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ARD GUIDELINES FOR MINE SITES IN BRITISH COLUMBIA

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Abstract; From previous project reviews and research, the British Columbia Reclamation Advisory Committee (RAC) developed a set of policies, rules, and procedures that guide its assessment of projects with issues involving acid rock drainage (ARD). This information was compiled into a comprehensive working policy, which covered the entire spectrum of ARD issues, including sections dealing with exploration, proposed mine developments, prediction, prevention, collection and treatment, commercial leaching, permitting, bonding, monitoring, historic sites and existing mines. The *RAC* policy was released in July 1993, both for public information, and industry discussion and comment. Presently, the RAC is compiling the comments received and forming an expert review group to consider the contentious issues.

In the meantime, a large number of projects are undergoing active development and review, including at least 7 proposed mines and 11 closure plans with ARD concerns. To guide its ongoing review and as a tool for advising proponents, B.C. MEMPR have produced this revised set of ARD guidelines, based in part on the July 1993 Policy, with revisions and additions derived from recent mine reviews and from comments received from the public and industry. The guidelines set forth in this paper govern the information required from a prediction program, the type of materials used for construction purposes, preventive techniques such as underwater disposal and blending, and inventory and monitoring requirements associated with waste handling.

INTRODUCTION

The British Columbia government regards mining as a temporary use of the land. This principle is enforced by current mining legislation, which requires that disturbed land and water resources be reclaimed to a level of productivity not less than that which existed previously, and that water released from the mine site meet long-term water quality standards.

As part of the regulation of the mining industry, all mine proposals and closure plans are examined by interagency Regional Mine Development Review Committees (RMDRC). The Victoria-based Reclamation Advisory Committee (RAC) reviews the decisions of the RMDRC and issues the Reclamation Permits, which are required before mining can proceed. A major factor in many mine reviews is the consideration of acid rock drainage (ARD) and associated metal release.

To enable the British Columbia mining industry to comply with the present comprehensive reclamation requirements, the provincial government is participating in a program of research aimed at developing cost-effective solutions to major environmental problems. Much of this program focuses on acid rock drainage. As part of this research, the provincial government coordinates and provides funding for the British Columbia Acid Mine Drainage Task Force and is a vital participant in activities of the national acid rock drainage program (Mine Environmental Neutral Drainage Program - MEND). In 1992, research expenditures for the British Columbia Acid Mine Drainage Task Force amounted to $1.5 million, with funding shared by industry and the provincial and federal governments.

From previous project reviews and research, the RAC developed a series of working policies and technical initiatives to deal with acid rock drainage. These procedures, rules, and guidelines were first compiled as a working document in 1991 (Errington, 1991). A revised working document was released by the RAC as a draft discussion document in July, 1993, both for public information, and industry discussion and comment. In attempting to cover the entire spectrum of ARD issues, the July 1993 Policy document contained sections dealing with exploration, proposed mine developments, prediction, prevention, collection and treatment, commercial leaching, permitting, bonding, monitoring, historic sites, and existing mines. Presently the RAC is compiling the comments received, and forming an expert review group to consider the contentious issues.

In the meantime, a large number of projects are undergoing active development and review, including at least 7 proposed mines and 11 closure plans with ARD concerns. To guide our ongoing review and as a tool for advising proponents, MEMPR have produced this revised set of ARD guidelines, based in part on the July 1993 Policy, with revisions and additions derived from recent mine reviews and from comments received from the public and industry. The guidelines set forth in this paper govern the information required from a prediction program, the type of materials used for construction purposes, preventive techniques such as underwater disposal and blending, and inventory and monitoring requirements associated with waste handling. The ARD guidelines set forth herein reflects the RAC's current philosophy of preventing ARD generation through prediction and design, avoiding long-term treatment wherever possible.

GENERAL PRINCIPLES

All mining and exploration activity will be regulated in a manner that protects the environment and minimizes the economic risks to the province.

All potential environmental and social impacts of acid drainage for a proposed mine will be assessed during the Mine Development Assessment Process, prior to issuance of a Mine Development Certificate.

