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Environmental Code of Practice for Metal Mines

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Mining Section
Mining and Processing Division
Public and Resources Sectors Directorate
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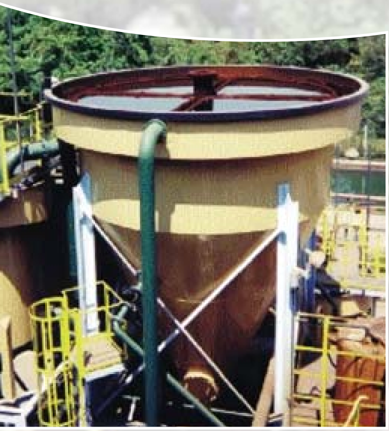
Environment Canada



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ABSTRACT

The Environmental Code of Practice for Metal Mines describes operational activities and associated environmental concerns of this industrial sector. The document applies to the complete life cycle of mining, from exploration to mine closure, and environmental management practices are recommended to mitigate the identified environmental concerns. The recommended practices in the Code include the development and implementation of environmental management tools, the management of wastewater and mining wastes, and the prevention and control of environmental releases to air, water and land. The Code of Practice will be adopted by Environment Canada and others as a guidance document that recommends environmental protection practices for the mine life cycle. The Code applies specifically to metal mines but will provide useful guidance for all sectors of the mining industry.

RÉSUMÉ

Le Code de pratiques écologiques pour les mines de métaux décrit les activités d'exploitation de ce secteur industriel et les préoccupations environnementales connexes. Il porte sur l'ensemble du cycle de vie minier, de l'exploration à la fermeture, et recommande des pratiques de gestion environnementale pour atténuer les problèmes environnementaux qui ont été répertoriés. Entre autres, le Code recommande l'élaboration et l'utilisation d'outils de gestion environnementale, la gestion des eaux usées et des résidus miniers ainsi que la prévention et le contrôle des rejets nocifs dans l'atmosphère, l'eau et le sol. Le Code sera adopté par Environnement Canada et d'autres organismes comme document d'orientation recommandant l'adoption de pratiques de protection de l'environnement tout au long du cycle de vie des mines. Bien qu'il vise tout particulièrement les mines de métaux, il renferme des conseils utiles pour tous les secteurs de l'industrie minière.

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S.1 CONTEXT

The Environmental Code of Practice for Metal Mines is designed to support the *Metal Mining Effluent Regulations* (MMER) under the Fisheries Act and includes other subjects that are not dealt with in the MMER that may have an influence on the environmental impact of mining operations. The text of the MMER is available online at **http://laws.justice.gc.ca/en/F-14/SOR-2002-222/index.html.**

The starting point for the development of the Code of Practice is the final report (1996) of the multi-stakeholder Assessment of the Aquatic Effects of Mining in Canada (AQUAMIN). AQUAMIN was initiated in 1993 to evaluate the effectiveness of the *Metal Mining Liquid Effluent Regulations* (MMLER). This process included consideration of the Environmental Code of Practice for Mines that was published in conjunction with the MMLER in 1977.

It is important to note that while this Code is intended to apply specifically to metal mines, the recommendations in the document may be helpful to all sectors of the mining industry.

S.2 CODE OBJECTIVE, SCOPE AND IMPLEMENTATION

The objective of the Code is to identify and promote recommended best practices in order to facilitate and encourage continual improvement in the environmental performance of mining facilities throughout the mine life cycle, in Canada and elsewhere. The document is intended to be a resource for mine owners and operators and regulatory agencies, as well as the general public, particularly those who live in communities potentially affected by mining activities.

The Code addresses all phases of the mining life cycle from exploration and feasibility studies through planning and construction, operation, and closure, and it covers a broad spectrum of environmental aspects ranging from air, water and waste management to biodiversity conservation.

The Code was developed by Environment Canada in consultation with a broad range of stakeholders.

The Code of Practice will be adopted by Environment Canada and others as a guidance document that recommends environmental protection practices for metal mines.

Recommendations in the Code do not carry regulatory status, and a commitment by companies to implement the recommendations in the Code does not remove obligations for such companies to comply with all applicable municipal, Aboriginal, provincial, territorial, and federal legal requirements.

S.3 MINING LIFE CYCLE ACTIVITIES AND ENVIRONMENTAL CONCERNS

The mine life cycle typically includes the following phases: exploration and feasibility, planning and construction, operations, and closure. Activities associated with the mine life cycle may include:

- line cutting, drilling, trenching and bulk sampling;
- development of mine workings and construction of associated infrastructure;
- extraction of ore;
- management of mine and site drainage;
- ore processing;
- disposal of waste rock, tailings and other wastes; and
- site reclamation activities.

Potential environmental concerns associated with mining include:

- wastewater from site runoff, mining and ore processing, and mine wastes;
- releases of airborne particulate matter and air emissions from engine operations and other processes;
- effects on terrestrial ecosystems, including wildlife;
- effects on aquatic ecosystems, including fish;
- effects on local and regional surface water and groundwater flow;

- noise;
- planned and accidental releases of pollutants;
- aesthetic impacts, such as alteration of landscapes; and
- social impacts, such as impacts on sport or subsistence fisheries.

S.4 RECOMMENDED ENVIRONMENTAL PROTECTION PRACTICES

To reduce or eliminate the potential negative environmental impacts associated with mining activities, the environmental practices summarized in Tables S.1–S.5 are recommended.

TABLE S.1: RECOMMENDATIONS FOR ENVIRONMENTAL MANAGEMENT TOOLS

Number	Subject	Summary of Recommendations: Environmental Management Tools
R 101	Environmental Policy Statement	Each company owning or operating a metal mine or engaged in exploration activities should develop and implement a corporate environmental policy statement that includes commitments to: • continually improve environmental protection measures and practices; • focus on pollution prevention, where feasible, rather than treatment; • comply with relevant environmental legislation and regulations and other requirements, such as industry association policies and best management practices to which the metal mine subscribes; • maintain the environmental policy, communicate it to all employees, and communicate relevant components of the policy to on-site contractors; and • make the environmental policy available to the public.
R 102	Environmental Assessment	Mine proponents or current owners/operators should consult with federal and provincial/territorial regulatory and environmental assessment agencies early in the planning process to determine whether a proposed project will require an environmental assessment. Environmental assessment principles should be followed by companies proposing new or significantly modified or expanded facilities. Proponents may consult the Canadian Environmental Assessment Act Reference Guide: Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects or relevant provincial/territorial documents.
R 103	Environmental Assessment – Baseline Studies	Water quality, aquatic ecosystems, air quality, soil quality, terrestrial ecosystems, groundwater and other environmental data collected as part of pre-operational baseline studies associated with environmental impact assessments should be collected so that it is comparable with monitoring data collected later in the mine life cycle. Data should be collected and analyzed so that it will be possible to identify long-term trends, periodic change and fluctuations in rates of change.
R 104	Environmental Risk Management	Site-specific environmental risk management procedures should be developed and implemented in a manner consistent with guidance provided in: • CAN/CSA-Q634-M91 - Risk Analysis Requirements and Guidelines; and • CAN/CSA-Z763-96 - Introduction to Environmental Risk Assessment Studies.
R 105	Environmental Management Systems	Site-specific environmental management systems (EMS) should be developed, implemented, maintained and updated in a manner that is consistent with a nationally recognized standard or system such as ISO 14001, developed by the International Organization for Standardization (ISO). Environmental management systems should be used to manage all environmental aspects of the activities and operations over which an operation has control or which it can reasonably influence. Elements of an EMS should include: • a clear definition of objectives and targets to meet the company's environmental policy; • accountability for environmental action across the company; • stated procedures to translate the environmental policy into day-to-day practices; • monitoring, checking and auditing of the system; and • implementation of actions to provide continual improvement.
R 106	Pollution Prevention Plans	Site-specific pollution prevention plans should be developed, implemented and updated in a manner consistent with the guidance provided in the Environment Canada (2001) Guidelines for the Implementation of the Pollution Prevention Planning Provisions of Part 4 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999).

Number	Subject	Summary of Recommendations: Environmental Management Tools
R 107	Environmental Management Plans	Site-specific environmental management plans should be developed, implemented and updated throughout the mine life cycle. The plans should include, as a minimum, descriptions of the following: • information about the owner/operator of the mine and information about the mine itself, including a description of the mining and ore processing methods used and the geographic setting of the site; • the company's environmental policy statement; • environmental performance requirements; • air quality management programs; • water quality management programs; • management programs for tailings and waste rock; • land management programs; • pollution prevention planning; • management of garbage and other waste materials; • environmental objectives and targets along with schedules for achieving objectives and targets; • environmental management programs and auditing; • relationships with stakeholders, including local communities; • procedures for communicating with regulatory agencies and stakeholders; and • periodic review of the environmental management plan for effectiveness and continual improvement.
R 108	Environmental Performance Indicators	Environmental performance indicators should be developed to facilitate tracking of the mining facility's overall environmental performance through readily understood measures of the facility's environmental performance and effects.
R 109	Monitoring and Inspection of Environmental Management Facilities	Site-specific plans for the monitoring and inspection of on-site environmental facilities and infrastructure should be developed, implemented and updated. Plans should include: • documentation of procedures for the monitoring and inspection of each on-site environmental facility, including air emission control equipment; water management and wastewater treatment facilities; transportation, handling, storage, and containment facilities for chemicals; waste handling and disposal facilities; and air quality and water quality monitoring and control instrumentation; • a documented schedule for monitoring and inspections, including timing of monitoring and inspections and methods to be used; • identification of those responsible for monitoring and inspections and for following up on the results of inspections; • documentation of procedures for reporting the results of monitoring and inspection to both internal management and regulatory agencies; • documentation of procedures for following up on monitoring and inspection reports; • procedures for periodically reviewing and updating the monitoring and inspection plans; and • procedures for quality assurance and quality control (QA/QC).
R 110	Environmental Monitoring	Environmental monitoring should include: • monitoring of environmental releases, such as releases to air, water and land; and • monitoring of environmental performance indicators, including air and water quality and aquatic and terrestrial species and ecosystems. Site-specific environmental monitoring plans should be developed, implemented and updated throughout the mine life cycle that describe: • all environmental monitoring and reporting required under regulations and permits; • all environmental monitoring and reporting to be conducted which is beyond that required under regulations and permits; • applicable environmental standards and environmental quality objectives, such as water or air quality standards or objectives; • schedules for monitoring; • sampling procedures, sample preservation requirements, and analytical methods employed; • procedures for the comparison of monitoring results with applicable environmental standards and environmental quality objectives; • actions to be undertaken when requirements set out in regulations or permits have not been met; • procedures for reporting the results of monitoring to company management, regulatory agencies and the public; • procedures for following up on monitoring reports; • procedures for periodically reviewing and updating the environmental monitoring plans; and • procedures for quality assurance and quality control (QA/QC).

Number	Subject	Summary of Recommendations: Environmental Management Tools
R 111	Environmental Monitoring	Environmental monitoring should include specific plans to measure and verify all effects and endpoints that were predicted in the environmental assessment.
R 112	Cumulative Effects Monitoring	Environmental monitoring plans should include measures to assess possible cumulative effects. The assessment of cumulative effects associated with mine development and operation should begin as early as possible in the mine life cycle, with consideration given to: • applicable legislation related to the assessment of cumulative effects; • potential activities in the vicinity of the mining facility, including infrastructure, that may contribute to cumulative effects; and • existing monitoring activities, including any existing activities related to the assessment of cumulative effects.
R 113	Cumulative Effects Monitoring	When environmental monitoring activities identify an effect or a change not predicted or not deemed acceptable in the environmental assessment, additional monitoring measures should be implemented to investigate the cause of the effect.
R 114	Traditional Ecological Knowledge	Environmental assessment and monitoring should include, to the extent possible, a consideration of traditional ecological knowledge, and this knowledge should also be considered in relevant aspects of environmental planning and management. In gathering and incorporating traditional ecological knowledge into environmental management, mine owners/operators should: • respect the ownership, source and origins of the knowledge and the needs and sensitivities of its holders, and obtain their approval to use or disseminate that knowledge; • establish trusting relationships with those who hold traditional ecological knowledge; • work on projects of common interest and benefit; • foster good communication between partners; and • provide value-added knowledge back to the community in the form of useful products (such as reports) and services.
R 115	Emergency Planning	Site-specific environmental emergency plans should be developed and implemented, then tested and updated on a regular basis. These plans must respect legislated requirements, such as those under the *Environmental Emergency Regulations* and the *Metal Mining Effluent Regulations*. In this regard, the plan should be consistent with the Implementation Guidelines for Part 8 of the *Canadian Environmental Protection Act, 1999*- Environmental Emergency Plans from Environment Canada. However, the scope of environmental emergency plans should be broad and comprehensive in nature, and should go beyond the legislated requirements, particularly with respect to hazard identification, risk analysis and consequence as well as community involvement and communications. As such, the elements of emergency planning should also be consistent with recognized guidance documents such as APELL for Mining: Guidance for the Mining Industry in Raising Awareness and Preparedness for Emergencies at Local Level (United Nations Environment Programme, 2001).
R 116	Environmental Training and Awareness	Site-specific procedures should be developed and implemented to identify environmental training needs and ensure that all personnel receive environmental training. As such, the procedures should encompass: 1. general awareness training for employees and service providers, including contractors, where the training includes but is not limited to: • the organization's environmental program, including the environmental policy and relevant environmental practices; • regulatory obligations; and • environmental emergencies procedures, including spill prevention, reporting, response and evacuation procedures; 2. an environmental training program that includes: • a list of all personnel that require environmental training and a categorization of groups of personnel with regards to the nature of the specific environmental training required; and • an outline of the environmental training required for each group of personnel, the training methods to be used, and the required frequency of refresher training; and 3. the identification of requisite competencies of contractors and environmental auditors.
R 117	Closure Planning – Designing for Closure	The development of closure plans should begin during the planning phase for proposed mines and as early as possible in the mine life cycle for existing mines. Closure plans should be considered and incorporated into all aspects of mine planning, construction and operation so that key aspects of the closure are planned for throughout the mine life cycle. Plans should identify measures to be undertaken during the operations phase that are aimed at progressive reclamation of disturbed or developed areas of the mine site.

