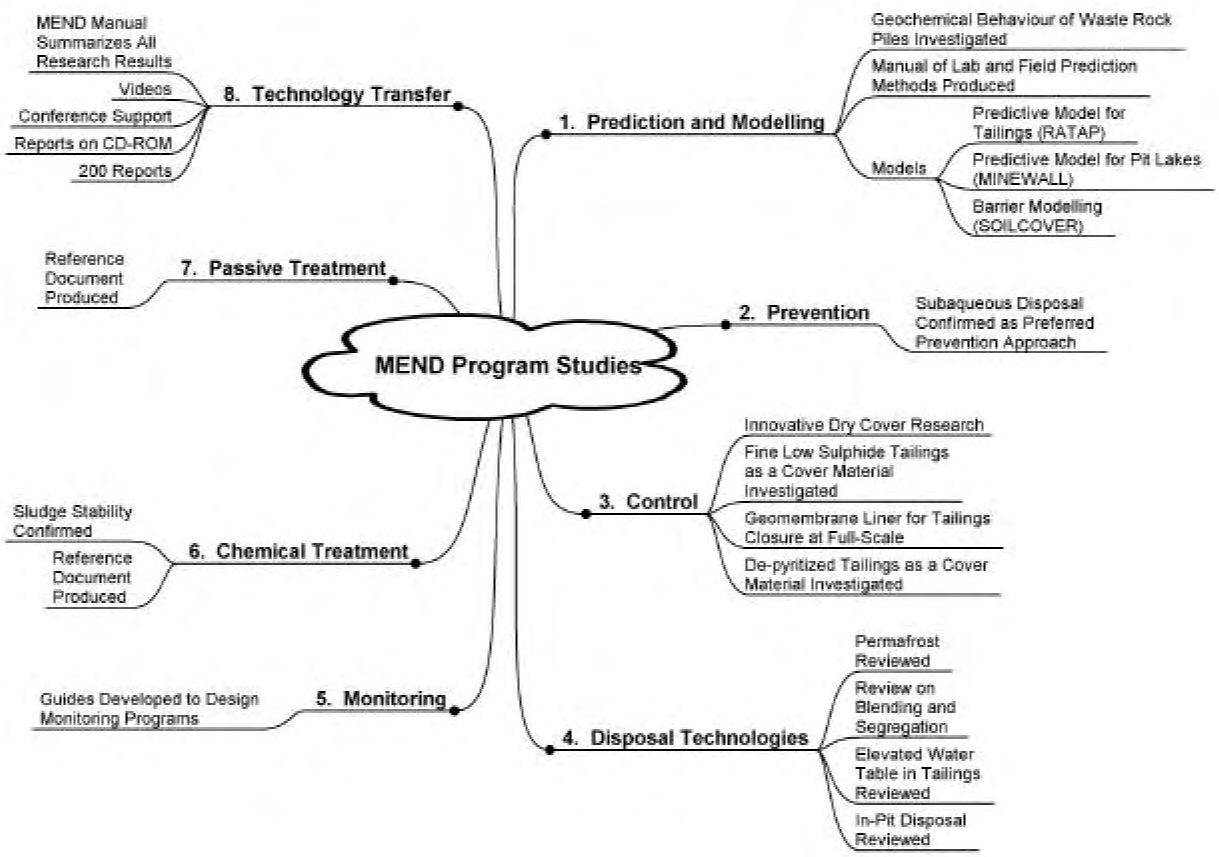
2. Fundamental research has been completed on mechanisms and processes;

3. Conceptual applications to mine waste management have been investigated; and

4. Full-scale design guidelines have been developed (narrowest gap).

The results of the MEND program will form the starting point for the Gap Analysis.

MEND was organized under four technical areas: prediction, prevention and control, treatment and monitoring, with technical committees in technology transfer and international activities. MEND produced over 200 technical reports. Some of the key technical results of the MEND Program are summarized in the graphic below.



Workshop Objective

The workshops will last one day. The intent of the workshops is to allow open discussion of directions and requirements for further research.

Participants will go through the following steps:

- Regional issues and opportunities will be classified based on knowledge of the participants of:
  - Geology, surficial geology, mineral deposit types, typical mining methods
  - Typical topographical constraints
  - Climate, hydrology and hydrogeology
  - Seismic factors
  - Regulatory regime
- The extent to which existing knowledge addresses the issues
- Development of ideas for research plans.

Contribute Your Knowledge!

MEND3 encourages you to contribute to this project through the questionnaire and workshops.

Thank you

APPENDIX B
Questionnaire Survey

APPENDIX B.1
Questionnaire

MEND3

ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY

Instructions for Completing the Questionnaire:

1. Please provide your response by September 7, 2001.
2. You can choose to respond anonymously.
3. Please provide your response in your specific regional context.
4. Rank each area of past research by placing a cross in one box (an example is provided).
5. Fill in the lines shown below as "Other" for other important opportunities for research and rank them using the same approach.

Email completed response to MEND3@srk.com (SUBJECT: MEND QUESTIONNAIRE) or
fax to 1-801-697-3021.

Further background can be found in the "Invitation to Participate" document. This document accompanies the questionnaire. It can also be found on MEND's website (http://mend2000.nrcan.gc.ca).

THANKYOU

This project is being funded on behalf of MEND3 by the Mining Association of Canada, Environment Canada and Natural Resources Canada. SRK Consulting (Vancouver, BC) and SENES Consultants Limited (Toronto, Ontario) are the contractors completing the work.

MEND3

ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY

Name:	
Title	
Organization	
General Category (Mining Company, Consultant, Gov't, Academic, NGO)	

The following responses are based on my experience in:

Province/Territory:		(write "CANADA" if not specific)
Permafrost Region (Yes or No):		
Other Country (Name, Province, State, etc)		
Commodity Type (Metal or Non-Metal or Coal)		
Mine Type (open pit, underground)		
Mine stage (permitting, operation, closure)		

I would be interested in a follow-up phone call (Yes/No)	
Phone	
Email	

Today's Date (mm/dd/yy)	

MEND3

ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY

	Fundamental Research Has Not Been Completed	Fundamental Research has been Completed	Application to Mine Sites Has been Investigated	Can be Applied to Design of Mine Waste Facilities	No Opinion
SAMPLE RESPONSE					
The "wheel"				X	
Intergalactic travel	X				
PREDICTION AND MODELLING					
Geochemical prediction methods (static geochemistry)					
Geochemical prediction methods (kinetic geochemistry)					
Understanding of waste rock geochemistry					
Understanding of tailings geochemistry					
Understanding of underground mine geochemistry					
Understanding of open pit geochemistry					
Waste rock geochemical model					
Tailings geochemical models (RATAP, WATAIL, SOILCOVER)					
Underground mine geochemical model					
Open pit geochemical model (eg MINEWALL)					
Other:					
Other:					
Other:					