Owing to the significant cost and site-specific needs of each mining project, a proponent is advised to discuss the ARD prediction or remediation program with regulatory agencies prior to its implementation.

Because some uncertainty is associated with predicting the occurrence and extent of acid rock drainage, treatment and control contingencies may be part of some mine approvals. Prediction is generally more difficult for waste rock dumps, open pits, and underground workings than for tailings impoundments. While the technology is available to prevent the release of acid rock drainage from operating mine sites, it is not yet possible to completely abandon acid-generating mines without requiring; long-term programs to collect and treat acid rock drainage or to maintain prevention and control measures.

As a condition of a reclamation permit security bonds will be required to ensure that sufficient funds are available to cover all outstanding reclamation obligations, including long-term costs associated with monitoring, maintenance of preventive structures, and treatment of acid rock drainage following mine closure.

ARD and its associated metal leaching is highly site specific. Consequently, the policy and procedures outlined in this document must be tailored to each site, and applied according to specific mining, geological and environmental conditions.

Acid drainage and metal leaching are ongoing, dynamic processes whose rates and significance are controlled by biological, physical, and chemical thresholds. As a result, ARD studies and remediation programs must consider both the surrounding environment and long term changes in inputs and mitigating processes.

Through research, the Province will continue to assist the development of improved acid rock drainage technology.

The Province will revise the ARD Policy and regulatory framework to reflect changes in acid rock drainage technology. Modifications and additional requirements for individual mines will be based upon site specific conditions.

PREDICTION OF ACID ROCK DRAINAGE

In order to design a mine which will not result in a major financial liability, a proponent must have a thorough understanding of the nature of all materials exposed during the mining cycle. This information will be required in the development of the extraction, waste handling, and remediation plans.

The proponent is required to predict the acid rock drainage potential for each overburden and rock type mined or exposed, and for any waste material, such as waste rock or tailings, created by the operation.

The choice of prediction methods will depend on the environment, status of the operation, types of exposed rock and the availability of materials such as drill core. A proponent should focus on the questions critical to their particular waste handling and remediation options. For example, the critical design feature for flooded tailings will be the effectiveness of the water barrier rather than the composition of the ore.

Proponents are warned that prediction errors generally result from erroneous assumptions used in the interpretation of ARD test work. All assumptions should be verified for the specific site conditions.

Typical questions asked in prediction include:

- What criteria should be used to distinguish acid drainage generating and non-acid drainage generating material?
- What disposal and remediation methods are needed, and what are the quantity or area requirements?
- What monitoring is required to inform the waste handling operation?

- How long will it take for acid drainage to develop in materials for which there is a delay prior to the application of remedial measures?

The prediction of acid rock drainage will typically require an iterative process of sampling, analysis, and classification, similar to that used to determine other geological characteristics such as ore reserves. Based on the results of the first round of sampling and analysis, it may be necessary to further subdivide some of the original rock types or to do additional analysis. Conversely, it may be possible to reduce the number when compiling different materials into management units.

Sampling and Statistical Requirements

Perhaps the most important phase of the prediction program is sampling. The objective in sampling should be to characterize the type of materials that will be exposed and to indicate which ones are likely to cause water quality problems. As much of the variability will result from differences in geology, sufficient samples should be taken to accurately characterize the variability and central tendency for critical parameters in each significant rock type, based on accepted statistical procedures.

The number of samples taken from a particular material will depend on its variability and the questions being asked. Where no additional guidance is available, the suggested *minimum* number of samples collected from *each* rock and/or overburden type during *initial* sampling is as follows:

Mass of Each Separate Rock Type (tonnes)	**Minimum Number of Samples**
< 10,000	3
< 100,000	8
< 1,000,000	26
10,000,000	80

Owing to the significant cost and specific requirements of each mining project, a proponent is advised to discuss the sampling program with regulatory agencies prior to its implementation.

Sample size should be based on the geology, the variability of the materials and the proposed modes of extraction, exposure and deposition. Compositing of samples should be avoided unless either the geological information indicates it is advisable (e.g., homogeneously disseminated sulphides and carbonate) or the materials will be composited during mining (e.g., over bench heights).