Number	Subject	Summary of Recommendations: Environmental Management Tools
R 118	Closure Planning – Designing for Closure	Mine closure should be carried out in a way that prevents or minimizes impacts and risks to the environment and human health after closure. Closure plans should identify site-specific objectives for mine closure and the intended post-closure land use for the site. Closure plans should detail the processes that will be used to decommission and reclaim all aspects of the mining facility, including: • mining and ore processing facilities; • site infrastructure; and • water and waste management facilities, including waste rock piles and tailings management facilities.
R 119	Review of Closure Plans	Closure plans should be reviewed and revised as necessary throughout the mine life cycle. The plans may become more detailed, incorporating to a greater degree all activities related to the mine and taking into greater consideration site conditions and monitoring results. Closure plans may also be revised in response to: • the results of progressive reclamation activities; • the results of tests to assess specific aspects of the closure plan; • public response to a proposed closure plan; • changes in mine operations, such as production rate or ore type; • changes in technology, such as improvement in technology for preventing or controlling acidic drainage; • changes in economic conditions, such as input costs and other economics related to mine closure; and • unexpected or adverse conditions encountered during the construction and operations phases of the mine life cycle.
R 120	Environmental Auditing	Periodic environmental audits should be conducted to determine (a) whether the site is operating in compliance with applicable regulatory requirements and appropriate non-regulatory and corporate requirements and (b) whether the EMS and other environmental plans have been properly implemented and maintained. The recommendations in the Code of Practice should be included in the audit criteria, and each audit should take into consideration the results of previous environmental audits. Environmental auditors should be qualified by virtue of their relevant experience and training, and audit team members should be objectively selected. ISO 19011, Guidelines for Quality and Environmental Management Systems Auditing, should be considered in the development and implementation of the audit program.
R 121	Public Involvement	Site-specific public involvement plans should be developed, implemented and updated throughout the mine life cycle. These plans should describe mechanisms by which public input will be sought and addressed. These plans should also: • include a list of key community contacts; • describe proposed mechanisms for informing the public that information is available and for distributing and receiving information; • describe measures to be used to provide information in a form that is understandable to the public; and • include plans for public reporting of monitoring activities.
R 122	Product Stewardship	Product stewardship programs should be developed and implemented, with the objective of minimizing the environmental impacts associated with the products used and produced by the mine. The programs should include consideration of: • types of materials used; • sources of supply of materials; • sources and types of energy used; • type and amount of packaging; • management of manufacturing by-products and wastes; • recycling or reuse of containers or the return of containers to the manufacturer; • possible exchanges of waste materials with other local industries, such as the use of pulp mill waste as tailings cover material; and • local purchase of supplies to support community businesses and residents.

Number	Subject	Summary of Recommendations: Environmental Management Tools
R 123	Adaptive Management	Mine owners/operators should use adaptive management methods to revise and refine the environmental management strategy. Adaptive management should consider a wide range of factors, including: • the results of environmental audits or other evaluation activities; • the results of environmental monitoring; • the results of monitoring of the performance or condition of environmental infrastructure, such as containment structures, water management systems or treatment facilities; • technological developments; and • changing environmental conditions.

TABLE S.2: ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE EXPLORATION AND FEASIBILITY PHASE

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Exploration and Feasibility Phase
R 201	Exploration and Feasibility	Environmental management plans should cover the full range of activities related to exploration, including land acquisition, surveys, access, camp and associated facilities, stripping, trenching, drilling and sampling. Environmental management practices should address water management and water quality, waste management, land disturbance, air quality, reclamation and closure. The recommended practices identified in Table 4.1 should be followed during the exploration and feasibility phase. In addition, practices recommended for the planning, construction and mine operations phases apply during exploration and feasibility, albeit on a smaller scale.
R 202	Exploration and Feasibility	The guidelines of the Environmental Excellence in Exploration (e3) program developed by the Prospectors and Developers Association of Canada should be considered in the design and implementation of environmental management plans during the exploration and feasibility phase.
R 203	Inclusion of Environmental Costs in Feasibility Studies	The anticipated costs of environmental management during mine operations, as well as the costs of mine closure and long-term post-closure liabilities, should be considered in the economic feasibility study for the mine and should be appropriately accounted for in the financial planning of the mine owner and operator.
R 204	Reclamation and Closure of Exploration Project	When exploration activities have ceased and further development of the site is not planned by the proponents: • water intakes, culverts, docks and other waterway structures, as well as all machinery, equipment and building structures, should be removed; • waste dumps, sewage/washwater pits and drill holes should be properly capped; and • all areas that have been disturbed should be revegetated or rehabilitated to allow for natural revegetation.

❑ TABLE S.3: ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE PLANNING AND CONSTRUCTION PHASE

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Planning and Construction Phase
R 301	Water Management Planning	Site-specific surface water management plans should be developed and implemented. The plans should include: • the identification of the mine property subwatersheds, including those for mine waste areas, drainage flow paths, and receiving water bodies; • estimates of flow rates for each subwatershed under normal climatic conditions and extreme precipitation (i.e., design storm or low flow) events; • analysis of the local groundwater regime, including flow direction and rates, recharge and discharge areas, and relationship with the local surface water regime; • a water balance for the mine property that takes into account all significant water inputs, losses, and water recycling; • descriptions of seasonal variations in surface water flow (e.g., due to melting of snow pack) and impacts on flow of any existing water level control structures; • descriptions of measures to be implemented to manage water; and • the identification and assessment of opportunities for diverting natural runoff away from the mine site to prevent pollution of this water.
R 302	Water Use and Recycling	Ore processing facilities should be designed to: • minimize the volume of fresh water that is used for ore processing by: - using ore processing methods that require less water; and - maximizing the recycling of water to reduce requirements for freshwater intake; and • avoid or minimize the use of reagents that require treatment prior to effluent discharge.
R 303	Diversion of Clean Runoff and Consolidation of Wastewater Streams	In planning the site layout, consideration should be given to: • consolidating to the degree practicable all facilities that are potential sources of wastewater with similar characteristics and treatment requirements; • diverting all clean streams and drainage runoff away from areas of possible contamination by constructing ditches or dikes; and • locating effluent discharge points away from environmentally sensitive areas.
R 304	Designing for Extreme Weather Events	Surface drainage facilities should be designed to handle peak conditions at least equivalent to a once in 100 year flood event. Consideration should be given to projections of increased extreme weather events resulting from global climate change, and facilities should be planned accordingly.
R 305	Prediction of Wastewater Quality	Site-specific programs for the prediction of wastewater quality should be developed and implemented. This work should begin as early as possible in the mine life cycle and continue throughout the planning and construction and mine operations phases. Programs for the prediction of wastewater quality should include: • the identification and description of all geological materials (including rock as well as overburden) to be excavated, exposed or otherwise disturbed by mining; • the prediction of the metal leaching and acidic drainage potential of all geological materials, including the timing and conditions during which metal leaching and acidic drainage are expected to occur; and • the prediction of other potentially harmful components in mine wastewater, including processing reagents, ammonia, algae-promoting substances, thiosalts, chlorides and elevated pH. These steps are further detailed in recommendations R 306, R 307 and R 308.
R 306	Identification and Description of Geologic Materials	Site-specific programs for the identification and description of rock and other geological materials that will be or have been moved or exposed as a result of mining activity should include, for each material: • spatial distribution of the material, as well as the estimated mass of material present; • geological characterization of the material, including its mineral and chemical composition; • physical characterization of the material, including grain size, particle size and structural characteristics including fracturing, faulting and material strength; • hydraulic conductivity of the material; and • the degree of any oxidation of the material that has taken place.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Planning and Construction Phase
R 307	Prediction of Metal Leaching and Acidic Drainage Potential	All rock units and other geological materials that will be or have been moved or exposed as a result of mining activity should be tested for their metal leaching and acid generation potential. The testing program should be designed to meet site-specific needs, using a combination of static and kinetic test methods, as appropriate. The following documents should be consulted in designing, implementing and interpreting the results of the prediction program: • William A. Price (1997). Draft Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia. British Columbia Ministry of Employment and Investment; • MEND Manual, Volume 3 – Prediction (2000); and • Bill Price (2005). List of Potential Information Requirements in Metal Leaching/Acid Rock Drainage Assessment and Mitigation Work. MEND Report 5.10E.
R 308	Prediction of Other Potentially Harmful Components in Mine Wastewater	The presence of other components in mine wastewater that are potentially harmful to the environment should be predicted, in particular: • the potential concentrations of ore processing reagents (e.g., cyanide) and their breakdown products in processing wastewater; • the potential concentration of ammonia in wastewater; • the potential pH of wastewater from ore processing, since processing is often carried out at a high pH; and • the potential for the occurrence of thiosalts in wastewater from ore processing.
R 309	Waste Rock and Tailings Disposal Planning	The results of site-specific programs for the prediction of water quality should be considered in the planning of waste rock and tailings disposal management practices. In particular, where there is a potential for metal leaching or acidic drainage, prevention and control of metal leaching and acidic drainage should be primary considerations in the design of waste rock piles, tailings management facilities, and associated water management facilities.
R 310	Prevention and Control of Metal Leaching and Acidic Drainage from Waste Rock and Tailings	Demonstrated practices should be planned and implemented to prevent or control acid generation and/or metal leaching from waste rock piles and tailings management facilities, where the potential exists. These practices may include: • limiting the production of waste rock with acid generation or metal leaching potential; • preventing or limiting the availability of oxygen to the acid-generating material by: - disposing of potentially acid generating waste rock or tailings under a water cover; or - using composite covers with a saturated layer to limit infiltration of oxygen; • blending or layering potentially acid generating material with neutralizing materials; • segregating potentially acid generating or metal leaching material from other material to facilitate efficient management of this material and to reduce the volume of material that needs to be managed in a way that prevents or controls acid generation and metal leaching; and, • diverting surface water away from storage areas to minimize flushing and volumes of effluent.
R 311	Prevention and Control of Metal Leaching and Acidic Drainage from Waste Rock and Tailings	In cases where freezing of waste rock or tailings in permafrost is to be used as a method to prevent or control acidic drainage, consideration should be given to the potential for a warmer climate to thaw the construction material in the future. An alternative method to prevent or control acidic drainage that does not depend on the use of frozen material should be developed if it is determined that there is a significant risk of future thawing.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Planning and Construction Phase
R 312	Selection of Locations for Waste Rock Piles and Tailings Management Facilities	The following factors should be considered in choosing the location for waste rock piles and tailings management facilities: • local and regional surface water and groundwater flow and potential surface water and groundwater contamination; • water management scheme and preliminary water balance; • permafrost conditions in northern areas; • topography; • sites of existing (open or closed) waste rock piles; • existing and possible future land and resource uses, including use of the receiving watershed and distance from habitation and areas of human activity; • baseline environmental conditions, including natural flora and fauna; • potential impacts on vegetation, wildlife, aquatic life and any downstream communities; • condition of basin and dam foundations; • deposition plane and storage volume/capacity; • preliminary design of containment and water management structures; • potential impact area; • potential releases of airborne particulate matter; • aesthetic considerations; and • mine closure considerations. The rationale for the selection of the site should be clearly documented, including discussion of alternate sites that were considered and rejected.
R 313	Tailings Management Facility Design	The following factors should be considered in the design of tailings management facilities: • physical and chemical characteristics of the tailings material, including metal leaching and acidic drainage potential, as well as the potential for liquefaction; • hydrology and hydrogeology, including local climatic conditions and extreme weather events (projections of increased extreme weather events as a result of global climate change should also be included); • foundation geology and geotechnical considerations, as well as seismic data and earthquake risk; • availability and characteristics of construction materials; • topography of the tailings management facility and adjacent areas; and • permafrost conditions in northern areas.
R 314	Tailings Management Facility Design	In designing tailings management facilities, the retention time for wastewater in the facilities should be maximized to allow for settling of suspended solids and the natural degradation of contaminants such as ammonia and cyanide.
R 315	Design of Containment Structures for Tailings Management Facilities	In designing and constructing containment structures for tailings management facilities, such as dams, stringent engineering standards should be employed.
R 316	Design of Containment Structures for Tailings Management Facilities	The long-term monitoring and inspection of containment structures for tailings management facilities should be considered during the design and construction phase. In particular, appropriate instrumentation should be installed during construction to facilitate monitoring during the mine operations and closure phases. Specific design allowances should be made for and consideration should be given to location-specific conditions, such as the presence of permafrost, slopes, seismic activity and site drainage requirements, particularly during peak flow conditions.
R 317	Long-term Stability of Waste Rock Piles	Waste rock piles should be designed to remain structurally stable throughout the mine life cycle and post closure. Local seismic stability data and the risk of earthquakes should be considered in the design of waste rock piles.
R 318	Long-term Stability of Tailings Management Facilities	Tailings management facility risks should be assessed and managed in each phase of the life cycle to determine potential failure modes and probabilities and the consequences of failure. Measures should be planned to reduce these risks and to put in place contingency plans in the event of failure.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Planning and Construction Phase
R 319	Long-term Stability of Tailings Management Facilities	Tailings management facilities should be designed to remain structurally stable, as per the Dam Safety Guidelines of the Canadian Dam Association. Tailings management facilities should be designed to withstand a probable maximum flood (PMF) event. Further, containment structures should be designed to remain structurally stable in the event of a maximum credible earthquake (MCE).
R 320	Planning and Construction of Wastewater Treatment Systems	Wastewater treatment systems should be planned taking into account: • the water management plan; • the results of prediction of wastewater quality; • the waste rock and tailings disposal plans; • relevant regulatory requirements for effluent quality; and • relevant environmental performance indicators, including any water quality objectives.
R 321	Cyanide Management Panning	For mines that will use cyanide for the processing of gold or base metals ores, cyanide management should be planned in a manner consistent with practices described in the International Cyanide Management Code (International Cyanide Management Institute, 2008). In particular, cyanide management planning should take into consideration: • measures to minimize the amount of cyanide required, thereby reducing reagent use and limiting concentrations in tailings; • design and implementation of measures to manage seepage from cyanide facilities to protect surface water and groundwater; • design and operation of cyanide treatment systems to reduce cyanide concentrations in effluent discharged to the environment; and • design and implementation of spill prevention and containment measures for process tanks and pipelines.
R 322	Cyanide Management Panning	If natural degradation of cyanide is to be used as a treatment method for cyanide, the tailings management facility should be designed to ensure that the retention time of the liquid phase is adequate for natural degradation to occur during high flow conditions, e.g., during spring runoff.
R 323	Management of Chemicals	The design processes for new metal mines and modifications to existing metal mines should include procedures to: • identify potential environmental concerns associated with proposed chemical processes and related environmental effects; and • assess the use of alternative processes and chemicals, when they are available, with a view to mitigating or eliminating environmental effects.
R 324	Management of Chemicals	Site-specific chemical management procedures should be developed and implemented for the safe transportation, storage, handling, use and disposal of chemicals, fuels and lubricants. These procedures should include appropriate emergency preparedness planning.
R 325	Management of Chemicals	Each mine owner/operator should evaluate, on an ongoing basis, opportunities to reduce the quantities of potentially harmful chemicals used in the operation of the mine. This evaluation should include consideration of: • selection of equipment and processes; • potential modifications to existing equipment; • new technologies, processes and procedures; • the substitution of different materials; • equipment maintenance; and • employee training programs. Based on this evaluation, measures to reduce the use of potentially harmful chemicals should be implemented, as appropriate.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Planning and Construction Phase
R 326	Management of Chemicals	The chemical storage and containment facilities used at each mine should be designed and constructed to meet the appropriate standards, regulations and guidelines of pertinent regulatory agencies and the owner/operator's environmental policy, objectives and targets. As a minimum, chemical storage and containment facilities should: • be managed to minimize the potential for spills; • provide containment in the event of spillage and be managed to minimize opportunities for spillage; • comply with Workplace Hazardous Materials Information System (WHMIS) standards; • ensure that incompatible materials are stored in ways to prevent accidental contact and chemical reactions with other materials; and • minimize the probability that a spill could have a significant impact on the environment.
R 327	Domestic Sewage and Wastewater Disposal	Where sewage or domestic wastewater is to be disposed of on site rather than sent to a municipal sewage treatment plant for disposal, an on-site sewage treatment facility should be constructed. The objective of these facilities is to prevent the contamination of surface water and groundwater, including drinking water supplies, and to meet all applicable regulatory standards.
R 328	Domestic Sewage and Wastewater Disposal	Sludge from the treatment of sewage and domestic wastewater should be disposed of in an acceptable manner. Sludge may be disposed of on site or in a landfill, it may be used as cover material for tailings or waste rock, or it may be disposed of off site.
R 329	Management of Kitchen and Food Wastes	Wastes from on-site kitchen and dining facilities should be disposed of in a manner that does not attract wildlife. Measures should be put in place to ensure that all food wastes and food containers are properly disposed of, including those used away from kitchen and dining facilities. Training programs should be put in place to ensure that all employees and on-site contractors are aware of the importance of proper disposal of food wastes and the importance of not feeding wildlife on site.
R 330	Avoidance of Environmentally Sensitive Areas	All mine facilities should be located and designed to avoid environmentally sensitive areas. The determination of environmentally sensitive areas should be undertaken in consultation with appropriate stakeholders, local Aboriginal communities and government officials.
R 331	On-Site Roads and Access Roads	Roads should be routed to avoid water bodies and wildlife habitat, where possible, and should be designed to avoid sharp turns to minimize the risk of spills and accidents. Route placement should consider the final use of roads with respect to either enhancing or limiting continued access to wilderness and developed areas by the public following closure.
R 332	On-Site Roads and Access Roads	Measures should be designed and implemented to prevent and control erosion from roads associated with mining facilities. These measures should include: • providing buffer zones of at least 100 m between roads and water bodies to the extent practicable; and • designing road grades and ditches to limit the potential for erosion, including avoiding road grades exceeding 12% (5% near water bodies).
R 333	On-Site Roads and Access Roads	Stream crossings for roads should be designed and constructed in a manner that protects fish and fish habitat. In particular, design and construction should prevent sedimentation of the streams and not obstruct movement of fish. Where stream crossings have the potential to alter or destroy fish habitat, the Policy for the Management of Fish Habitat (1986), prepared by the Department of Fisheries and Oceans, should be consulted. In designing crossings, the Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta prepared by Alberta Transportation may be consulted.
R 334	Disposal of Snow	Locations for the disposal of snow should be identified. Snow should not be disposed of directly into lakes and streams or onto any ice-covered water body. Groundwater recharge areas, wetlands and areas with sensitive vegetation should be avoided. Measures should be taken to prevent contamination of water bodies by runoff from snow disposal areas, such as by directing runoff to settling ponds prior to discharge. Snow should be piled down from south to north. The south side will melt first and water will flow around or under the pile rather than over potential contaminants left upstream.
R 335	Pipelines	The routes of pipelines should be selected so as to limit risk of harm to aquatic and terrestrial ecosystems in the event of a failure. Pipelines should be designed to reduce the risk of failure, and measures should be in place to limit impacts in the event of a failure. Once operational, pipelines should be inspected on a regular basis to ensure they are in good condition, and monitoring systems should be in place to alert operators in the event of a potential problem.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Planning and Construction Phase
R 336	Conveyor Systems	The routes of conveyor systems should be selected so as to limit risks to the environment or human health from airborne particulate matter associated with the systems. To the extent feasible, conveyor systems should be enclosed to prevent or limit the release of airborne particulate matter. Loading and off-loading facilities for conveyor systems should be enclosed or other measures should be in place to prevent or limit the release of airborne particulate matter from loading and off-loading operations.
R 337	Clearing of Vegetation	Clearing of vegetation in preparation for construction should be carried out in such a way that: • the area cleared is minimized; • buffer zones of natural vegetative cover of at least 100 m are retained wherever possible between cleared areas and adjacent bodies of water; and • the time between clearing of an area and subsequent development is minimized. Note that the first two bullets also apply during the exploration and feasibility phase, particularly in the context of establishing camps and access roads and stripping outcrops. Where feasible, vegetation from cleared areas may be replanted in nearby habitats for future relocation following mine closure.
R 338	Preservation and Stockpiling of Overburden	Site-specific procedures should be developed and implemented to ensure that overburden, particularly organic soils, excavated from the mine site during construction is preserved and stockpiled for future reuse in site reclamation. Facilities for stockpiling should be designed to prevent or limit erosion of the stockpiled material by rainfall or wind. Measures should be put in place to ensure that stockpiled material is not contaminated during mine operations.
R 339	Sedimentation Control	Site-specific plans for site erosion and sediment control should be developed and implemented. Measures that should be considered during the mine planning, construction, operations and closure phases include: • determining site erosion potential and identifying water bodies at risk; • establishing, to the extent possible, buffer zones of at least 100 m around water bodies that are at risk of sedimentation; • recontouring to reduce the susceptibility of soil to erosion; • revegetating and maintaining vegetated buffer zones adjacent to water bodies for erosion control; • diverting site drainage away from cleared, graded, or excavated areas; • using and maintaining sediment barriers or sediment traps to prevent or control sedimentation; • directing surface runoff from erodible areas to a settling pond prior to discharge to the environment; and • monitoring and maintaining the measures once they are in place to ensure they are effective.
R 340	Northern Conditions and Permafrost	The planning and construction of mines in the North should be undertaken in a manner that minimizes impacts to the environment, including surface water and groundwater quality, fish and wildlife, natural habitat and other unique northern features such as permafrost. Activities should be planned with consideration of: • the project's requirements in terms of air landing strips, campsites or accommodation facilities, fuel and supply storage areas, survey lines and monuments, excavations, waste disposal and other infrastructure; • the geography and vegetation of the area, including natural features such as eskers, rivers, streams, lakes and ponds, and pingos; and • consideration of appropriate siting of mine components and monitoring of conditions that account for the presence of permafrost.
R 341	Climate Change and Adaptation – Carbon Reduction	Strategies for reducing carbon releases to the atmosphere should be considered and implemented throughout all phases of the mine life cycle. Carbon reduction opportunities should include the use of heavy equipment and vehicles that are fuel efficient and/or use alternative fuel.
R 342	Climate Change and Adaptation – Sites in the Planning and Construction Phase	In planning all aspects of mine operations, particularly water management and mine waste management and disposal, the potential impacts of climate change should be considered. Regional long-term predictions of climate change should be consulted, and predicted changes with respect to temperature, precipitation and extreme weather events should be taken into account. In areas of permafrost, the potential impacts of climate change should also be considered with respect to other aspects of site infrastructure, such as roads, pipelines, and on-site structures, all of which could be affected by deterioration of the permafrost. Any aspects of site infrastructure that could be affected by climate change should be planned, constructed and operated in a manner that will reduce or eliminate the potential impacts associated with climate change.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Planning and Construction Phase
R 343	Climate Change and Adaptation – Sites in the Mine Operations or Mine Closure Phases	Owners/operators of sites in the mine operations or mine closure phases should consult regional long-term predictions of climate change. A risk assessment should be carried out to identify any aspects of site infrastructure that could be affected by climate change, including predicted changes with respect to temperature, precipitation and extreme weather events. Measures to mitigate these risks should be planned and implemented in a manner that reduces or eliminates the potential impacts associated with climate change.