MEND3

ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY

	Fundamental Research Has Not Been Completed	Fundamental Research has been Completed	Application to Mine Sites Has been Investigated	Can be Applied to Design of Mine Waste Facilities	No Opinion
PREVENTION					
Water covers for unoxidized waste rock					
Water covers for oxidized waste rock					
Water covers for unoxidized tailings					
Water covers for oxidized tailings					
Other:					
Other:					
Other:					
CONTROL					
Dry soil covers for waste rock (oxygen barrier)					
Dry soil covers for waste rock (hydrological barrier)					
Dry soil covers for tailings (oxygen barrier)					
Dry soil covers for tailings (hydrological barrier)					
Desulphidized tailings as a cover					
Use of non-mining wastes as covers					
Other:					
Other:					
Other:					

MEND3

ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY

	Fundamental Research Has Not Been Completed	Fundamental Research has been Completed	Application to Mine Sites Has been Investigated	Can be Applied to Design of Mine Waste Facilities	No Opinion
DISPOSAL TECHNOLOGIES					
Permafrost					
Blending or layering of waste rock					
Blending of tailings					
Blending of tailings and waste rock					
Segregation of waste rock (segregation methods)					
De-sulphidization of tailings					
Elevated water tables in tailings					
In-pit disposal of mine wastes					
Underground mine backfill					
Other:					
Other:					
Other:					

MEND3

ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY

	Fundamental Research Has Not Been Completed	Fundamental Research has been Completed	Application to Mine Sites Has been Investigated	Can be Applied to Design of Mine Waste Facilities	No Opinion
TREATMENT					
Conventional lime treatment					
HDS Process					
Sludge stability					
Passive treatment systems					
Other:					
Other:					
Other:					
MONITORING					
Monitoring Approaches					
Sampling Guidelines					
Chemical Analysis					
Other:					
Other:					
Other:					

MEND Use Only: Response Number

APPENDIX B.2
Tallied Questionnaire Response

MEND3
ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY
TALLY OF QUESTIONNAIRE RESPONSES

	Fundamental Research Has Not Been Completed	Fundamental Research has been Completed	Application to Mine Sites Has been Investigated	Can be Applied to Design of Mine Waste Facilities	No Opinion
SAMPLE RESPONSE					
The "wheel"				X	
Intergalactic travel	X				
PREDICTION AND MODELLING					
Geochemical prediction methods (static geochemistry)	5	5	7	17	5
Geochemical prediction methods (kinetic geochemistry)	7	4	12	12	5
Understanding of waste rock geochemistry	10	8	11	10	4
Understanding of tailings geochemistry	7	6	14	10	6
Understanding of underground mine geochemistry	13	7	4	5	14
Understanding of open pit geochemistry	9	11	4	6	13
Waste rock geochemical model	12	8	12	3	8
Tailings geochemical models (RATAP, WATAIL, SOILCOVER)	6	7	11	6	12
Underground mine geochemical model	9	7	1	3	23
Open pit geochemical model (eg MINEWALL)	9	6	7	3	18
Other:					
Other:					
Other:					

Note: Tallies do not include incomplete or unclear responses.

MEND3
ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY
TALLY OF QUESTIONNAIRE RESPONSES

	Fundamental Research Has Not Been Completed	Fundamental Research has been Completed	Application to Mine Sites Has been Investigated	Can be Applied to Design of Mine Waste Facilities	No Opinion
PREVENTION					
Water covers for unoxidized waste rock	5	8	9	15	6
Water covers for oxidized waste rock	7	8	12	10	6
Water covers for unoxidized tailings	4	8	9	18	4
Water covers for oxidized tailings	7	8	12	12	5
Other:					
Other:					
Other:					
CONTROL					
Dry soil covers for waste rock (oxygen barrier)	5	9	11	9	9
Dry soil covers for waste rock (hydrological barrier)	7	9	9	10	9
Dry soil covers for tailings (oxygen barrier)	6	7	12	10	8
Dry soil covers for tailings (hydrological barrier)	6	7	10	11	9
Desulphidized tailings as a cover	12	6	6	6	13
Use of non-mining wastes as covers	12	7	11	4	9
Other:					
Other:					
Other:					

Note: Tallies do not include incomplete or unclear responses.

MEND3
ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY
TALLY OF QUESTIONNAIRE RESPONSES

	Fundamental Research Has Not Been Completed	Fundamental Research has been Completed	Application to Mine Sites Has been Investigated	Can be Applied to Design of Mine Waste Facilities	No Opinion
DISPOSAL TECHNOLOGIES					
Permafrost	7	4	5	3	23
Blending or layering of waste rock	13	9	10	4	7
Blending of tailings	12	5	6	5	15
Blending of tailings and waste rock	16	5	6	5	10
Segregation of waste rock (segregation methods)	2	7	11	15	8
De-sulphidization of tailings	5	7	12	5	15
Elevated water tables in tailings	7	6	9	8	7
In-pit disposal of mine wastes	6	5	6	18	8
Underground mine backfill	9	3	3	16	12
Other:					
Other:					
Other:					

Note: Tallies do not include incomplete or unclear responses.

MEND3
ACID DRAINAGE TECHNOLOGIES GAP ANALYSIS AND OPPORTUNITIES STUDY
TALLY OF QUESTIONNAIRE RESPONSES

	Fundamental Research Has Not Been Completed	Fundamental Research has been Completed	Application to Mine Sites Has been Investigated	Can be Applied to Design of Mine Waste Facilities	No Opinion
TREATMENT					
Conventional lime treatment	2	5	6	25	4
HDS Process	3	6	2	21	10
Sludge stability	8	8	6	10	10
Passive treatment systems	12	10	6	7	8
Other:					
Other:					
Other:					
MONITORING					
Monitoring Approaches	8	5	7	18	3
Sampling Guidelines	5	5	6	18	5
Chemical Analysis	4	6	4	20	5
Other:					
Other:					
Other:					

MEND Use Only: Response Number

Note: Tallies do not include incomplete or unclear responses.