Requirements of the Prediction Program

The prediction program should incorporate the following procedure:

Step 1. Separate and Describe Different Materials Based on particle size, petrology, mineralogy and chemical composition, separate significantly different overburden and rock types and describe their distribution, lithologie unit, and identifying properties.

For each distinct rock or overburden type, determine the quantity, spatial distribution, and eventual form of exposure (e.g., pit wall, tailings, or waste rock).

Step 2. Initial Screening Conduct initial screening of materials based on the sulphide content, available metal content, and pH value. Materials with a paste pH less than 3.5 will be considered a potential source of acid drainage. All materials with either more than 0.3% sulphide-S or a pH less than 5.0 should be tested further.

The form and amount of readily soluble constituents should be measured in materials that are already oxidized to identify situations where there is a potential for the dissolution of residual weathering products. The method for determining availability should be selected according to site-specific criteria.

For projects where the geology indicates there will be sulphides present, a proponent is advised to combine steps 2 and 3.

Step 3. Acid Base Accounting and Other Static Tests The next phase of the ARD test work should include static tests to measure the maximum acid generation potential (AP) and maximum neutralizing potential (NP) of each rock and overburden type, and traditional acid base accounting procedures to calculate the net neutralization potential (NNP) and neutralization potential ratio (NPR).

The criteria used to evaluate materials based on acid base accounting tests are:

> Materials with sulphide minerals whose net neutralizing potential (NNP = NP-AP) is negative are likely to be a potential acid drainage source. Exceptions are possible if the sulphide content is very low and/or there are significant slow release, non-carbonate sources of alkalinity.
>
> The acid drainage potential will be considered uncertain if materials have a ratio of neutralization potential to potential acidity (NP:AP) of less than 4:1.

The ratio of 4:1 represents the worst case to date and was selected to ensure the detection of sites where there is an unfavorable balance between long-term acid generation and neutralization reactions or where the composition of a waste rock's fine-sized fraction varies significantly from that of the whole rock. It is recognized that a 4:1 ratio is conservative and will be higher than the actual composition of acid drainage generating materials at most sites.

Where the acid rock drainage potential of a waste material or geological unit is uncertain, it will be considered acid drainage generating unless the proponent can show through further testing (step 4) that the acid and neutralization reaction rates are favorably balanced.

It is cautioned that acid base accounting provides only a rough assessment of the potential for acid drainage. More refined site and material-specific interpretation or testing should be used if less conservative, more accurate information is required.

Step 4. Prediction of Reaction Rates and Water Quality To more accurately predict the ARD potential and to address the prediction questions listed previously, the proponent will be required to develop site and material-specific criteria based on the relative rates of acid generation and neutralization reactions, and the size of the reactive fraction. The data used may be obtained from a variety of sources, including a more detailed characterization of the material, comparisons with similar materials at other sites, weathering and leachate quality observed in soils and outcrops, the quality of seepage from existing waste materials, kinetic laboratory tests, and field trials.

Often there is no one piece of evidence or conclusive test, and the proponent must combine information from a variety of sources. For example, experience at other sites might be presented in combination with detailed geological data showing that the rock or waste types are very similar.

Kinetic tests are often used to estimate relative acidity-neutralization reaction rates and to predict

metal release and loading. The value of kinetic tests as a predictive tool will be greatly enhanced where it is shown that these tests simulate either the real field release rates or the actual balance of important processes, such as oxidation, dissolution, and entrainment.

Valuable field evidence may be obtained from trends in the relative elemental ratios of seepage water, and from the relative weathering rates and fine particle replenishment observed in old wastes or similar natural soils.

Depending on the materials and site, it may be necessary to determine the neutralizing potential of non-titratable, slow release minerals, or the size and rate of additions from biotic and climatic sources.

Although universal ABA rules may not apply, ABA characteristics can often be the best criteria to use for distinguishing materials.

Although it is often overlooked in the rush to do ARD-specific tests, detailed geological characterization is necessary if one is to predict how materials will perform. Where there is a potential for the generation of acid drainage or metal release through weathering or dissolution, the proponent should determine the range, variability, and central tendencies for the following properties:

- Mineralogy and associated elemental composition
- Readily soluble constituents
- Sulphide types (amount, reactivity, and spatial distribution)
- Carbonate types (amount, reactivity, and spatial distribution)
- Mineralogical and rock fabric characteristics that will influence weathering.