❑ TABLE S.4: ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE MINE OPERATIONS PHASE

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Mine Operations Phase
R 401	Water Management	Site-specific programs should be developed and implemented to monitor the quality of collected mine water and seepage from waste rock dumps and tailings management facilities. As a minimum, these programs should: • describe the surficial and subsurface geology, including aquifers and aquitards; • identify and characterize local groundwater resources and uses; • indicate the locations of mine water and seepage sampling stations and mine waste areas; • provide water sampling, handling and analyses protocols (where analyses are completed by outside laboratories, metal mines should have copies of the protocols used); and • provide a groundwater database that is updated as sampling is undertaken.
R 402	Water Management	The hydrological models that were used in planning the water management system should be recalibrated. Data collected to complete this calibration should include: • climatic variables, such as precipitation, temperature, solar radiation, relative humidity, and wind speed and direction; • lake levels and snow pack thickness; • stream flow and effluent discharge rates; and • beaver activity and dam construction, where applicable.
R 403	Water Management	Water management activities during the mine operations phase should include: • monitoring to check and report on the performance, status and safety of water management facilities; • inspection of pipelines for flow and hydraulic integrity; • monitoring of water quality and level in retention facilities, such as tailings management facilities, sedimentation ponds and polishing ponds; and • inspection of drainage ditches and dikes for sediment accumulation and bank erosion and damage; and • efforts to determine and implement ways to recycle water and reduce the use of fresh water as much as possible.
R 404	Use of Tailings and Waste Rock as Mine Backfill	Where feasible, the owner/operator of a mine should use tailings and waste rock as mine backfill in order to reduce the quantities of these wastes that are placed in tailings management facilities and waste rock piles.
R 405	Use of Tailings and Waste Rock as Mine Backfill	Tailings and waste rock being considered for use as mine backfill should be assessed to ensure that the material will be suitable for use as backfill, particularly if the material is to be used to provide structural support in underground mines. This should include an assessment of the physical as well as the chemical characteristics of the material to ensure that it has appropriate structural properties for use underground and to ensure that chemical alteration of the material will not compromise its structural properties or pose a risk to the environment.
R 406	Use of Tailings and Waste Rock as Mine Backfill	Where potentially acid generating materials are used as mine backfill, monitoring measures should be implemented to assess impacts of the material on the quality of mine water and to predict potential impacts on the quality of mine water after mine closure. Potential impacts on regional groundwater quality should also be assessed.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Mine Operations Phase
R 407	Management of Tailings Management Facilities	Tailings management facilities should be controlled and monitored using a formalized procedure that is incorporated into the mine's EMS. Key control and monitoring subject areas should include: • inspections of tailings management facilities with regard to performance monitoring, instability indicators, stability monitoring, tailings deposition, water management and control, and quality of effluent; • construction controls, including the use of a construction management program; • procedures for dust control; and • quality assurance and quality control measures for all aspects of operations, monitoring and inspections.
R 408	Management of Tailings Management Facilities	All procedures related to the environmental management of tailings management facilities should be clearly documented, together with the roles and responsibilities of all relevant staff. This documentation should be revised as needed to ensure that it is up to date and accurate, and it should be maintained throughout the mine operations and mine closure phases.
R 409	Monitoring of Waste Rock and Tailings	Site-specific waste rock and tailings monitoring programs should be designed and implemented to: • assess the potential of waste rock and tailings for metal leaching and acidic drainage; • verify predictions made during the mine planning phase; • collect data required for modelling; • assess the level of acid generation when oxidizing reactions are occurring, and assess acidity and reaction products that are potentially available to migrate; • evaluate the effectiveness of measures that have been implemented to prevent and control metal leaching and acidic drainage; and • identify potential surface seeps and groundwater contamination.
R 410	Management of Treatment Sludge	Sludge that is a by-product of the treatment of mine effluent should be managed so that it will remain in a physically and chemically stable state. In this regard, a mine owner/operator should: • characterize treatment sludge to determine whether there are potential leaching concerns; • avoid disposal of treatment sludge with potentially acid generating wastes; • dispose of sludge in a physically secure facility under conditions that will maintain the chemical stability of the sludge; and • treat and monitor wastewater from the sludge management facility as necessary to ensure regulatory requirements are met. In cases where a mine is predicted to produce large volumes of sludge over an extended period of time, the mine owner/operator should consider using a treatment process that produces a denser, lower volume sludge.
R 411	Ammonia Management	Mines using ammonium-based explosives should adopt best management practices for blasting and for the handling of these explosives to avoid spillage and minimize ammonium residue remaining after blasting, thereby lowering the potential for ammonium contamination.
R 412	Ammonia Management	Site-specific ammonia monitoring and management plans should be developed and implemented to assist in ensuring that final effluent is not acutely lethal and does not have an adverse impact on the receiving aquatic environment. As a minimum, the plans should: • identify potential sources of ammonia, including explosives and cyanate hydrolysis; • estimate ammonia loading and identify the need for additional controls if warranted; and • include procedures to assist in mitigating ammonia contributions from blasting agent spillage or other losses.
R 413	Cyanide Management	Building on recommendation R 321, cyanide and cyanide-related materials should be transported, stored, used and disposed of in a manner consistent with the practices described in the International Cyanide Management Code (International Cyanide Management Institute, 2002). In particular, mines using cyanide should: • implement preventative and mitigative measures to protect fish and wildlife from direct and indirect discharges of cyanide process solutions to surface water and groundwater; • implement routine monitoring programs to evaluate the effects of cyanide exposure on wildlife, surface water and groundwater quality; and • plan and implement procedures for effective decommissioning of cyanide facilities to protect surface water and groundwater.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Mine Operations Phase
R 414	Thiosalts Management	At sites where there is a risk of thiosalts occurring in wastewater from ore processing: • measures should be taken to minimize the discharge of thiosalt-bearing wastes to the environment either by recycling the water back to the ore processing facility or by implementing measures to ensure thiosalt degradation on site; • programs should be designed and implemented to monitor concentrations of thiosalts in wastewater as well as to check for pH depression downstream; and • treatment systems or mitigation measures should be put in place to minimize the concentration of thiosalts in effluent before it is discharged to the environment.
R 415	Measures to Control Greenhouse Gas Emissions	Site-specific plans should be developed and implemented to minimize releases of greenhouse gases. Plans should describe: • potential sources of releases of greenhouse gases; • factors that may influence releases of greenhouse gases; • measures to minimize releases of greenhouse gases; • monitoring and reporting programs for releases of greenhouse gases; • mechanisms to incorporate the results of monitoring programs into further improvements to measures to minimize releases; and • mechanisms to periodically update the plans.
R 416	Measures to Control Releases of Airborne Particulate Matter	Site-specific plans should be developed and implemented to minimize releases of airborne particulate matter. These plans should describe: • potential sources of releases of airborne particulate matter, including specific activities and specific components of mine infrastructure; • factors that may influence releases of airborne particulate matter, including climate and wind; • potential risks to the environment and human health from releases of airborne particulate matter; • measures to minimize releases of airborne particulate matter from the sources identified; • monitoring programs for local weather, for consideration in the ongoing management of releases of airborne particulate matter; • monitoring and reporting programs for releases of airborne particulate matter and for environmental impacts of releases; • mechanisms to incorporate the results of monitoring programs into further improvements to measures to minimize releases; and • mechanisms to periodically update the plans.
R 417	Measures to Control Releases of Airborne Particulate Matter	Consistent with the Canada Wide Standard for particulate matter (PM), the concentration of particulate matter less than 2.5 microns in size ($PM_{2.5}$) should not exceed 15 $\mu g/m^3$ (24-hour averaging time) outside the boundary of a mining facility.
R 418	Measures to Control Noise	Site-specific assessments should be conducted to identify sources, or potential sources, of noise, and measures should be implemented to reduce noise levels from these sources. Such measures should include consideration of: • elimination of noise sources; • the purchase of equipment with improved noise characteristics; • proper maintenance of equipment; • enclosure or shielding of sources of noise; • suppression of the noise at source; • locating noise sources to allow natural attenuation to reduce levels to potential recipients; and • the operation of noise sources only during hours agreed to in consultation with local communities. Monitoring should be conducted to assess the effectiveness of these measures and to plan further improvements in noise reduction.
R 419	Ambient Noise from Mining Operations	In residential areas adjacent to mine sites, the equilibrium sound pressure level (L_{eq}) from mining activities should not exceed 55 dBA during the day and 45 dBA at night. Ambient noise can also affect wildlife, so sites in remote locations should also work to meet these objectives for off-site ambient noise levels.
R 420	Control of Noise and Vibration from Blasting	Mines in areas where ground vibration and noise from blasting are not regulated should design their blasts so that the following criteria are not exceeded at or beyond the boundaries of the mine property: • ground vibration of 12.5 mm/sec peak particle velocity measured below grade or less than 1 metre above grade; and • concussion noise of a maximum of 128 dB.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Mine Operations Phase
R 421	Blasting in or Adjacent to Fish-Bearing Water Bodies	Blasting conducted in or adjacent to any fish-bearing water body should be done in accordance with the Guidelines for the Use of Explosives in or near Canadian Fisheries Waters, prepared by the Department of Fisheries and Oceans (1998).
R 422	Engine Operation and Maintenance	Engines in vehicles and stationary equipment should be maintained and operated in a manner that minimizes emissions of criteria air contaminants, particularly: • total particulate matter (TPM); • particulate matter less than or equal to 10 microns (PM_{10}); • particulate matter less than or equal to 2.5 microns ($PM_{2.5}$); • sulphur oxides (SO_x); • nitrogen oxides (NO_x); • volatile organic compounds (VOCs); and • carbon monoxide (CO).
R 423	Engine Operation and Maintenance	Maintenance shops should be operated to ensure that potential contaminants, such as used lubricants, batteries and other wastes, are properly managed. Appropriate disposal mechanisms should also be in place for these materials. Stores should be managed such that potentially hazardous materials are handled in accordance with procedures detailed in the environmental management system for the mine.
R 424	Progressive Reclamation	Progressive reclamation should be undertaken over the mine life cycle to reduce environmental impacts and the amount of work to be done during the mine closure phase. The owner/operator of each metal mine should develop a site-specific progressive reclamation schedule as part of the closure plan. The schedule should be used by mine staff to monitor the status of progressive reclamation activities, and the schedule should be updated on a regular basis. Progressive reclamation activities should be consistent with the site-specific objectives for mine closure and the intended post-closure land use for the site.
R 425	Progressive Reclamation of Waste Rock Piles and Tailings Management Facilities	Progressive reclamation of waste rock piles and tailings management facilities should be carried out during the mine operations phase, to the extent feasible. Progressive reclamation activities should be carried out in a manner consistent with the site-specific objectives for mine closure and the intended post-closure land use for the site, as identified in the closure plan. The planning and implementation of progressive reclamation measures should include consideration of: • the final contouring of waste rock piles; • the establishment of a final drainage system; • the establishment of wet covers or dry covers, where these cover systems are to be used to prevent or control acidic drainage; and • the revegetation of exposed areas.
R 426	Progressive Reclamation of Mine Site Infrastructure	Progressive reclamation of mine site infrastructure should be carried out during the mine operations phase, to the extent feasible. This may include roads which are no longer used and areas affected during earlier activities, such as drill pads or campsites established during the exploration or construction phases.