APPENDIX B.3

List of Other Research Areas

SPECIFIC COMMENTS FROM QUESTIONNAIRES
AS OF SEPTEMBER 14, 2001

Response Number	Area	Rank
001	Microbial interactions with geochemistry	1
	Phosphate to inhibit iron oxidation	1
	Reaction rates in water samples	1
	(some unreadable)	
002	Chemical evolution of pit lakes/tailings supernatant	1
	Scaling up static and kinetic lab work to operational	1
	Model standard deviation/uncertainty tested, refined resolved	1
	Climatic change assumptions affecting water covers	1
	Trace metal transfer, organic from water cover to receiving environment	1
	Effectiveness of dry covers over time, hydrological complications, infiltration vs groundwater recharge	1
	Segregation siting to avoid hydrological recharge zones	?
	EEM/biological effects tracking	
005	Prevention: Long term performance	1
	Development of methods to assess performance	1
	Passivation	1
	RA methods applied to covers	
	TDS removal	1
006	Biogeochemistry of pyrite oxidation	1
	Interaction of snow-melt hydrology with acid formation and prevention	1
	In situ bioremediation of acid generating rock formations	1
	Mineral (nitrate, iron, sulfate) reduction by acidophilic bacteria	1
	Bioassays for iron oxidizig and other acidophilic bacteria	1
007	Waste dump hydrology	2
	Permanganate coatings	1
	Synthetic covers for tails or waste rock	1
	Blending waste rock or tails with limestone	1
	Reprocessing existing tails to remove metals and S.	1
	Solvent extraction from ARD	1
	SRB (passive treatment0	2
	Treatment of sulphate in effluent	1
	Use of sublethal bioassays for discharge criteria	1
012	Stability of secondary oxidation products in subaqueous settings	1
	Stability of arsenic-bearing tailings wasterock and treatment products in subaerial and subaqueous settings	1
	Arsenic treatment products (eg ferric arsenates)	1
	Diffusion barriers to control the release of metals from submerges tailings and wasterock	1
	Stability of arsenic-bearing wasterock, tailings and treatment products (eg) arsenates, calcium arsenates) in passive in-pit treatment methods	1
	Use of metal speciation (eg DGT, ASV etc)	?
	Analytical methods will always be in a constant state of evolution	?

013	Example methods for removal of metals from waste streams and receiving water where metal concentrations level are low	?
	ERM program should look at other parameters as well as antimony selection	?
019	Understanding waste rock hydrology	2
	Understanding underground mine hydrology	2
	Predicting underground mine hydrology	1
020	Transferring lab/bench → real pile "situation"→ production	1
	Technical necessities to work in long term (ie cover depth, eco system evaluation)	1
	Long term performance 9implications of revegetation ?)	1
	Ecosystem health assessment/predict	1
022	Electrowinning	1
027	Flow through wasterock	1
	Reduction of sulphide oxidation rate by "coating"	2
	measurement of oxygen flux through base of dry cover	1
	Measurement of water flux though base of dry cover	1
029	Neutralization with MgCO3 + Algal adsorption ponds	2
031	Paste technology	1,2,3
034	Mobility in neutral mine waste environments	2,3,4
039	Pit lake geochemistry & modelling	2,3
040	New models for chemicals and kinetic modelling eg artificial intelligence application, chaos theory etc.	1,4
	Generic models incorporating current knowledge	1,4
	Molecular biology approaches to monitoring eg gene arrays for EEM, fibre optic sensor for other	1,4
	Real time monitoring using satellite routing	1,4
042	Infiltration/percolation (?)	3
	Long term observation approach	4
	Geochemistry	3
043	Tailings management during subaqueous drainage operations	1
044	Application of sampling methodology	1
	Chemical amendments	2
	Chemical treatments to isolate	2
	Grout walls/geotechnical barriers	3
	Sludge covers	3
	Complex versus single layer cover	3
	Evolving chemical treatments	3
045	Dry-stacking of tailings/surface disposal of paste fill	1
047	Role of plants in water covers for tailings	1

APPENDIX C
Workshops

APPENDIX C.1

Workshop Agenda (Toronto and Vancouver)

AGENDA

MEND3 Workshop

THIS WORKSHOP IS FULL!

By Receiving this Agenda You Are A Confirmed Attendee
THANK YOU FOR PARTICIPATING

Date of Workshop: Friday, September 28, 2001

Location: 5th Floor Boardroom
TeckCominco
500-200 Burrard Street
Vancouver, BC
Tel (604) 687-1117

9:00 – 9:30 Coffee and muffins prior to commencement

9:30 – 10:00 Welcome and Introductions

10:00 – 10:15 BREAK

10:15 – 12:00 Workshop Participants Viewpoints Session

Each participant will be given 3 minutes to give their opinion on acidic drainage issues/research gaps.

12:00 – 1:00 Lunch (buffet style in boardroom)

1:00 – 1:15 Morning findings and target research areas

1:15 – 2:15 Full group workshop assessment of one target research area

- Issues Scan (what are key issues, geochemical, regulatory, infrastructure, etc…) (5 minutes).
- Status - where are we (20 minutes)?
- What are the gaps (20 minutes)?
- Potential research projects (15 minutes)?

2:15 – 2:30 BREAK

2:30 – 4:00 Small groups workshop.

- Each group to evaluate two research areas using the same approach as above

4:00 Thank-you and wrap- up

APPENDIX C.2
Toronto Workshop Report

1.0 GENERAL

The MEND3 gap analysis Toronto Workshop was held at the PDAC offices in Toronto on 17 September 2001. Attendees are listed below.

Grouping	Name	Affiliation
Mining Companies	Craig Ford	Inmet
	Luc St-Arnaud	Noranda NTC
	Denis Kemp	Falconbridge
Consultant	Mike Sudbury	Consultant
	Ron Nicholson	Beak International
	Bing Wang	SNC-Lavalin
University Researchers	Ziad Saghir	Ryerson University
	Heather Jamieson	Queens University
	Denis Bois	UQAT
First Nations	Richard Nolan	Missanabie Cree First Nation
Regulators	John Robertson	Ministry of Northern Development and Mines
	Louis Bienvenu	Government Quebec-MRN
	Chris Doiron	Environment Canada
Mining/Professional Associations	Elizabeth Gardiner	Mining Association of Canada
	Patricia Dillon	CIM-Past President
Observer	Gilles Tremblay	MEND3 Program
Workshop Chair	Dave Orava	SENES Consultants Limited

The introductory session of the workshop comprised opening remarks by Dave Orava, followed by: 1) a succient presentation on MEND3 by Elizabeth Gardiner; 2) an overview presentation by Patricia Dillon on the strategic planning process used by the CIM; and 3) an overview by Dave Orava on the Environmental Excellence in Exploration initiative of the Prospectors and Developers Association of Canada. Workshop participants were then asked to give their opinion on key acidic drainage issues and/or possible directions of future research in this area. Their opinions are summarized in Section 2.0 below.