The properties listed above may be modified to match the specific conditions of each site, material and disposal option.

In addition, and in many cases in preference, to doing whole rock analysis, the proponent should estimate the composition of the fine-sized fraction and the surfaces of coarse particles. For proposed operations which do not yet have wastes to analyze, comminution effects may be predicted from the geological characteristics of the rock and weathering simulation methods, such as grinding and slaking.

PREVENTION OF ACID ROCK DRAINAGE

All mines with a potential for acid drainage must provide operational reclamation and abandonment plans showing how they will reduce the generation of acid drainage to levels not considered deleterious to the environment, both in the short and long term. In cases where the success of prevention measures cannot be assured, an assessment of the potential for failure and of the possible impacts will be required. Detailed contingency plans to reduce the risk to the environment will also be needed. This will usually consist of a collection and treatment system.

Until it is determined that there is no potential for acid drainage or other water quality problems, material with one or more of the following properties shall not be used for roads, dams or other construction purposes:

- A total sulphide-S level greater than 0.3%
- A paste pH less than 5
- A potential for significant metal loss from residual weathering products.

Underwater Disposal

Secure underwater disposal of tailings or waste rock in manmade structures is currently an acceptable form of acid rock drainage prevention. Underwater disposal in natural water bodies will only be considered where there is shown to be no significant impact on water quality, fisheries, recreation, or downstream flow, and where the water bodies are shown to be the most environmentally suitable disposal site.

Further research is required to assess the impact of the underwater disposal of tailings or waste rock in biologically or water-quality-sensitive lakes before this disposal alternative will be considered.

In cases where underwater disposal of tailings or waste rock is proposed, the proponent must show that:

- The mine wastes do not contain significant readily soluble deleterious substances.
- The water balance ensures that all potentially acid-generating wastes will be continuously covered by water.

- There will be no significant impact as a result of wave action, ice, avalanches, flooding, earthquakes, thermal overturn, and other relevant natural factors.
- The mode of deposition, the water depth and other design features satisfy the requirement for long-term prevention of acid drainage.

Manmade impoundments shall be designed and maintained for long-term geotechnical stability, taking into account the possible effects of biological activity.

A water cover is currently an acceptable form of acid rock drainage prevention for underground workings or open pits.

The timing and inflow rate requirements in flooding open pits and underground workings will be based on the hydrologie conditions, the relative reaction rates of acid generation versus neutralization, and the potential release of acid products. Proponents must demonstrate that any water released to the environment will be of acceptable quality. Hydraulic bulkheads or material barriers in underground workings shall be designed to allow ongoing verification of the water level and of geotechnical stability.

Blending

Blending of acid generating and acid consuming materials may be an acceptable acid rock drainage prevention strategy. The proponent will be required to show that there is sufficient information about the materials and sufficient neutralizing capability to ensure that blending can be carried out safely. Given the potential for incomplete mixing, more conservative NNP and NPR criteria will likely be required than those set for single homogeneous materials (see earlier discussion of acid rock drainage prediction).

The proponent will also be required to demonstrate that the blending plan is compatible with the mine plan, that it is possible to achieve the required control in materials handling and that there is sufficient disposal capacity. This should include any interim prevention measures required for the protection of exposed material stockpiled prior to final disposal.

At permitting, the proponent will be required to itemize the sample size, sampling frequency, the list of analyses, proposed QA/QC and processes for communicating monitoring results to the blending operation.

COLLECTION AND TREATMENT OF ACID ROCK DRAINAGE

Although prevention will be the primary method of acid rock drainage control for new mines, collection and treatment may be accepted as a mitigation method if the proponent can demonstrate that -

- All preventative methods have been examined and are not economically feasible with current technology
- The risk (likelihood of occurrence and consequences) to the environment caused by a failure to the system is acceptable
- The quantity of acid rock drainage is readily manageable
- Treatment sludge can be disposed of safely.