❑ TABLE S.5: ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE MINE CLOSURE PHASE

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Mine Closure Phase
R 501	Evaluation of Revision of Existing Environmental Plans	At the end of the mine operations phase and throughout the mine closure phase, plans to manage various environmental aspects of the mine that were established and implemented earlier in the mine life cycle should be evaluated and revised to ensure that they remain appropriate for the changing conditions of mine closure. In particular, consideration should be given to the evaluation and revision of the following: • pollution prevention plans; • environmental management plans; • plans for the monitoring and inspection of environmental facilities; • plans for environmental monitoring; and • emergency plans.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Mine Closure Phase
R 502	Mine Closure Costs	The anticipated costs of mine closure should be re-evaluated regularly throughout the mine life cycle. The mine owner/operator should ensure that adequate funds are available to cover all closure costs, and the amounts of any security deposits should be adjusted accordingly.
R 503	Financing Long-term Monitoring, Maintenance or Treatment	At sites where it is determined that long-term monitoring, maintenance or effluent treatment will be necessary post closure, mechanisms should be identified and implemented that will ensure that adequate and stable long-term funding is available for these activities. In determining funding levels required, consideration should be given to contingency requirements in the event of changes in economic conditions, system failures, or major repair work post closure.
R 504	Suspended Operations and Inactive Mines	Each mine should develop a plan for the care and maintenance of the mine site in the event that mine operations are suspended or the mine otherwise becomes inactive. The plan should include continued monitoring and assessment of the environmental performance of the site, as well as the maintenance of all environmental controls necessary to ensure continued compliance with relevant regulatory requirements.
R 505	Aspects to be Considered in Mine Closure	Mine closure activities should address the following environmental aspects: • underground and open pit mine workings; • ore processing facilities and site infrastructure; • waste rock piles and tailings management facilities; • sludge disposal areas as well as ongoing sludge disposal requirements, post closure; • water management facilities; • landfill and waste disposal facilities; and • exploration areas.
R 506	Decommissioning of Underground and Open Pit Mine Workings	If it is technically and economically feasible to do so, underground or in-pit infrastructure (e.g., crushers, rails, metal structures, water and air pipes) and equipment (e.g., fans and pumps) should be removed from the site. Any equipment to be left underground or in the pit should be inspected and remediated as appropriate to ensure that there is no risk of leakage of any contaminants.
R 507	Decommissioning of Underground and Open Pit Mine Workings	During the decommissioning of underground and open pit mines, any contamination associated with vehicle and equipment operations and maintenance should be identified and remediated, as appropriate.
R 508	Decommissioning of Underground and Open Pit Mine Workings	Underground mine workings should be secured and signs should be posted warning the public of potential dangers associated with the facility. In the event that underground openings are utilized by bats, gates should be installed that allow for continued access by them, while protecting the public.
R 509	Decommissioning of Underground and Open Pit Mine Workings	The risk of subsidence in underground mines should be assessed. Appropriate measures should be taken to prevent subsidence in cases where the risk of subsidence is determined to be significant. The primary measure used to prevent subsidence is the backfilling of underground voids.
R 510	Decommissioning of Underground and Open Pit Mine Workings	Open pits should be backfilled or flooded to the extent practicable to prevent unauthorized access and to protect public safety. In cases where backfilling or flooding is not practically feasible, fencing should be installed to protect the public. In all cases, signs should be posted warning the public of potential dangers associated with the site.
R 511	Decommissioning of Underground and Open Pit Mine Workings	The potential for mine water discharges should be assessed. For underground mines, this should be done using a hydrogeological assessment. For open pit mines, this may be done using water balance calculations and, in some cases, hydrogeological assessment. Where mine water discharge is predicted, the flow rate should be estimated.
R 512	Decommissioning of Underground and Open Pit Mine Workings	Where there is the potential of mine water discharge after mine closure, the quality of the discharge should be predicted. Mine water quality should be assessed once closure has been completed to verify the accuracy of the predictions.
R 513	Decommissioning of Underground and Open Pit Mine Workings	Where there is the potential of mine water discharge of poor quality, measures should be implemented to prevent or control that discharge and to collect the mine water for treatment. Prevention methods may include capping of mine openings to prevent mine water discharge.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Mine Closure Phase
R 514	Decommissioning of Ore Processing Facilities and Site Infrastructure	On-site facilities and equipment that are no longer needed should be removed and disposed of in a safe manner, unless facilities or equipment are to be preserved for post-closure land use. Efforts should be made to sell equipment for reuse elsewhere or to send equipment for recycling, rather than disposing of it in landfill facilities.
R 515	Buildings and Foundations	The walls of on-site buildings should be razed to the ground, except in cases where they are to be preserved for post-closure land use. Foundations should be removed or covered with a sufficiently thick layer of soil to support revegetation.
R 516	Buildings and Foundations	If buildings are to be preserved, either as a heritage resource or for some other post-closure land use, structures and foundations should be inspected to ensure that no contamination is present. If the structures or foundations are contaminated, they should be remediated as necessary to ensure public health and safety for post-closure land use.
R 517	Support Infrastructure	Support infrastructure, such as fuel storage tanks, pipelines, conveyors and underground services, should be removed, except in cases where it is to be preserved for post-closure land use.
R 518	Roads	The main access road to the site (or runway in the case of remote sites) and other on-site roads, as appropriate, should be preserved in a sufficient condition to allow post-closure access for monitoring, inspection and maintenance activities.
R 519	Roads	Roads, runways or railways that will not be preserved for post-closure use should be reclaimed: • bridges, culverts and pipes should be removed, natural stream flow should be restored, and stream banks should be stabilized by revegetating or by using rip-rap; • surfaces, shoulders, escarpments, steep slopes, regular and irregular benches, etc., should be rehabilitated to prevent erosion; and • surfaces and shoulders should be scarified, blended into natural contours, and revegetated.
R 520	Electrical Infrastructure	Electrical infrastructure, including pylons, electrical cables and transformers, should be dismantled and removed, except in cases where this infrastructure is to be preserved for post-closure land use or will be needed for post-closure monitoring, inspection and maintenance. This includes infrastructure on site as well as any off-site infrastructure owned by the mining company.
R 521	Electrical Infrastructure	If polychlorinated biphenyls (PCBs) were used on site, any equipment contaminated with PCBs should be disposed of in accordance with relevant regulatory requirements. Soils and subsoils near electrical stations should be assessed to determine whether there is any contamination due to PCBs. If soils are contaminated with PCBs, this contamination should be mitigated in an appropriate manner.
R 522	Waste Disposal and Contamination	Waste from the decommissioning of ore processing facilities and site infrastructure, such as waste from the demolition of buildings and the removal of equipment, should be removed from the site and stored in an appropriate waste disposal site or disposed of on site in an appropriate manner in accordance with relevant regulatory requirements. If material is disposed of on site, the location and contents of the disposal site should be documented.
R 523	Waste Disposal and Contamination	Sampling and analysis of soils and other materials should be conducted to ensure that none of the material is contaminated, e.g., with asbestos and mercury from buildings. If contaminated materials are identified, they should be handled and disposed of in an appropriate manner in accordance with all applicable regulatory requirements.
R 524	Long-term Physical Stability of Waste Rock Piles and Tailings Management Facilities	At the end of the mine operations phase, detailed inspections and assessments of waste rock piles and tailings management facilities, particularly dams and other containment structures, should be carried out. The objective of these inspections and assessments is to evaluate the actual performance against design projections related to anticipated post-closure conditions. Factors that should be considered include: • the extent of deformation; • the rate and quality of seepage; • the condition of foundations and sidewalls; and • design loads, which may be different after mine closure.
R 525	Long-term Physical Stability of Waste Rock Piles and Tailings Management Facilities	At the end of the mine operations phase, comprehensive risk assessment should be conducted for mine closure to: • evaluate the long-term risks associated with possible failure modes for waste rock piles and tailings management facilities; • identify possible impacts on the environment and human health and safety in the event of a failure; • determine parameters critical to these failure modes and possible impacts; and • develop and implement long-term control strategies to manage the identified risks.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Mine Closure Phase
R 526	Long-term Physical Stability of Waste Rock Piles and Tailings Management Facilities	At sites where long-term risks are identified under recommendation R 525, a long-term monitoring and maintenance plan for waste rock piles and tailings management facilities should be developed and implemented, as appropriate, to ensure post-closure monitoring and maintenance of these facilities. This plan should include the following elements: • identification of roles and responsibilities of persons to be involved in monitoring and maintenance; • identification of aspects to be monitored and the frequency; • identification of routine maintenance activities to be conducted and the frequency; • description of contingency plans to address any problems identified during routine maintenance and monitoring.
R 527	Prevention, Control and Treatment of Metal Leaching and Acidic Drainage	At the end of the mine operations phase, plans for management of waste rock and tailings to prevent, control and treat metal leaching and acidic drainage should be re-evaluated and revised as necessary, to ensure that they are consistent with the objectives and plans for mine closure and post closure. This evaluation should consider: • the results of the re-evaluation of the performance of these facilities; • the performance of progressive reclamation to date; and • possible alternative technologies for closure.
R 528	Prevention, Control and Treatment of Metal Leaching and Acidic Drainage	At sites where there is an identified long-term risk of metal leaching or acidic drainage, the site-specific monitoring programs for waste rock and tailings developed under recommendation R 409 should be revised and updated to ensure that monitoring programs are consistent with objectives and plans of mine closure and post closure. The revised plans should include the following elements: • identification of roles and responsibilities of persons to be involved in monitoring; • identification of parameters to be monitored and the frequency; and • description of contingency plans to address any problems identified during routine monitoring.
R 529	Closure in Permafrost Conditions	At all mines that exist in permafrost conditions, downstream slopes of tailings containment structures should be revegetated.
R 530	Decommissioning of Tailings from Uranium Mining Facilities	At uranium mines, measures should be taken in decommissioning tailings management facilities to prevent or control the release of radon gas. Such measures may include single or multiple soil layers involving waste rock and low-grade tailings or water covers.
R 531	Water Management	At the end of the mine operations phase, water management plans should be evaluated and revised as necessary to ensure that they are consistent with the objectives and plans for mine closure and post closure. This evaluation should consider: • the results of an evaluation of the performance of the existing water management plan; • expected changes in water flow and water balance on site; and • expected changes in wastewater volume and composition. Based on this evaluation, the following should be identified: • water management structures, such as dams and diversion ditches, that will no longer be needed, methods to be used for decommissioning these structures, and the timing of decommissioning; • water management structures that will continue to be needed and any long-term maintenance or replacement requirements associated with these structures; • water management structures that will need to be modified, methods to be used to modify these structures, the timing of modification, and any long-term maintenance requirements associated with these structures; and • long-term monitoring requirements to ensure that the water management system continues to function as designed.