Workshop participants then reviewed opportunities for research through a general discussion on acidic drainage control technologies (see Section 3.0 below).

The workshop concluded with a summary by chair Dave Orava who indicated that based on the input received during the workshop:

1. The MEND "toolbox" is acceptable and working. There is a need to bring unproven technologies forward so that they can be (if possible) available for use.

2. There are definite gaps – specifically where technologies are not ready to be applied.
3. There is considerable need to improve communication/information management.
4. As an overall comment, the MEND program appears to have being going in the right direction.
5. There is an expressed need to investigate the long-term performance of acidic drainage prevention and control technologies.
6. There is an expressed need to "audit" the performance of acidic drainage prevention and control technologies.
7. The type of monitoring data sought is of the type useful for decision-making (e.g. biological monitoring).
8. Monitoring should be very focussed.
9. There is an expressed need to undertake applied research.
10. There is clearly pressure to be efficient with funding.

The workshop participants added the following:

11. There is an expressed need to also take into consideration the MEND3 program organization, research objectives, and education of mine employers.
12. There is an expressed need to address pollution prevention, and investigate the use of approaches other than R.O.I. alone to select acidic drainage technologies.

2.0 KEY COMMENTS FROM ISSUES SCAN

2.1 Overall Guiding Direction

Mining company participants:

- Need to avoid duplication of efforts (e.g. possibly with INAP) especially with scarse resources.
- Can we research the joy de vivre of MEND?
- It is challenging to review a program. Look at ways to innovate and get momentum in a new program.

Consultants:

- There is a need to integrate research, to do collaborative research, and bring skill sets together.

University researchers:

- The UQAT acidic drainage program in Rouyn-Noranda focuses on:
    1) Integrating acidic drainage knowledge with mine operations (e.g. look at ways to reduce mine waste volumes); and
    2) Mine site restoration, with community involvement.

First Nations representative:

- Encouraged by MEND3 multi-staker planning process.

Federal, Ontario, Quebec regulators:

- The key focus has to be to avoid acidic drainage generation.
- The cessation of the MEND program represented the end of organized national research on dry and wet covers.

Mining/professional association representations:

- Must focus on Canadian needs.

- Need a multi-stakeholder perspective involving communities, downstream and biological effects.

2.2 PROGRAM FUNDING

Mining company participants:

- There would have to be a compiling reason for mining companies to provide significant funds for acidic drainage research.
- Research funding is hard to obtain – this situation is expected to persist for some time. There has been a significant decrease in available resour5ces.

Consultants:

- MEND3 could look at working with partners/other members.

University researchers:

- Potential opportunities for funding may exist through government (e.g. NSERC).

First Nations representative:

- Forest industry is undertaking extended initiatives (e.g. 20 yr programs) in conjunction with First Nations.

Federal, Ontario, Quebec regulators:

- There is considerable need to decommission historic/abandoned sites (where acidic drainage is an issue). There is a need to look at lower cost technologies such as biotechnology and alternate dry covers.

2.3 RESEARCH ISSUES

Mining company participants:

- Revised biological applications including passive treatment.
- Revisit NPV basis for costing the use of acidic drainage technologies.

Consultants:

- Need to further investigate acidic drainage in permafrost regions.
- Need to investigate performance of control technologies after closure and during transition stage.
- Need to investigate grey areas (e.g. PAG).
- Need to look at everything from source material to environmental impact.
- Need to revisit possible use to mine wasters for other purposes.

University researchers:

- Need to investigate hazards of contaminants (i.e. As, Se) and their long-term fate and effect on the environment.

Federal, Ontario, Quebec regulators:

- Biological aspects need to be further investigated.
- Further investigate biological aspects including as they relate to wet covers and passive treatment.
- Need to “audit” sits where acidic drainage technologies have been applied.
- Need to better understand the performance and service life of manmade materials (e.g. synthetic liners).
- Need to make control technologies compatible with post-closure land use.
- Need to assess use of alternate covers (i.e. using desulphurized tailings, red mud, etc.).

Mining/professional association representatives:

- Biological impacts and biological monitoring has not been studied sufficiently.

2.4 COMMUNICATION AND INFORMATION MANAGEMENT

Mining company participants:

- Considerable effort is required in the area of acidic drainage information management.
- Up-to-date acidic drainage information is scarse and not easy to obtain.
- Need to find different ways of information management and communication- make better use of IT.
- Emphasis communications and technology transfer.

First Nations representative:

- People including Tribal Council do not hear about developments in the mining sector. People need to hear about developments.
- Need to change the face of mining.

Federal, Ontario, Quebec regulators:

- Need to communicate both acidic drainage success stories and challenging sites.
- Widely communicate ongoing monitoring results.

Mining/Professional association representatives:

- Three is also a need to get information to the public at large.
- Canadian Institute of Mining conferences have provided venues for technical transfer in acidic drainage areas.

3.0 ACIDIC DRAINAGE CONTROL TECHNOLOGIES

It was generally felt by the workshop participants that acidic drainage issues and concerns have evolved to a point where they; blur with other aspects including, but not limited to, environmental assessment, permitting, closure planning, and environmental impacts. The greatest focus, in terms of mining company funding, is now given to metals and the environment rather than to specific acidic drainage research. Research for the advancement of technologies may best be done through linkages with universities.

A new acidic drainage program would need to be a strong, national organization with linkages to universities and other acidic drainage research organizations internationally.

There is a perceived need to integrate acidic drainage research results with mine site activities. Potential refinements are to:

- examine changes in mining methods to minimize or eliminate problems.
- further investigate potential acid generating (PAG) materials.
- further assess the performance of control technologies over time.
- investigate effects on the receiving environment including groundwater. Take into consideration transitioned effects, post-closure monitoring, and requirements such as MMER.
- assess control technologies in light of proposed post-closure land uses.
- for both dry and wet covers, report on field experience, and expand biological monitoring.
- prioritize gaps, keeping in mind that there are two key types of research information: 1) nice to know; and 2) need to know.