In addition, the proponent must provide adequate security to finance long-term collection and treatment.

Where collection and treatment is proposed as the principal means of protection, the proponent must show that the system can be maintained in perpetuity. The supportive evidence should include detailed engineering and economic analysis, including consideration of relevant biological factors, and a comprehensive risk analysis to show that environmental values will not be jeopardized. Any proposed collection and treatment technology must be proven to be effective, with adequate resources set aside to support its operation.

While treatment technology is generally effective, long-term collection and treatment is among the most expensive remediation options. Because of the long time frame and uncertainties about future costs, government's bonding requirements are likely to make collection and treatment an unattractive option for new mines. Since final site reclamation is not possible and there are ongoing sludge disposal problems, proponents must recognize that the use of collection and treatment as a primary means of control will only be approved in exceptional circumstances. Approval of such programs will be at the discretion of review agencies.

During the mine operation all collection ditches, dikes, impoundments, and pumping systems must be designed to handle a one-in-200-year flood during the mine operation. For abandonment, the

minimum design criteria for structures whose failure would jeopardize the effectiveness of the acid rock drainage prevention plan should be based on the consequence of failure. Where the consequences of failure are high, the minimum design criteria should be the probable maximum flood (PMF) and the maximum credible earthquake (MCE).

RECLAMATION PERMITTING

Following a detailed review under the Mine Development Assessment Process, mines are regulated under mine plan approvals, reclamation permits, and waste and water management approvals, permits, and licences. All of these approvals, permits, and licences are issued subject to monitoring and confirmation of predictions, and with conditions to prevent the generation and dispersal of acid rock drainage.

Bonding

As a condition of a reclamation permit, a security will be required to ensure that sufficient funding is available to cover all outstanding reclamation obligations, including long-term costs associated with the necessary monitoring, maintenance, collection, and treatment of acid rock drainage following mine closure.

Bonding requirements will be addressed at each stage of the Mine Development Assessment Process. The Regional Mine Development Review Committee, following a detailed technical review, will recommend an appropriate level of security to be required as a condition of the reclamation permit. The level of security will increase as reclamation obligations increase during mine operation. The security will be set at a level that will, in a self-perpetuating manner, pay for -

- the long-term inspection, monitoring, and maintenance, and if necessary the operation of collection, containment, and treatment plant facilities
- the long-term inspection, monitoring, and maintenance of preventive and control structures.

The security will take into account the high degree of uncertainty in predicting these costs. Securities attached to existing mines will be increased should acid rock drainage be discovered.

Should remediation efforts reduce the extent of acid generation or the risk of future acid generation, security levels will be reduced.

MONITORING

Monitoring programs designed for environmental protection and for the early detection of acid rock drainage will be required as a condition of permits issued by the Ministries of Energy, Mines and Petroleum Resources and Environment, Lands and Parks. Intermittently, QA/QC programs should be carried out to verify the accuracy and precision of the data.

During mine operation, companies will be required to maintain a detailed inventory for all waste or exposed materials. This information should be continually updated and readily accessible in a complete package, including analysis results for drill core, waste materials, exposed surfaces, and water draining from various wastes and off site. The ARD information should include the rock or overburden type, acid/base accounting data, mineralogical and elemental composition, storage location, and date of emplacement. Paste pH and readily soluble constituents should be measured where some weathering has already occurred.

Following mine closure, the permittee will be required to undertake all long-term requirements including monitoring, inspecting, reporting on, and maintaining the mine site and ancillary ARD facilities. Monitoring programs will be designed to ensure that operational procedures are being carried out and to determine if prevention techniques have been successful.

ANNUAL REPORTS

Annual reports summarizing the materials, methods, and results of the acid rock drainage monitoring program will be required as a condition of all reclamation permits. The annual reports should also summarize the previous year's mining and waste disposal, the materials mined and any anticipated changes to the mine plan. Cumulative detailed ARD monitoring records should be appended.

REFERENCES:

Errington, J.C. 1991. The Regulation of Acid Mine Drainage. Second International Conference of the Abatement of Acidic Drainage. Tome 2. pp. 89-99.