Number	Subject	Summary of Recommendations: Environmental Management Practices for the Mine Closure Phase
R 532	Long-term Treatment of Wastewater	At sites where it is determined that long-term treatment of wastewater will be necessary during post closure, a long-term wastewater treatment plan should be developed and implemented. This plan should include the following elements: • identification of roles and responsibilities of persons to be involved in operation and maintenance of the treatment system; • identification of the type of treatment system to be used; • identification of any by-products from the treatment system, such as treatment sludge, and management plans for the disposal of those by-products; • identification of routine maintenance activities to be conducted on the treatment system and the frequency; • identification of monitoring to assess ongoing performance of the treatment system and the frequency; • identification of reporting requirements for internal management and regulatory agencies; and • description of contingency plans to address any problems associated with the treatment system. Consideration should be given to the implementation of a passive treatment system. In some cases, these systems may have lower maintenance requirements than traditional treatment systems, although all systems do require some degree of ongoing maintenance.
R 533	Mine Site Rehabilitation and Revegetation	Post-closure landscapes should be designed in a manner consistent with the objectives of mine closure and the intended post-closure use of the site.
R 534	Mine Site Rehabilitation and Revegetation	In re-establishing soil cover on the site, consideration should be given to the characteristics of the soil that will be used as well as the soil requirements of the vegetation to be established on the site. Where possible, overburden that was stripped and stockpiled earlier in the mine life cycle should be used in the development of the reclamation surface. If this is not possible, or if there is insufficient stockpiled overburden, soil from a local source should be used to ensure similar soil conditions and avoid the importing of non-native seeds.
R 535	Mine Site Rehabilitation and Revegetation	Species used in revegetation and the resulting plant community should be consistent with the goals of mine closure and the intended post-closure use of the site. Species native to the area around the mine site should be used for this purpose, and invasive species should never be used.
R 536	Monitoring	Monitoring programs should be designed and implemented during mine closure to ensure that closure activities and any associated environmental effects are consistent with those predicted in the closure plan and to ensure that the objectives of mine closure are being met. Monitoring activities should include many of the monitoring activities conducted during the mine operations phase. Monitoring of aquatic and terrestrial ecosystems should continue until all work associated with mine closure is complete. Monitoring should also be conducted post closure to ensure that closure and rehabilitation measures are functioning as designed in accordance with applicable regulatory requirements.

1 INTRODUCTION

1.1 BACKGROUND

The Environmental Code of Practice for Metal Mines (henceforth called the "Code") is designed to support the *Metal Mining Effluent Regulations* (MMER 2002) under the *Fisheries Act* and includes other subjects that are not dealt with in the MMER that may have an influence on the environmental impact of mining operations. The *Metal Mining Effluent Regulations* (MMER) were registered on June 6, 2002, under subsections 34(2), 36(5) and 38(9) of the *Fisheries Act*.

The MMER applies to all Canadian metal mines (except placer mines) that exceed an effluent flow rate of 50 cubic metres per day and deposit effluent into fisheries waters at any time after the regulations were registered. The MMER prescribes limits for arsenic, copper, cyanide, lead, nickel, zinc, total suspended solids (TSS), radium-226, and pH in mine effluent. The MMER also includes a requirement that effluent be non-acutely lethal to rainbow trout.

Mines subject to the MMER are also required to conduct Environmental Effects Monitoring (EEM) programs in accordance with prescribed criteria. The objective of EEM is to evaluate the effects of mining effluent on the receiving aquatic environment, specifically with regard to effects on fish, fish habitat, and the use of fisheries resources.

The starting point for the development of the Code of Practice is the final report (1996) of the multi-stakeholder Assessment of the Aquatic Effects of Mining in Canada (AQUAMIN). AQUAMIN was initiated in 1993 to evaluate the effectiveness of the *Metal Mining Liquid Effluent Regulations* (MMLER). This process included consideration of the Environmental Code of Practice for Mines that was published in conjunction with the MMLER in 1977.

The AQUAMIN Final Report advanced the following recommendations specific to the 1977 code of practice:

- that the code of practice be updated;
- that the updated code continue to have a significant focus on the issues related to water management and water pollution prevention;
- that the updated code also address other issues, including stakeholder involvement; and
- that the code be revised by updating existing material and adding new sections to address other aspects of environmental management and monitoring.

The AQUAMIN report also recommended that the content of the updated code should:

- emphasize the principles of pollution prevention;
- be applicable to all phases of mining activity;
- provide references to address the production, prevention, control, treatment and monitoring of acid mine drainage, site management of fuels, reagents, solvents and refuse, power generation, and site close-out; and
- recommend measures to involve communities and Aboriginal groups.

It is important to note that while this code is intended to apply specifically to metal mines, the recommendations in the document may be helpful to all sectors within the mining industry.

1.2 THE METAL MINING SECTOR IN CANADA

As noted above, the primary focus of this document is metal mines that are extracting minerals that contain metals such as copper, nickel, iron, uranium and gold. In this document, mining also includes the primary processing of the minerals extracted to produce a metal concentrate or other product for sale or further processing.

Metal mines in Canada are commonly classified by primary commodity type, as follows:

- base metals, primarily copper, zinc, lead and nickel;
- precious metals, primarily gold, platinum group metals, and silver;
- uranium;

- iron ore; and
- other metals, including titanium, tantalum, tungsten, niobium and magnesium.

To give an indication of the geographic distribution of metal mining facilities across Canada, the locations of mines are illustrated in Figure 1.1.

The mine life cycle typically includes the following phases: exploration and feasibility, planning and construction, operations, and closure. Activities associated with the mine life cycle may include:

- line cutting, drilling, trenching and bulk sampling;
- development of mine workings and construction of associated infrastructure;
- extraction of ore;
- management of mine and site drainage;
- ore processing;
- disposal of waste rock, tailings and other wastes; and
- site reclamation activities.

Mining facilities are faced with the challenge of managing large volumes of ore, waste rock, and tailings, the disruption of the surface, and the need to address ongoing reclamation of the operational area.

1.3 CODE OBJECTIVES AND SCOPE

The overall objective of the Code is to identify and promote recommended best practices in order to facilitate and encourage continual improvement in the environmental performance of mining facilities throughout the mine life cycle, in Canada and elsewhere. It addresses all phases of the mining life cycle from exploration and feasibility studies through planning and construction, operation, and closure, and it covers a broad spectrum of environmental aspects ranging from air, water and waste management to biodiversity.

The Code is intended to be a resource for mine owners and operators and regulatory agencies, as well as the general public, particularly those people in communities potentially affected by mining activities.

The Code first describes the major operational activities that occur through the mine life cycle and the environmental concerns associated with these activities. It then presents recommended best practices to minimize the environmental impacts associated with mining operations. Recommendations are accompanied by background text that provides explanation of the rationale for the recommendations and information on the concerns to be addressed. These recommended best practices may be used by the mining sector, regulatory agencies, and the general public as sources of technical and policy guidance in the development and implementation of site-specific environmental protection practices.

Although the recommendations are intended to be clear and specific to the intended results, they are not intended to discourage the use of alternative technologies and practices that can achieve an equivalent or better level of environmental protection.

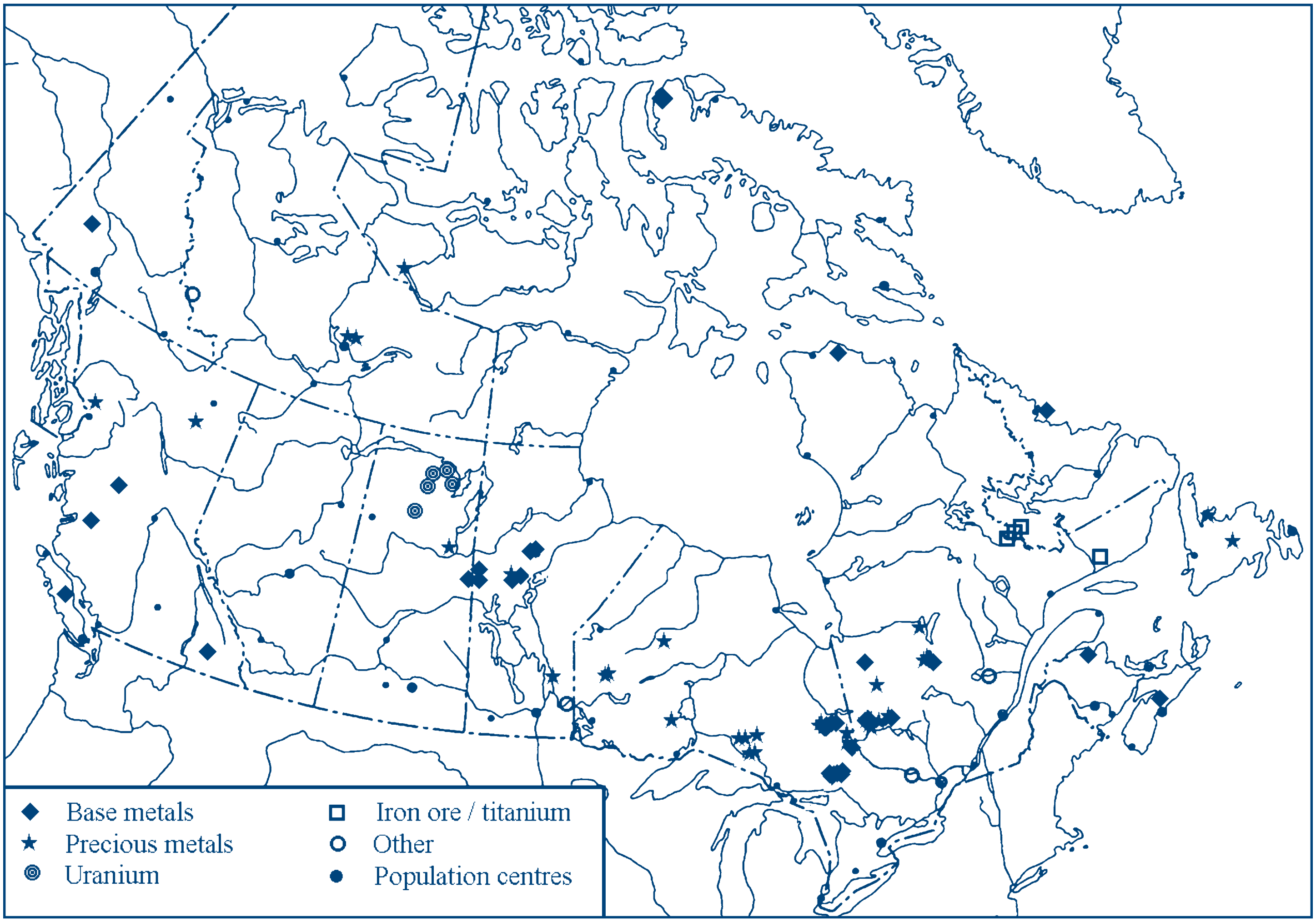
A glossary of key terms as well as a list of additional resources that were considered in the development of the Code is provided immediately following Chapter 4. The glossary should be consulted to clarify the precise meaning of terms that are used in this document, and the additional resources may be of value in helping readers determine how best to implement specific recommendations that are presented.

1.4 CODE DEVELOPMENT

The Code was developed by Environment Canada in consultation with a broad range of stakeholders.

Relevant federal, provincial/territorial, and international environmental standards were considered in the development of the recommendations in the Code. Environmental management practices recommended by various national and international organizations were also incorporated. Information on best management practices was drawn from various reports and literature produced by provinces/territories, Environment Canada, the Mine Environment Neutral Drainage Program (MEND), the Government of Australia, the United Nations and the Mining Association of Canada, as well as from individual mining facilities and technical journals. The document has also been widely reviewed by staff from federal, provincial and territorial governments, the mining industry, and a range of other stakeholders.

❑ FIGURE 1.1: DISTRIBUTION OF MINING FACILITIES SUBJECT TO THE *METAL MINING EFFLUENT REGULATIONS* IN CANADA IN 2007



1.5 CODE IMPLEMENTATION

The Code of Practice will be adopted by Environment Canada and others as a guidance document that recommends environmental protection practices for metal mines.

The Code may be adopted on a voluntary basis by individual mining corporations for activities in Canada and other countries, by the Mining Association of Canada (MAC) and its members, provincial or territorial mining associations or other industry associations. A commitment to this code may be included in environmental performance agreements that are entered into by mining companies or individual facilities with Environment Canada and provincial, territorial and Aboriginal environmental departments. It may also be adopted in whole or in part by regulatory agencies.

Some or all of the recommendations in the Code may be used as a requirement by financial lending institutions and/or insurance companies or underwriters.

The Code may be used for benchmarking best practices to achieve continual improvement in the environmental performance of metal mines in Canada and other countries. Code recommendations may also be used as benchmark criteria for use in audits of the environmental performance of sector facilities or companies.

Recommendations in the Code do not carry regulatory status, and a commitment by companies to implement the recommendations in the Code does not remove obligations for such companies to comply with all applicable municipal, Aboriginal, provincial, territorial and federal legal requirements.

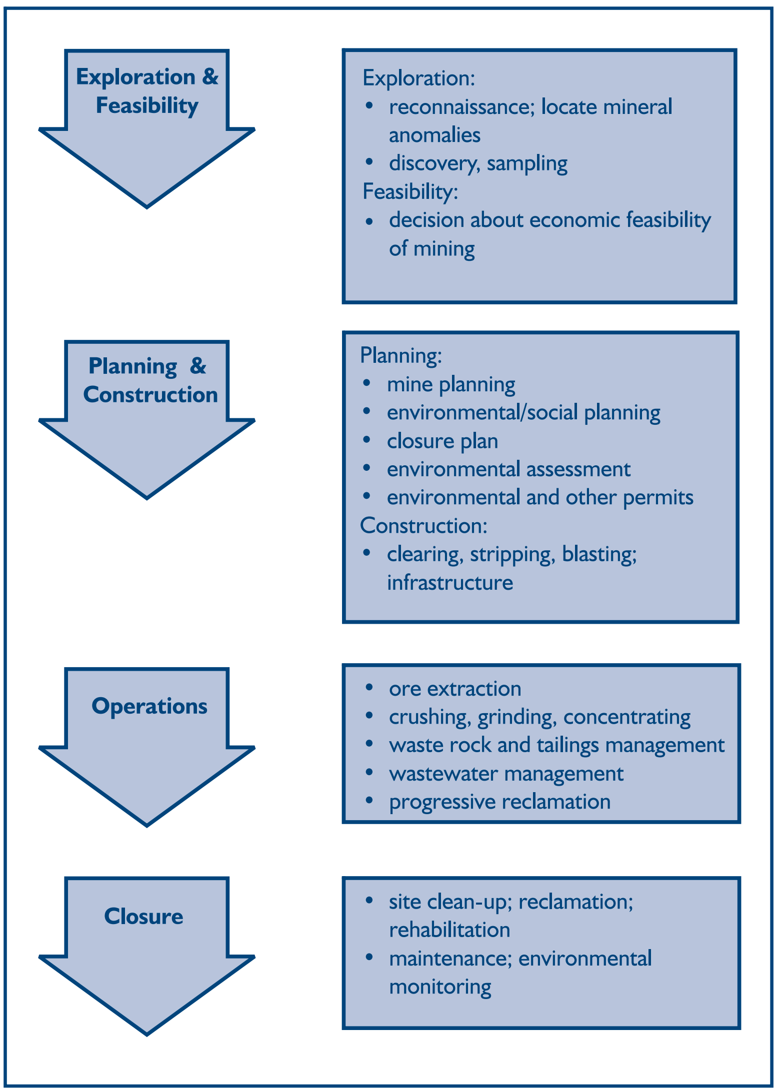
2 MINE LIFE CYCLE ACTIVITIES

In this document, the mine life cycle is described in the following steps, or phases. These phases and the associated key activities are illustrated in Figure 2.1, and consist of:

- the exploration and feasibility phase;
- the planning and construction phase;
- the mine operations phase; and
- the mine closure phase.