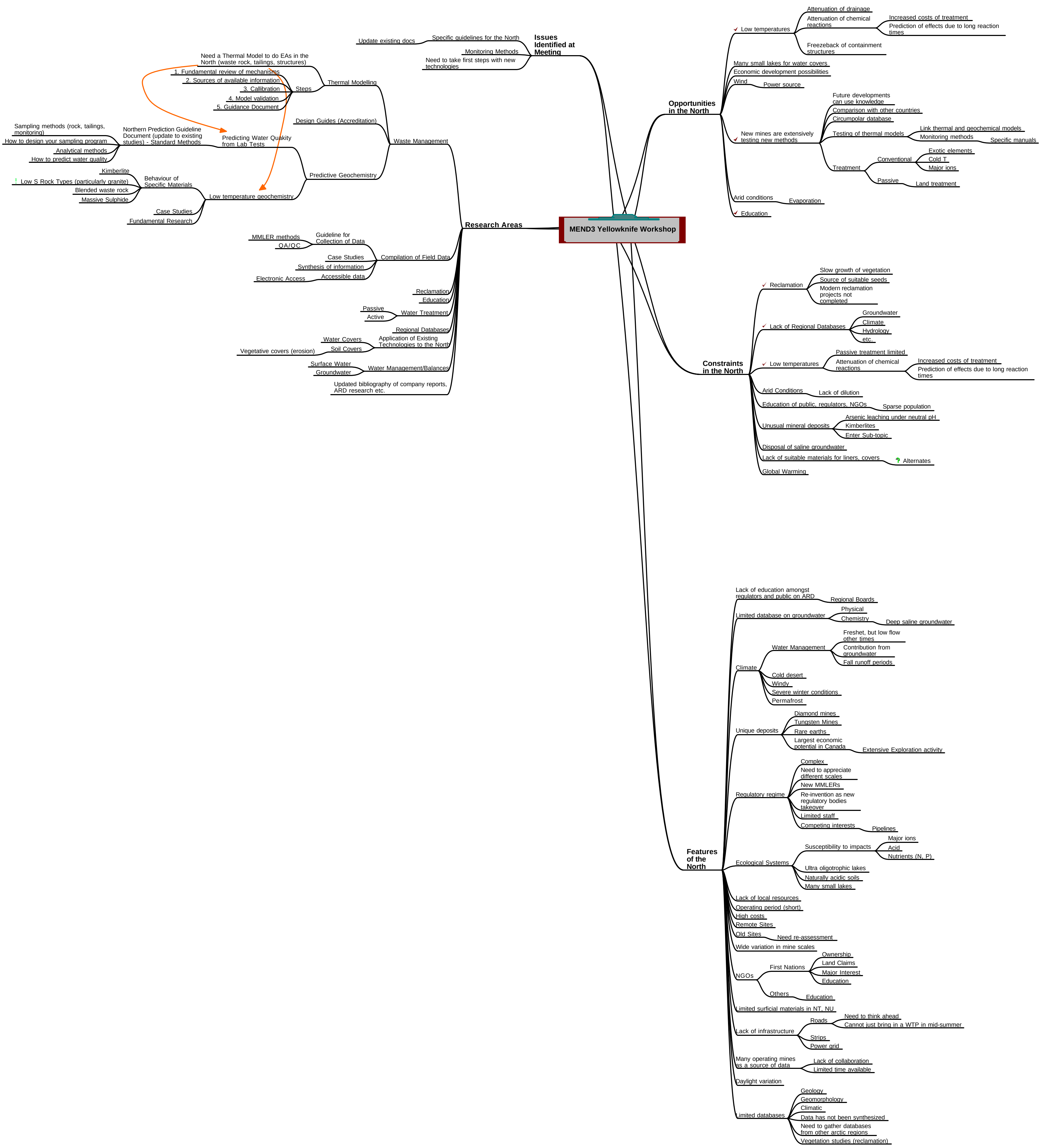
The largest gaps may exist where there is no field experience – passive treatment represents a huge gap.

The use of water covers should continue to be an area of research given its wide applicability in Canada. Possible methods to reduce the cost of dry covers are also of interest.

INAP has identified technical gaps in the:

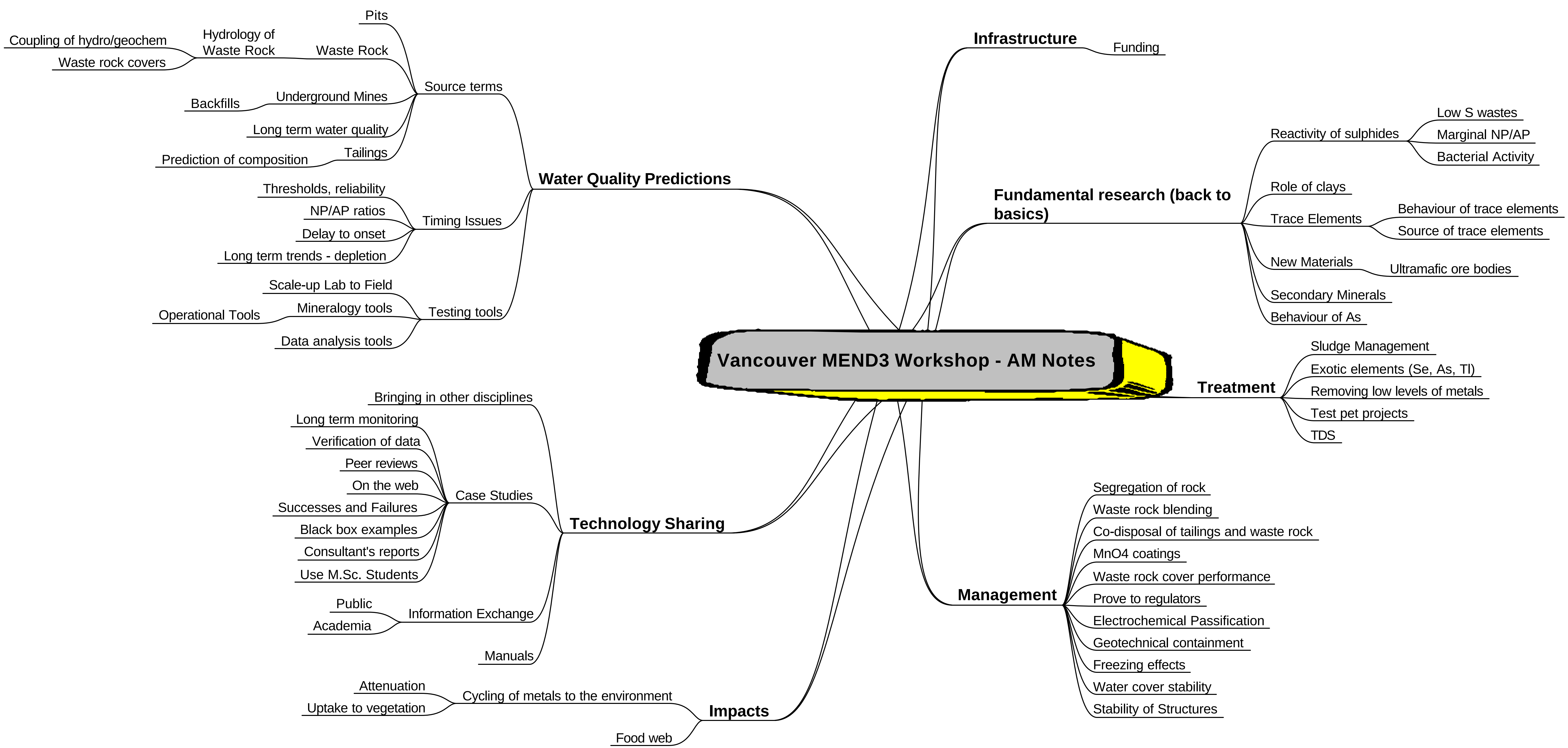
- use of water covers;
- Surface disposal of paste tailings;
- Measurement of tailings oxidation; and
- Sludge management.