This section provides a brief overview of the activities that take place during each phase of the mine life cycle. Associated environmental concerns are discussed in Section 3.

❑ FIGURE 2.1: ACTIVITIES OF THE MINE LIFE CYCLE



2.1 EXPLORATION AND FEASIBILITY

Initial Exploration

The objective of initial exploration is to identify and assess mineralized areas to determine whether more intensive exploration is warranted. The methods used in initial exploration include the following:

- *Geophysical Surveys:* Geophysical survey techniques include magnetic, electromagnetic, electrical, radiometric and gravity techniques, and surveys can be conducted from the air or on the ground. These surveys provide information on potential targets for ground-based exploration.
- *Prospecting and Geological Mapping:* This can involve the mapping and sampling of targets identified in airborne geophysical surveys, regional-scale mapping and more detailed mapping of areas of particular interest. The objective is to provide a preliminary assessment of the potential for mineralization over a relatively large area.
- *Geochemical Surveys:* A range of materials may be sampled, most commonly rocks and soil. Samples are sent for chemical analysis for metals of interest. Results of the analyses are compiled and compared with the results obtained from other exploration methods.
- *Diamond Drilling:* Diamond drills recover a core of rock, and cores from several holes allow geologists to build a three-dimensional picture of the local geology. Core samples are also subjected to chemical analysis.
- *Trenching:* Trenches may be dug or areas of outcrop stripped of vegetation and soil to enable mapping of near-surface geology and for bulk sampling where ore and other geologic units may be very near the surface.

Advanced Exploration

In areas where the results of initial exploration are positive, advanced exploration may commence. The primary goals of advanced exploration are to define the quantity and quality of potential ore and the geometry of the deposit and to determine the most appropriate mining and processing methods. The establishment of small-scale underground or open pit mine workings are essential to provide the information needed to make decisions regarding further development at a site. Larger amounts of rock are removed during bulk sampling as part of advanced exploration. Valuable information can be obtained concerning rock quality, mineralogy and geochemistry. Bulk sampling is commonly accompanied by extensive diamond drilling, the results of which are used to improve the understanding of the geometry of the mineral deposit, as well as the quantity, characteristics and delineation of the potential ore body.

If the quantity and quality of potential ore present are adequate to proceed to a feasibility study, the data from advanced exploration are used for preliminary planning of mine layout, ore processing design, and estimating the cost of developing and operating a mine.

Feasibility

Mineral deposits that are worthy of further evaluation following advanced exploration are subjected to a rigorous process to determine the feasibility of developing a mine at the site. This process involves an assessment of the technical, legal and economic feasibility of the envisaged project, including assessments of the mineral reserve and investment returns. The mineral reserve is estimated based on the results of advanced exploration. Mining methods are determined on the basis of safety, economics, practicality and environmental considerations.

Mineral exploration targets that are demonstrated to be viable and that receive the necessary funding and permits are ultimately brought into production. Once a decision has been made to proceed with production at a site, final site planning and engineering studies are completed in preparation for the beginning of mine construction.

2.2 PLANNING AND CONSTRUCTION

Planning

During the planning phase, which in practice may overlap with the completion of feasibility studies, all aspects of the mine are planned in detail. This includes planning related to mining and ore separation processes, as well as site infrastructure needs, schedules for construction and commissioning of facilities, and all planning associated with environmental aspects of operations.

Construction

The most significant activity during mine construction is the establishment of underground or surface mine workings to provide direct access to the ore body. Related activities include the construction of ore processing facilities, waste management areas, and site infrastructure. The scope and complexity of the works to be completed during this phase vary considerably from project to project; however, some elements are common to all mine construction projects. These key activities are briefly described below.

Site Preparation - Clearing, Stripping and Grading: The clearing and stripping of overburden is completed in preparation for the construction of various facilities on site. The overburden is typically stockpiled if it is suitable for later use in mine reclamation.

Construction of Mine Infrastructure: Most of the on-site facilities and utilities associated with the mine are developed during the construction phase. Depending on a number of factors, including the size of the operatiown, the location, and the proposed mining and milling processes to be used, infrastructure may include:

- transportation facilities, including access roads to the site, on-site roads, and in some cases an airstrip, rail line or port facility;
- ore handling and processing facilities;
- mine waste disposal facilities;
- water management and wastewater treatment systems;
- power infrastructure, including power distribution system and any on-site generation facilities;
- shops, offices, warehouses and accommodations;
- fuel supply and storage;
- vehicle storage and maintenance facilities;
- explosives storage facility;
- water supply, potable water treatment and distribution system; and
- sewage and waste disposal (including incinerators, landfill and land farm).

Establishment of Mine Workings: During the construction phase, underground or surface mine workings are established to provide direct access to the ore body. Surface mines, also known as open pit mines, are preferred for the extraction of ore close to the surface. Deeper or more irregularly shaped ore bodies are generally mined by underground methods. The mine workings are excavated by drilling and blasting. Drills are used to drill patterns in the rock that, upon blasting, will fragment the rock. To fragment the rock, explosives are injected into drill holes and detonated. Once the rock is fractured it is removed from the mine. Most of the material removed during the construction phase is waste rock, and any ore that is removed is stockpiled for later processing. Mine construction may also include some ore production for use in testing the ore handling and processing facilities.

2.3 MINE OPERATIONS

The mine operations phase represents the period during which a mine produces and processes ore to produce a product for market. At some sites, the mine operations phase may extend continuously over a period of several years to decades while at other sites, the mine operations phase may include short or extended periods of inactivity due to changes in market conditions. The mine operations phase includes both ore extraction and ore processing and associated activities.

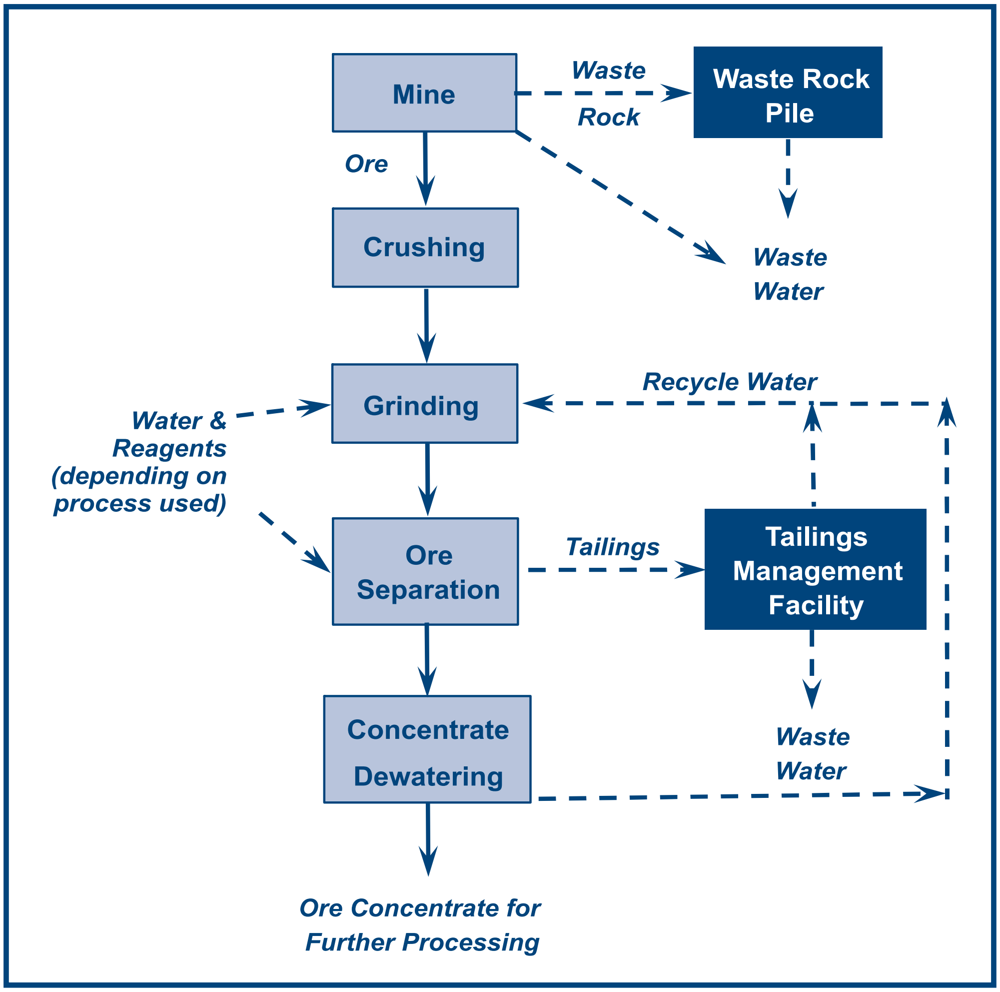
The key activities of the mine operations phase are illustrated in Figure 2.2.

2.3.1 ORE EXTRACTION

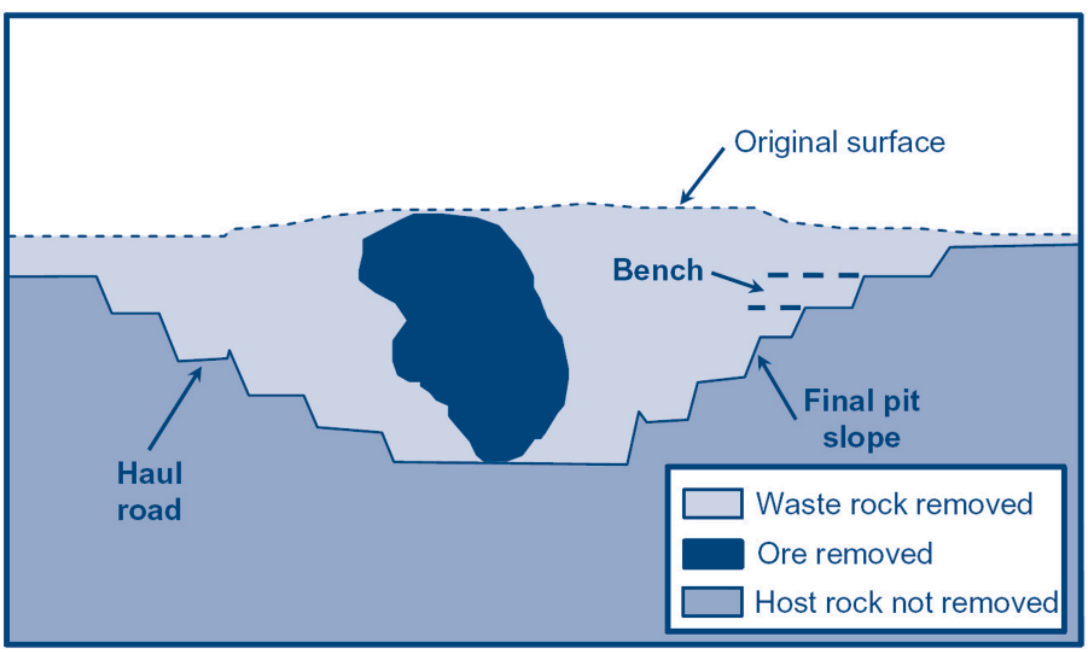
Open Pit Mines

Open pit mining is the preferred method for the extraction of ore from deposits that are close to the surface, since the cost per tonne of ore mined is generally lower than that for underground mining. Other factors that may influence the decision about whether to mine using open pit or underground methods include the ore grade, the geometry of the deposit, other physical characteristics, and site characteristics such as topography. Open pits are generally much wider than they are deep to ensure the stability of the pit walls (see Figure 2.3). The stripping ratio (the ratio of waste rock to ore) varies dramatically over the life of an open pit mine and depends on the geometry of the ore body, ore grades, slope stability, site geology, and variations in the price of the metal.