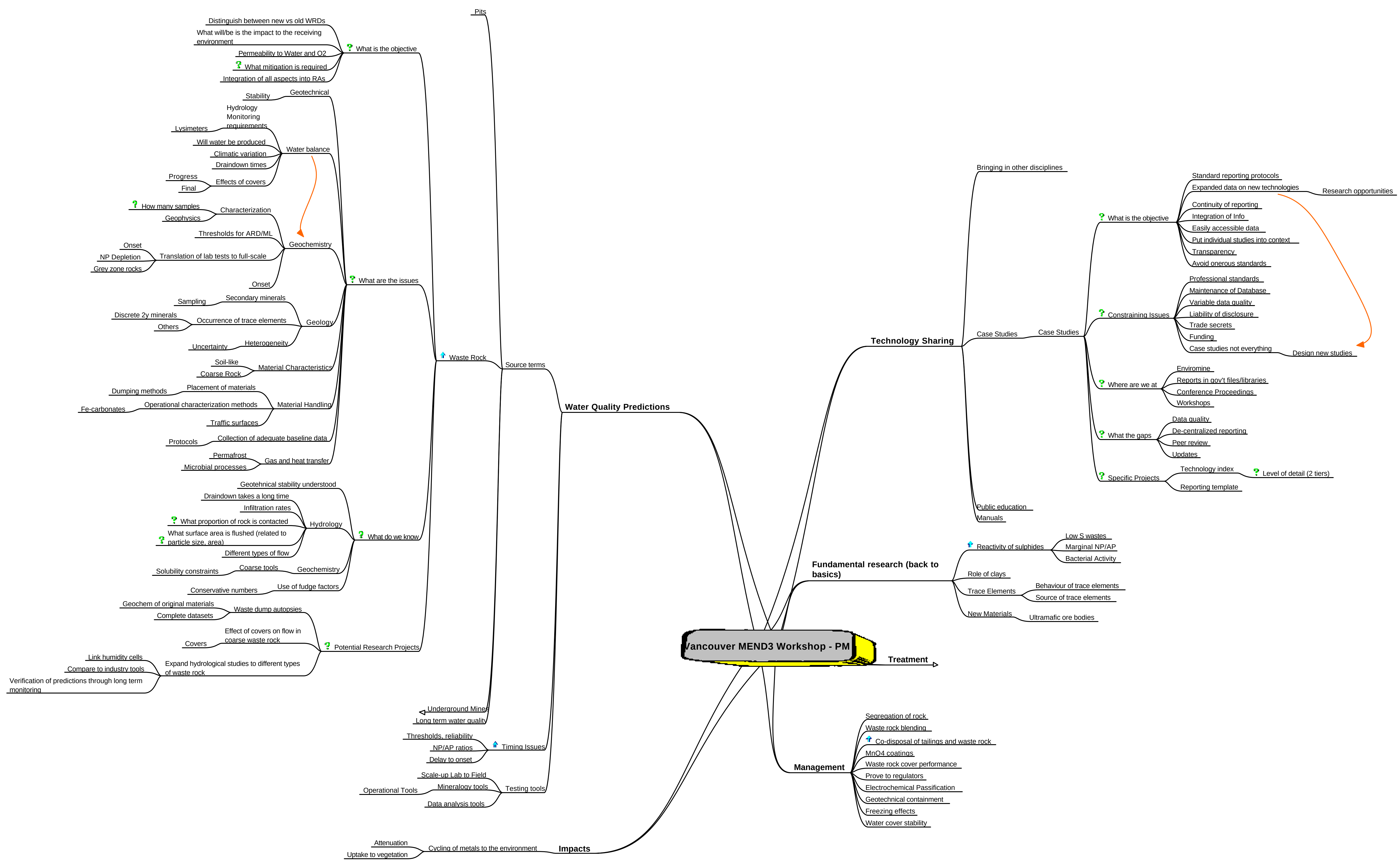
APPENDIX C.3
Yellowknife Workshop Notes


MEND3 Yellowknife Workshop
Issues Identified at Meeting
Specific guidelines for the North
Update existing docs
Monitoring Methods
Need to take first steps with new technologies
Research Areas
Waste Management
Thermal Modelling
Need a Thermal Model to do EAs in the North (waste rock, tailings, structures)
Steps
1. Fundamental review of mechanisms
2. Sources of available information
3. Calibration
4. Model validation
5. Guidance Document
Design Guides (Accreditation)
Predictive Geochemistry
Predicting Water Quality from Lab Tests
Northern Prediction Guideline Document (update to existing studies) - Standard Methods
Sampling methods (rock, tailings, monitoring)
How to design your sampling program
Analytical methods
How to predict water quality
Low temperature geochemistry
Behaviour of Specific Materials
Kimberlite
Low S Rock Types (particularly granite)
Blended waste rock
Massive Sulphide
Case Studies
Fundamental Research
Compilation of Field Data
Guideline for Collection of Data
MMLER methods
QA/QC
Case Studies
Synthesis of information
Accessible data
Electronic Access
Reclamation
Education
Water Treatment
Passive
Active
Regional Databases
Application of Existing Technologies to the North
Water Covers
Soil Covers
Vegetative covers (erosion)
Water Management/Balances
Surface Water
Groundwater
Updated bibliography of company reports, ARD research etc.
Opportunities in the North
Low temperatures
Attenuation of drainage
Attenuation of chemical reactions
Increased costs of treatment
Prediction of effects due to long reaction times
Freezeback of containment structures
Many small lakes for water covers
Economic development possibilities
Wind
Power source
New mines are extensively testing new methods
Future developments can use knowledge
Comparison with other countries
Circumpolar database
Testing of thermal models
Link thermal and geochemical models
Monitoring methods
Specific manuals
Treatment
Conventional
Exotic elements
Cold T
Major ions
Passive
Land treatment
Arid conditions
Evaporation
Education
Constraints in the North
Reclamation
Slow growth of vegetation
Source of suitable seeds
Modern reclamation projects not completed
Lack of Regional Databases
Groundwater
Climate
Hydrology
etc.
Low temperatures
Passive treatment limited
Attenuation of chemical reactions
Increased costs of treatment
Prediction of effects due to long reaction times
Arid Conditions
Lack of dilution
Education of public, regulators, NGOs
Sparse population
Unusual mineral deposits
Arsenic leaching under neutral pH
Kimberlites
Enter Sub-topic
Disposal of saline groundwater
Lack of suitable materials for liners, covers
Alternates
Global Warming
Features of the North
Lack of education amongst regulators and public on ARD
Regional Boards
Limited database on groundwater
Physical
Chemistry
Deep saline groundwater
Climate
Water Management
Freshet, but low flow other times
Contribution from groundwater
Fall runoff periods
Cold desert
Windy
Severe winter conditions
Permafrost
Unique deposits
Diamond mines
Tungsten Mines
Rare earths
Largest economic potential in Canada
Extensive Exploration activity
Regulatory regime
Complex
Need to appreciate different scales
New MMLERs
Re-invention as new regulatory bodies takeover
Limited staff
Competing interests
Pipelines
Ecological Systems
Susceptibility to impacts
Major ions
Acid
Nutrients (N, P)
Ultra oligotrophic lakes
Naturally acidic soils
Many small lakes
Lack of local resources
Operating period (short)
High costs
Remote Sites
Old Sites
Need re-assessment
Wide variation in mine scales
NGOs
First Nations
Ownership
Land Claims
Major Interest
Education
Others
Education
Limited surficial materials in NT, NU
Lack of infrastructure
Roads
Need to think ahead
Cannot just bring in a WTP in mid-summer
Strips
Power grid
Many operating mines as a source of data
Lack of collaboration
Limited time available
Daylight variation
Limited databases
Geology
Geomorphology
Climatic
Data has not been synthesized
Need to gather databases from other arctic regions
Vegetation studies (reclamation)

Steven Day

APPENDIX C.4
Vancouver Workshop Notes


Vancouver MEND3 Workshop - AM Notes
Water Quality Predictions
Source terms
Pits
Waste Rock
Hydrology of Waste Rock
Coupling of hydro/geochem
Waste rock covers
Underground Mines
Backfills
Long term water quality
Tailings
Prediction of composition
Timing Issues
Thresholds, reliability
NP/AP ratios
Delay to onset
Long term trends - depletion
Testing tools
Scale-up Lab to Field
Mineralogy tools
Operational Tools
Data analysis tools
Technology Sharing
Bringing in other disciplines
Case Studies
Long term monitoring
Verification of data
Peer reviews
On the web
Successes and Failures
Black box examples
Consultant's reports
Use M.Sc. Students
Information Exchange
Public
Academia
Manuals
Impacts
Cycling of metals to the environment
Attenuation
Uptake to vegetation
Food web
Infrastructure
Funding
Fundamental research (back to basics)
Reactivity of sulphides
Low S wastes
Marginal NP/AP
Bacterial Activity
Role of clays
Trace Elements
Behaviour of trace elements
Source of trace elements
New Materials
Ultramafic ore bodies
Secondary Minerals
Behaviour of As
Treatment
Sludge Management
Exotic elements (Se, As, Tl)
Removing low levels of metals
Test pet projects
TDS
Management
Segregation of rock
Waste rock blending
Co-disposal of tailings and waste rock
MnO4 coatings
Waste rock cover performance
Prove to regulators
Electrochemical Passification
Geotechnical containment
Freezing effects
Water cover stability
Stability of Structures



Vancouver MEND3 Workshop - PM
Water Quality Predictions
Source terms
Pits
Waste Rock
What is the objective
Distinguish between new vs old WRDs
What will/be is the impact to the receiving environment
Permeability to Water and O2
What mitigation is required
Integration of all aspects into RAs
What are the issues
Geotechnical
Stability
Water balance
Hydrology Monitoring requirements
Lysimeters
Will water be produced
Climatic variation
Draindown times
Effects of covers
Progress
Final
Geochemistry
Characterization
How many samples
Geophysics
Thresholds for ARD/ML
Translation of lab tests to full-scale
Onset
NP Depletion
Grey zone rocks
Onset
Geology
Secondary minerals
Sampling
Occurrence of trace elements
Discrete 2y minerals
Others
Heterogeneity
Uncertainty
Material Characteristics
Soil-like
Coarse Rock
Material Handling
Placement of materials
Dumping methods
Operational characterization methods
Fe-carbonates
Traffic surfaces
Collection of adequate baseline data
Protocols
Gas and heat transfer
Permafrost
Microbial processes
What do we know
Geotehnical stability understood
Hydrology
Draindown takes a long time
Infiltration rates
What proportion of rock is contacted
What surface area is flushed (related to particle size, area)
Different types of flow
Geochemistry
Coarse tools
Solubility constraints
Use of fudge factors
Conservative numbers
Potential Research Projects
Waste dump autopsies
Geochem of original materials
Complete datasets
Effect of covers on flow in coarse waste rock
Covers
Expand hydrological studies to different types of waste rock
Link humidity cells
Compare to industry tools
Verification of predictions through long term monitoring
Underground Mines
Long term water quality
Timing Issues
Thresholds, reliability
NP/AP ratios
Delay to onset
Testing tools
Scale-up Lab to Field
Mineralogy tools
Operational Tools
Data analysis tools
Impacts
Cycling of metals to the environment
Attenuation
Uptake to vegetation
Technology Sharing
Bringing in other disciplines
Case Studies
Case Studies
What is the objective
Standard reporting protocols
Expanded data on new technologies
Research opportunities
Continuity of reporting
Integration of Info
Easily accessible data
Put individual studies into context
Transparency
Avoid onerous standards
Constraining Issues
Professional standards
Maintenance of Database
Variable data quality
Liability of disclosure
Trade secrets
Funding
Case studies not everything
Design new studies
Where are we at
Enviromine
Reports in gov't files/libraries
Conference Proceedings
Workshops
What the gaps
Data quality
De-centralized reporting
Peer review
Updates
Specific Projects
Technology index
Level of detail (2 tiers)
Reporting template
Public education
Manuals
Fundamental research (back to basics)
Reactivity of sulphides
Low S wastes
Marginal NP/AP
Bacterial Activity
Role of clays
Trace Elements
Behaviour of trace elements
Source of trace elements
New Materials
Ultramafic ore bodies
Treatment
Management
Segregation of rock
Waste rock blending
Co-disposal of tailings and waste rock
MnO4 coatings
Waste rock cover performance
Prove to regulators
Electrochemical Passification
Geotechnical containment
Freezing effects
Water cover stability