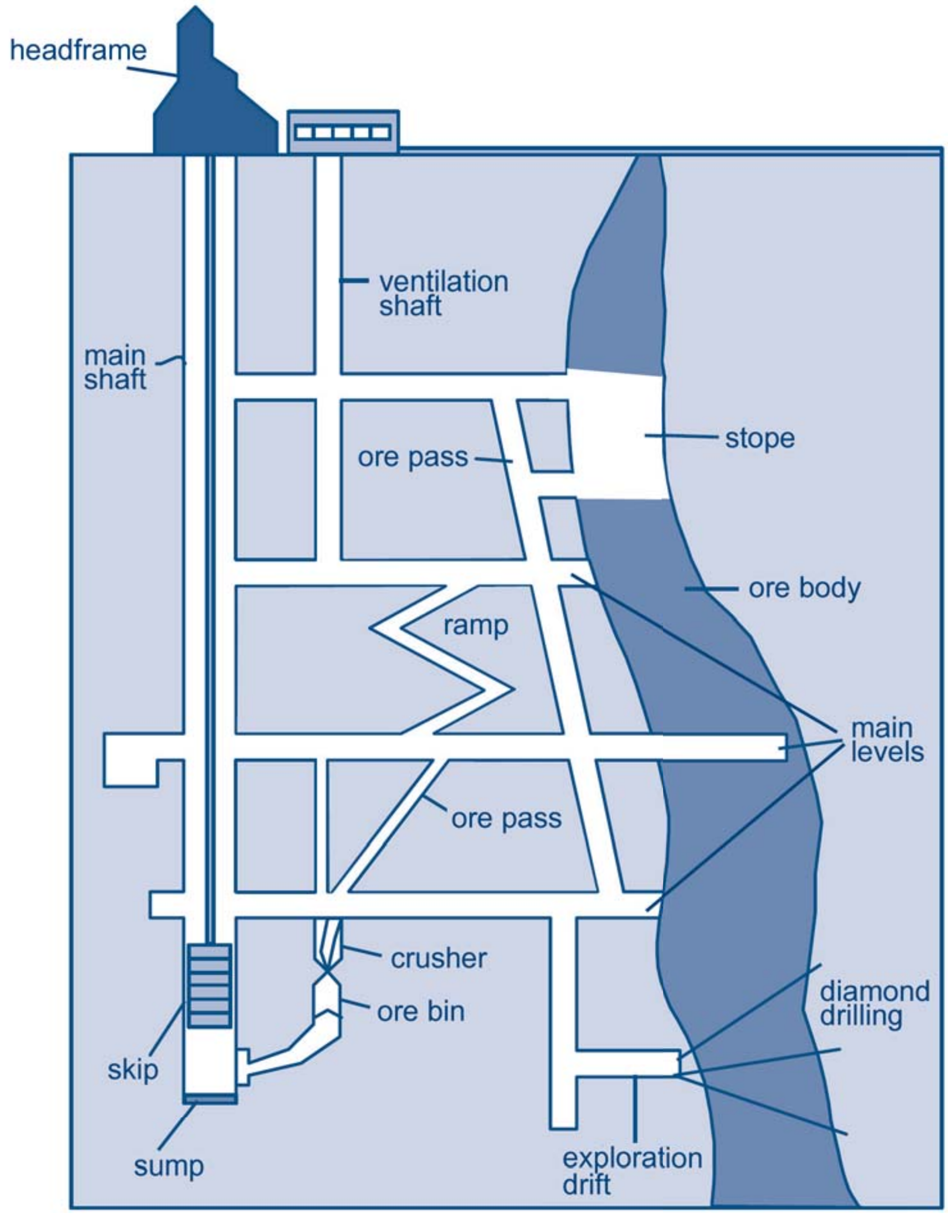
❑ FIGURE 2.2: TYPICAL ACTIVITIES OF THE MINE OPERATIONS PHASE



❑ FIGURE 2.3: CROSS-SECTION THROUGH A TYPICAL OPEN PIT MINE



❑ FIGURE 2.4: CROSS-SECTION THROUGH A TYPICAL UNDERGROUND MINE



Underground Mines

In underground mines, the ore is extracted through a series of vertical shafts and ramps and horizontal drifts and adits (see Figure 2.4). Extraction is more selective than in open pit mining, and the ratio of waste rock to ore generated is much lower. In about one half of Canadian underground mines, waste rock is used as mine backfill to provide roof and wall support underground. Waste rock that is not used for construction or as backfill is disposed of on the surface.

2.3.2 ORE PROCESSING

Once ore is extracted from a mine it is processed to recover the valuable minerals. Ore typically consists of small amounts of valuable minerals in close association with much larger amounts of waste minerals of no economic value (gangue). The valuable ore minerals are separated (liberated) from the gangue in milling operations to obtain higher quality metal. Major steps in ore processing include grinding and crushing, chemical/physical separation and dewatering.

Grinding and Crushing

Grinding and crushing of ore is undertaken to physically liberate valuable minerals prior to separation by physical and chemical processes. Crushing is done dry, and is used for coarse size reduction. Grinding is used to achieve finer size reduction. Grinding is conducted wet, and chemicals such as lime, soda ash, sodium cyanide, and sulphur dioxide may be added in the grinding circuit in preparation for ore separation. Ore must be ground fine enough to liberate the ore minerals from the gangue, or subsequent separation methods will not be as effective.

Ore Separation

Ore separation may be done using physical or chemical separation methods. The end product of ore separation is an ore concentrate. After separation, some ore concentrates are sent for further processing, such as smelting, to produce pure metal for sale.

A by-product of ore separation is tailings, which are a mixture of water and finely ground rock from which most of the minerals of value have been removed. Tailings may still contain metal-bearing minerals, and the mixture may also contain residues of reagents used in ore processing.

Physical Separation Processes: Physical separation processes exploit differences in the physical properties or behaviour of mineral particles, such as size, density and surface energy. The bulk of the mineral is not chemically altered, although chemical reagents may be used to help in the separation process. Commonly used physical separation processes are as follows:

- *Gravity Separation:* Minerals can be separated on the basis of differences in density, particularly for iron ore and gold, as well as tungsten, tantalum and niobium. Gravity separation may also be used to pre-concentrate metallic minerals prior to further processing. Gravity separation tends to require the use of smaller amounts of process reagents than some other ore separation methods.
- *Magnetic Separation:* Minerals can be separated on the basis of differences in magnetic susceptibility. Magnetic separation has been used in Canada to separate iron ore from waste minerals, to remove magnetite (iron oxide) and pyrrhotite (iron sulphide) from base metal ores prior to flotation, and to recover magnetite from copper concentrates. Like gravity separation, magnetic separation tends to require the use of smaller amounts of process reagents than some other ore separation methods.
- *Flotation Separation:* Flotation is used for the separation of a wide variety of minerals on the basis of differences in surface properties of minerals in contact with air and water. It is the dominant process for the recovery of base metal ores and is also used in uranium and gold processing operations. To separate minerals using flotation, fine air bubbles are introduced into a mixture of ground ore in water, known as a slurry. In this slurry, mineral particles collide with air bubbles, and minerals that favour contact with air attach to the air bubbles and float to the surface of the flotation cell. As air bubbles accumulate at the surface, a froth forms and eventually overflows as

the flotation cell concentrate. Minerals that favour contact with water remain in the slurry and go to the flotation cell tailings. A number of chemical reagents are used to aid the process.

Chemical Separation Processes: Chemical separation processes involve the preferential leaching of one or more minerals, particularly for the recovery of gold, silver and uranium and in some cases copper. A number of chemical processes are used for ore separation:

- *Leaching with Cyanide:* This is the dominant method for recovery of metallic gold or silver. A dilute solution of calcium or sodium cyanide is used to dissolve the metal. Following leaching, metals are recovered from the solution by absorption directly from the leach slurry onto activated carbon granules or by the addition of zinc dust to the solution which causes the precious metals to precipitate from the solution.
- *Leaching with Sulphuric Acid:* Uranium ores are processed using sulphuric acid to dissolve the uranium. The uranium is then removed from the solution using ion exchange or solvent extraction, which results in the adsorption of uranium on a resin or organic solvent. The uranium is then removed from the resin or solvent. In some cases, copper ores are also leached with sulphuric acid.

2.3.3 DEWATERING

The ore concentrates obtained from most physical ore separation processes are slurries with high water content that must be dewatered prior to further processing. Dewatering involves two processes, i.e., thickening and filtration. In thickening, slurries are thickened by gravity settling. The excess water is decanted off and may be recycled in the milling processes. After thickening, the slurry is passed through a vacuum filter, which traps the particulates. Most of the remaining water is removed.

2.4 MINE CLOSURE

Mines are closed when the ore minerals are completely exhausted or when it is no longer profitable to recover the minerals that remain. In some cases, mines may be closed temporarily and put into a status called “care and maintenance,” also known as temporary suspension. This is frequently done during periods of low commodity prices in the expectation that higher prices in the future will make further commercial operations financially viable. Eventually, ore reserves are depleted, and mines are permanently closed.

Since much of the work conducted at a mine site during the mine closure phase is related to environmental protection and rehabilitation, mine closure is discussed in further detail in Section 3.

3 ENVIRONMENTAL CONCERNS THROUGH THE MINE LIFE CYCLE

3.1 EXPLORATION AND FEASIBILITY

Environmental concerns which may arise during the exploration and feasibility phase are summarized in Table 3.1. Most initial exploration activities are relatively non-intrusive and have limited, short-term impacts on the environment, particularly when compared to impacts associated with other phases of the mine life cycle. Access during initial exploration is seldom intensive and work camps are normally tent based, supporting a few people for short periods of time. In most areas, the main environmental effect associated with initial exploration is noise from aircraft during airborne surveys, which can affect wildlife. Line cutting for geophysical surveys results in environmental effects of varying magnitude, depending on the width of the lines that are cut and the number of lines in a given area.

Diamond drilling can also have effects. For example, access roads may be required. Drilling also requires the preparation of drill sites; the transportation, storage and handling of fuel; and the establishment of campsites for drilling and geological crews, facilities to deal with drilling waste, and an infrastructure to manage and supply the camp. All of these activities have the potential to affect the environment.

The risk of environmental effects increases as exploration becomes more intensive. Diamond drilling is generally more extensive during advanced exploration, leading to increased risk of effects on the environment. In addition, the collection of bulk samples may result in the release of contaminants to water and air, as well as noise and vibrations that may affect wildlife. The accommodation and infrastructure requirements of advanced exploration programs can also have effects. Though bulk sampling is an advanced exploration activity, it has the potential to generate environmental effects similar to those of the mine operations phase, albeit on a smaller scale.

Activities related to feasibility studies are an extension of advanced exploration activities, and the related environmental concerns are similar.

3.2 PLANNING AND CONSTRUCTION

3.2.1 PLANNING

The planning phase is very important from an environmental perspective. All required environmental assessments must be conducted and all relevant environmental permits must be obtained before the project can proceed. In addition, during this phase, a broad range of plans are developed covering all aspects of environmental operations at a site.

❑ TABLE 3.1: POTENTIAL ENVIRONMENTAL CONCERNS ASSOCIATED WITH THE EXPLORATION AND FEASIBILITY PHASE

Activity	Potential Environmental Concerns
Access/Line Cutting	• Possible concerns with terrestrial/wildlife habitat and stream crossings
Geophysical Surveys	• Possible impacts on wildlife from airborne surveys
Field Camps	• Sewage and garbage disposal, water supply, fuel storage • Impacts on terrestrial/wildlife habitat, access to remote areas
Trenching/Pitting	• Physical scarring/land disturbance • Acid generation from exposed sulphide minerals • Metal leaching • Sediment erosion • Impacts on wildlife of blasting
Drilling	• Water supply, drilling fluid disposal, fuel storage/risk of spills, groundwater contamination • Physical scarring/land disturbance • Acid generation from exposed sulphide minerals • Release of metal-bearing groundwater
Bulk Sampling	• All of the above but potentially greater impacts are possible, and reclamation needs to be considered • Dewatering of historic mine workings may have impacts on receiving water quality
Exploratory Mining	• Potential impacts can occur that are similar to those during full-scale mining operations, albeit on a smaller scale

3.2.2 CONSTRUCTION

Site Preparation and Construction of Mine Infrastructure

Site preparation (clearing, stripping and grading) and construction of infrastructure can have potentially important environmental implications, as identified in Table 3.2. Potential concerns are related to impacts on air quality, water quality, aquatic ecosystems, soil quality and terrestrial ecosystems.

Establishment of Mine Workings

The principal concerns related to the establishment of mine workings during the mine construction phase are the management of waste rock and mine water. These concerns are further discussed in Section 3.3. The establishment of mine workings can also affect the environment as a result of dust, noise and vibration, which are mainly the result of drilling and blasting activities.

3.3 MINE OPERATIONS

3.3.1 ORE EXTRACTION

The primary environmental concerns associated with ore extraction activities are the disposal of waste rock and the release of mine water. Waste rock disposal and water management and treatment are further discussed below. Ore extraction activities can also affect the environment as a result of dust, noise and vibration, which are mainly the result of drilling and blasting, but may also be associated with transportation activities.

There are significant differences between open pit mines and underground mines in terms of implications for environmental management (see Table 3.3). One of the most significant differences is that open pit mines result in a larger area of surface disruption and tend to produce much larger volumes of waste rock than underground mines.

3.3.2 ORE PROCESSING

The primary environmental concerns associated with ore processing relate to the disposal of tailings and the management and treatment of wastewater. Tailings disposal is further discussed below. There are also concerns associated with the risk of spills and accidents, which could result in the release of contaminants such as chemical reagents used in ore processing.

❑ TABLE 3.2: POTENTIAL ENVIRONMENTAL CONCERNS DURING SITE PREPARATION AND THE CONSTRUCTION OF MINE INFRASTRUCTURE

Potential Sources of Concern	Nature of Potential Concern
Air Quality	
Operation and maintenance of vehicles and any on-site power generation facilities	• Potential releases of particulate matter, carbon monoxide, oxides of nitrogen, sulphur dioxide, and volatile organic compounds
Fuel and chemical transportation, handling and storage	• Potential releases of volatile organic compounds and other harmful substances
Site preparation and construction activities	• Potential releases of particulate matter
Water Quality and Aquatic Ecosystems	
Operation and maintenance of vehicles and any on-site power generation facilities	• Potential releases of substances such as suspended solids, trace metals, oil, degreasers, and detergents and other harmful substances that could affect water quality and aquatic ecosystems
Fuel and chemical transportation, handling and storage	• In the event of spills, potential releases of petroleum products or chemicals that could affect surface waters or groundwater as well as aquatic ecosystems
Site preparation and construction activities	• Potential release of sediments, increasing concentrations of total suspended solids in receiving waters
Sewage and wastewater disposal	• Potential releases of nutrients and other contaminants
Construction of site access roads and power lines	• Potential release of sediments along the routes, increasing total suspended solids in receiving waters • Potential for acidic drainage if sulphide-bearing minerals are exposed during construction • Stream crossings for access roads may affect aquatic ecosystems, particularly those of migratory or spawning fish • Increased road access in remote areas may lead to increased fishing, stressing fish populations
Soil Quality and Terrestrial Ecosystems	
Fuel and chemical transportation, handling and storage	• In the event of spills, potential releases of petroleum products or chemicals that could affect soils, vegetation and wildlife
Operation of vehicles	• Vehicle operations may result in collisions with wildlife • Low altitude aircraft operations could disrupt wildlife
Site preparation and construction activities	• Clearing of vegetation on site may have impacts on biodiversity, particularly if any rare, threatened or keystone species are present • Activities on site may disrupt and dislocate local wildlife and any migratory wildlife in the area • Some animals may be drawn to the site as a result of improper waste disposal or kitchen odours, which could lead to potential hazards for both workers and the animals
Construction of site access roads and power lines	• Construction activities may disrupt and dislocate wildlife and any migratory wildlife in the area • Increased road access in remote areas may lead to increased hunting, stressing wildlife populations • Vehicle operations may result in collisions with wildlife
Noise	
Noise from exploration activities, including vehicle operations, drilling, and blasting	• Noise may affect local wildlife populations, and well as people living in communities near the exploration activity

❑ TABLE 3.3: COMPARISON OF OPEN PIT AND UNDERGROUND MINES, HIGHLIGHTING DIFFERENCES IN ENVIRONMENTAL MANAGEMENT CONCERNS

Environmental Aspect	Open Pit Mine	Underground Mine
Land Disturbance	Relatively large area	Smaller disturbed area than for open pit mines
Waste Rock Disposal	Can require large area; involves trucking, runoff and leachate management, dusting and aesthetic considerations	Less waste rock than open pit mines, but may involve similar management considerations
Tailings	Tailings volumes generally larger due to large volume of ore processed	Tailings volumes generally smaller
Acid Drainage	May be associated with both mine and waste rock areas	May be associated with both mine and waste rock areas
Reclamation	Both mine and waste rock area can represent major concerns due to the extent of the waste rock and pit	Waste rock can be a concern, as can seepage or overflow of water from the mine workings
Land Subsidence	Not a concern	Can be a concern
Truck Noise	Truck traffic between pit and waste rock dumps and mill can be a serious noise problem	Normally not a concern
Vent Fan Noise	Not a concern	Requires careful consideration/mitigation
Blasting Effects	Noise and vibration can be a concern requiring careful management	Noise and vibration could also be a concern at underground mines, particularly when the mine workings are relatively shallow
Dust	Can be a concern due to pit operations, haulage roads and waste rock piles	Can be a concern due to haulage roads and waste rock piles
Mine Water	Mine water volume influenced by precipitation, surface and groundwater ingress. Elevated ammonium levels from blasting can be a concern. High sediment loadings are common. Mine water may contain metals and may have a low pH.	Mine water volume normally quite stable. Elevated ammonium levels from blasting can be a concern. High sediment loadings are common. Mine water may contain metals, and may have a low pH.