APPENDIX D
Consultation List

CONSULTATION LIST

Response	Questionnaire	Workshop	Follow-Up	Category	Province	Permafrost	Country	Commodity	Mine Type	Stage
1	X			C	Canada	Y	Brazil, Germany	All	All	C
2	X	X		N	BC	N		All	All	All
3	X	X		M	ON	Y		M	All	O, C
4	X			M	BC	N		M	U	All
5	X			M	Canada	N	SA	M	All	All
6	X			A	None	N	USA	M	All	C
7	X	X		M	BC	N		M	All	C
8	X			G	YT	Y		All	All	All
9	X			C	QC	N		M	All	All
10	X			A	Canada	N		M	All	All
11	X			M	QC	N	Guyana	M	All	O, C
12	X			C	ON	N	US, SA, Asia	M	All	All
13	X			G	BC	N	SA, Europe	All	All	All
14	X			M	None	N	Germany	M	All	C
15	X			N	Canada	Y	Brazil, Guyana	M	All	All
16	X	X		M	Canada	Y		All	All	All
17	X			C	None	N	US	M	All	C
18	X	X		M	BC	Y	US	M	All	All
19	X	X		A	SK	N	US	All	All	P/C
20	X			G	SK	Y		M/N	All	P
21	X			N	YT	Y		M	All	All
22	X	X		C	BC	N		M	All	P/O
23	X			G	ON	N		All	All	C
24	X			M	None	N	Tanzania	M	O	O
25	X			C	Canada	Y	US/SA,Africa	All	All	All
26	X			C	ON	N	Ghana/Kyrgystan	M	All	All
27	X			C	Canada	Y	Many	All	All	All
28	X			C	Canada	Y	Guyana	M	All	All
29	X			M	ON	N		M	U	All
30	X			A	ON	N		None	None	None
31	X			C	Canada	Y	World	All	All	All
32	X			M	BC	N		M	O	P
33	X			A	BC	N		M	O	C
34	X	X		A	Canada	Y	US/Europe	M	All	C
35	X			M	ON	N		M	U	C
36	X			M	Canada	N	SA, Aust	M	All	All
37	X			C	Canada	Y	World	M/N	All	All
38	X			A	None	N	US	C	All	All
39	X			M	Canada	N	US	M	All	All
40	X			A	Canada	Y		All	All	All
41	X	X		M	BC	N		M	O	O
42	X			M	SK	N		M	All	All
43	X			C	Canada	N	World	M	All	All
44	X	X		M	BC	N	Peru	M	U	O/C
45	X	X		C	Canada	Y	World	M	All	All
46	X			M	SK	Y		M	O	All
47	X			A	ON	N		M	All	All
48		X		M	NT	-	-	-	-	-
49		X		G	NT	-	-	-	-	-
50		X		M	NT	-	-	-	-	-
51		X		M	NT	-	-	-	-	-
52		X		M	NT	-	-	-	-	-

CONSULTATION LIST

Response	Questionnaire	Workshop	Follow-Up	Category	Province	Permafrost	Country	Commodity	Mine Type	Stage
53		X		G	NT	-	-	-	-	-
54		X		C	-	-	-	-	-	-
55		X		C	-	-	-	-	-	-
56		X		G	-	-	-	-	-	-
57		X		A	-	-	-	-	-	-
58		X		G	-	-	-	-	-	-
59		X		G	-	-	-	-	-	-
60		X		M	-	-	-	-	-	-
61		X		C	-	-	-	-	-	-
62		X		C	-	-	-	-	-	-
63		X		C	-	-	-	-	-	-
64		X		G	-	-	-	-	-	-
65		X		M	-	-	-	-	-	-
66		X		M	-	-	-	-	-	-
67		X		C	-	-	-	-	-	-
68		X		C	-	-	-	-	-	-
69		X		C	-	-	-	-	-	-
70		X		A	-	-	-	-	-	-
71		X		A	-	-	-	-	-	-
72		X		N	-	-	-	-	-	-
73		X		G	-	-	-	-	-	-
74		X		G	-	-	-	-	-	-
75		X		G	-	-	-	-	-	-
76		X		N	-	-	-	-	-	-
77		X		N	-	-	-	-	-	-
78		X		C	-	-	-	-	-	-
79			X	M	-	-	-	-	-	-
80			X	M	-	-	-	-	-	-
81			X	C	-	-	-	-	-	-
82			X	A	-	-	-	-	-	-
83			X	M	-	-	-	-	-	-
84			X	M	-	-	-	-	-	-
85			X	M	-	-	-	-	-	-
86			X	M	-	-	-	-	-	-
87			X	M	-	-	-	-	-	-
88			X	C	-	-	-	-	-	-
89			X	C	-	-	-	-	-	-
90			X	M	-	-	-	-	-	-
91			X	C	-	-	-	-	-	-
92			X	C	-	-	-	-	-	-
93			X	C	-	-	-	-	-	-
94			X	M	-	-	-	-	-	-

Notes
Category : M = Mining Company, G = Government, N = Non-Governmental Organization, A = Academic, C = Consultant
Commodity: M = Metal, N = Non-metal, C = Coal
Mine Type: O = Open Pit, U = Underground
Stage: P = Permitting, C = Closure, O = Operating
"-" indicates data not available