3.3.3 POTENTIAL SOURCES OF CONTAMINATION IN WASTEWATER

Acidic Drainage: Sulphide minerals are ore minerals for many base metals, such as copper, lead and zinc, and are ubiquitous in ore deposits. Sulphides may also occur in host rock for ore deposits, and as a result they are common in waste rock. Sulphides are important from an environmental perspective because, in the presence of water and oxygen, they can oxidize to create sulphuric acid, a process commonly known as acidic drainage and also known as acid mine drainage or acid rock drainage. The result is the generation of metal-laden effluents of low pH. Acidic drainage can have very significant impacts on aquatic ecosystems unless it is carefully managed, and it can lead to long-term liability and effluent treatment costs for the mine owner/operator.

Alkaline Effluents: Many ore separation processes, particularly flotation separation, are most efficient at an alkaline pH, and chemical additives are used to ensure an alkaline pH, sometimes as high as 10 or 11, during processing. As a result, effluents from ore processing facilities are frequently alkaline, even at the point of final effluent discharge. At some sites, pH adjustment is required to lower the effluent pH prior to discharge.

Metal Leaching: Wastewater from mining and ore processing facilities can contain metals that naturally occur in the rock. Most metals are more soluble in water at low pH, so the concentrations of metals are frequently elevated in acidic drainage. However, metal leaching can also occur in cases where acidic drainage is not a concern.

Cyanide: Cyanide is used in the recovery of gold in many facilities that process gold ore. Some cyanide is reused in processing but some is discarded in tailings. As a result, wastewater from facilities using cyanide mills may contain cyanide and a number of cyanide compounds.

Cyanide is also used in small amounts in some flotation separation circuits. Thus, cyanide compounds may also occur in wastewater from tailings from some base metal flotation mills.

Ammonia: Ammonia may be present in wastewater from mining operations as a result of the use of ammonium nitrate and fuel oil (ANFO) as a blasting agent. Any ammonium nitrate spilled in preparation for blasting or left over after a blast may contribute to increased ammonia concentrations in wastewater. In addition, ammonia may occur as a decomposition product from cyanide wastes.

Suspended Solids: Wastewater may contain suspended solids ranging from colloidal (non-settleable) to settleable materials. The discharge of effluents with high levels of suspended solids can cause a range of problems in aquatic environments that include impeded oxygen intake by fish and reduced light availability for aquatic plants. Depending on the composition of the solids in suspension, the settling of these sediments can also result in the contamination of sediments, particularly with metals.

Thiosalts: Thiosalts are sulphur oxide compounds, including thiosulphate ($S_2O_3^{2-}$) and polythionates ($S_xO_6^{2-}$), that are formed when partial oxidation occurs during the milling, grinding and floatation of some sulphide ores under alkaline conditions. Thiosalts are a concern because they can oxidize in water to form sulphuric acid, which lowers the pH of the receiving water and affect metal mobility. Both of these aspects could have significant effects on resident aquatic organisms.

3.3.4 MINE WASTE DISPOSAL

In planning the disposal of waste rock and tailings, the risks of metal leaching and acidic drainage can be predicted and the results considered in the design of waste rock piles and tailings management facilities.

If there is a risk of acidic drainage, there are several methods that may be used to prevent or control it. MEND[1] concluded that the most effective method of preventing acidic drainage is subaqueous disposal. Disposal of waste rock or tailings under water significantly reduces the exposure of the material to oxygen. The avoidance of oxidation reactions results in substantial reduction in the risk of acidic drainage and the associated metal leaching problem.

If prevention of acidic drainage is not possible, several methods may be used, alone or in combination, to control or limit it, including:

- dry covers consisting of alternating layers of material of different porosity to limit water infiltration;
- dry covers using innovative materials such as sewage sludge stabilized by lime or sludge from pulp and paper mills;
- impermeable geomembrane liners to prevent infiltration of acidic drainage into underlying materials;
- waste rock or tailings maintained in a frozen state (in permafrost areas);
- direct addition of lime or other alkaline substances;
- raising of the water table to inhibit acid generation of materials disposed of below the water table; and
- use of tailings as mine backfill, or disposing of tailings in mined-out open pits.

Waste Rock and Tailings Disposal

The production of both waste rock and tailings continues throughout the mine operations phase, and effluents originate from both. Effluent from waste rock is often sent to the tailings disposal area for treatment prior to final discharge, but it may also be directed to a separate treatment facility.

The key concern in the management of mine waste is the prevention or control of the release of contaminants that could have significant environmental impacts. Groundwater seepage is also a concern for both waste

1 MEND Manual Volume 4 - Prevention and Control, February 2001. MEND 5.4.2d

rock piles and tailings management facilities, in that seepage into the groundwater could result in the release of contaminants through a permeable foundation layer or other instability.

Failure of dams or other containment structures for tailings management facilities can lead to severe environmental impacts and significant risks to human health.

Treatment Sludge Disposal

Acidic drainage from mines is commonly treated with lime. A by-product of this treatment is sludge. The composition of sludge varies, and sludge may contain a wide range of metals. The volumes of sludge produced are large, and in some cases they may exceed the volume of tailings produced over the life of an operation. Sludge is generally disposed of on site, but it may also be sent to smelters for recycling.

There are uncertainties about the long-term chemical stability of many sludges, and there are risks that sludge could become an additional source of releases of metals.

3.3.5 WATER MANAGEMENT

Water and wastewater management constitute the primary environmental concern at most metal mines in Canada. An effective water management program can incorporate measures to:

- segregate clean and contaminated water flows in order to help reduce the requirement for the treatment of effluent;
- control and address seepage losses from tailings containment structures;
- reduce water usage;
- recycle water for further process use; and
- reduce impacts on the groundwater regime.

Measures that can be used in water management include drainage ditches to divert off-site water and drainage ditches and diversions to control the flow of on-site water and prevent contamination in order to prevent contaminated waters from leaving the site before treatment.

3.3.6 CONCERNS RELATED TO AIR QUALITY

Air quality impacts from mining are mainly associated with the releases of airborne particulate matter. Operation of vehicles and generators can also lead to releases of greenhouse gases and various air contaminants, including sulphur oxides, nitrogen oxides, carbon monoxide and particulate matter.

Releases of airborne particulate matter can result from various activities, including blasting, crushing, loading, hauling, and transferring by conveyor. Open pits, waste rock piles, tailings management facilities, and stockpiles are potential sources of wind-blown particulate matter.

Common methods to minimize releases of airborne particulate matter include:

- spraying water to maintain sufficient surface moisture;
- using environmentally acceptable chemical sprays to stabilize the surface;
- revegetating the parts of the mine site that will not be disturbed in the future;
- controlling dumping or transfer rates of materials;
- covering dump trucks or rail cars to minimize releases during the transportation of material;
- establishing speed limits on unpaved surfaces that are low enough to minimize dust from vehicle operations, considering local weather conditions;
- storing ore or concentrate in storage bins, hoppers or other buildings to eliminate dusting concerns and position the material for loading or transfer;
- covering or enclosing conveyor lines;
- using baghouses or precipitators for point sources of releases such as stacks from ore concentrate driers;
- covering stockpiles or other material that may be a source of releases; and
- temporarily ceasing operations if weather conditions are such that the risks of significant releases of airborne particulate matter are unacceptably high.

3.3.7 CONCERNS RELATED TO THE TERRESTRIAL ENVIRONMENT

Effects on Plants

The stripping of outcrops during exploration and the clearing of sites for mine construction can have significant local effects on resident plant communities. These communities also represent wildlife habitat, and destroying habitat can lead to the loss of local breeding grounds and wildlife movement corridors or other locally important features. Mining activity may also contaminate terrestrial plants. Metals may be transported into terrestrial ecosystems adjacent to mine sites as a result of releases of airborne particulate matter and seepage of groundwater or surface water.

In some cases, the uptake of contaminants from the soil in mining areas can lead to stressed vegetation. In such cases, the vegetation could be stunted or dwarfed.

Effects on Wildlife

Mining activity can affect wildlife as a result of habitat loss and habitat degradation. For example, mining activity may affect migration routes, breeding grounds, or nesting areas. Mining activity may also affect species that carry special cultural significance to local communities. As a minimum, most large mammals are dislocated from mine sites and associated facilities. Some large species may not be affected in the long term by such dislocation, but dislocation could affect others, depending on the species and the significance to that species of the lost habitat.

Conversely, some wildlife species may be attracted to mine sites, particularly if food wastes and other wastes that may attract wildlife are not properly managed. This may lead to increased interactions between humans and wildlife, and it could result in animals that pose a risk to persons on site having to be relocated or destroyed.

Terrestrial wildlife, like plants, may also be affected by contamination associated with mining activity. In particular, food sources for animals may become contaminated, and some contaminants, particularly metals, can magnify up the food chain.

3.3.8 PROGRESSIVE MINE CLOSURE ACTIVITIES DURING MINE OPERATIONS

Large areas of land may be disturbed through ore extraction and other mining activities. Disturbed areas that are not stabilized can be susceptible to erosion caused by both wind and water; erosion can lead to problems with dust as well as water quality problems related to sedimentation.

During the mine operations phase, landscape rehabilitation may include the reshaping and restructuring of the landscape and erosion control measures. In addition to reshaping or recontouring, landscape restructuring activities can include the use of stockpiled soils to reconstruct soil structure in preparation for revegetation.

3.4 MINE CLOSURE

The objectives of mine closure are:

- to ensure public and wildlife safety by capping shafts and preventing inadvertent access to mine openings and other infrastructure;
- to provide for the stable, long-term storage of waste rock and tailings;
- to ensure that the site is self-sustaining and to prevent or minimize environmental impacts; and
- to rehabilitate disturbed areas for a specified land use (e.g., return of disturbed areas to a natural state or other acceptable land use).

Many of the environmental considerations during the mine closure phase are common to all types of metal mines. However, there are additional concerns unique to some sites, such as the reclamation of radioactive wastes at uranium mines. A summary of components to be addressed in the mine closure phase is provided in Table 3.4.

❑ TABLE 3.4: MINE COMPONENTS TO BE ADDRESSED IN THE CLOSURE PLAN

Components	Aspects to be Addressed
Underground Mines	• Sealing of shafts, inclines and declines, or ventilation raises to prevent unauthorized access • Effects of seepage from backfill • Mine water drainage • Formation of potentially unstable ice plugs
Open Pit Mines	• Slope and bench stability • Groundwater and rainwater management • Security and unauthorized access • Wildlife entrapment • Effects of drainage into and from the pit
Ore Processing Facilities	• Removal of buildings and foundations • Clean-up of workshops, fuel and reagent • Disposal of scrap and waste materials • Re-profiling and revegetation of site
Waste Rock Piles	• Slope stability • Effects of leaching and seepage on surface and groundwater • Dust generation • Visual impact • Special considerations for some types of mines such as uranium mines
Tailings Management Facilities	• Dam stability • Changes in tailings geochemistry • Effects of seepage past the dam and from the base of the facility • Surface water management and discharge • Dust generation • Access and security • Wildlife entrapment • Special considerations for some types of mines such as uranium mines
Water Management Facilities	• Restoration or removal of dams, reservoirs, settling ponds, culverts, pipelines, spillways or culverts which are no longer needed • Surface drainage of the site and discharge of drainage waters • Maintenance of water management facilities
Landfill/Waste Disposal Facilities	• Disposal or removal from site of hazardous wastes • Disposal and stability of treatment sludge • Removal of sewage treatment plant • Prevention of groundwater contamination • Prevention of illegal dumping • Security and unauthorized access
Infrastructure	• Removal of power and water supply • Removal of haul and access roads • Reuse of transportation and supply depots

4 RECOMMENDED ENVIRONMENTAL MANAGEMENT PRACTICES

This section presents recommended best environmental management practices and mitigation measures that address potential environmental concerns throughout the mine life cycle. These recommendations were derived from regulatory and non-regulatory standards published by various agencies and organizations.

The overall objective of the Code is to identify and promote recommended best practices in order to facilitate and encourage continual improvement in environmental performance of mining facilities throughout the mine life cycle, in Canada and elsewhere.

Application of the recommendations to individual mines may involve practices that are not mentioned in the Code of Practice but achieve an equivalent or better level of environmental protection. Site-specific municipal, provincial/territorial, Aboriginal, federal or other legal requirements must be adhered to where they exist.

Recommendations are presented for environmental management tools that will be applicable throughout the mine life cycle, and some specific recommendations for practices focus on each life cycle phase. There are some recommended practices that may be applicable to more than one life cycle phase. These recommendations are presented in the life cycle in which the concern they address is most significant, and the potential applicability to other phases of the mine life cycle is noted.

Note that in this section, the term *mine* is used in a broad sense, to include stand-alone mines, integrated mining/milling facilities, and stand-alone milling facilities.

4.1 RECOMMENDATIONS FOR ENVIRONMENTAL MANAGEMENT TOOLS

In the context of the Code of Practice, environmental management tools can be broadly defined as an organized set of activities, actions, processes, and procedures that go beyond legal requirements in aiding mine owners and operators to ensure that their operations have minimal impact on the environment. The effective development and implementation of the environmental management tools recommended in this section will provide an overall systematic perspective on all aspects of environmental management and will facilitate efforts to achieve continual improvement in the overall environmental performance of mining operations.

The recommendations presented in this section take into account policies, principles, and commitments advanced by Environment Canada, the Canadian Council of Ministers of the Environment (CCME), provinces/territories, the Mining Association of Canada and other organizations. The recommendations are applicable to each phase of the mining cycle and should be implemented to the degree appropriate to the scale and potential significance of environmental impacts of each phase of the mine life cycle.

4.1.1 ENVIRONMENTAL POLICY STATEMENT

R 101: Each company owning or operating a metal mine or engaged in exploration activities should develop and implement a corporate environmental policy statement that includes commitments to:

- continually improve environmental protection measures and practices;
- focus on pollution prevention, where feasible, rather than treatment;
- comply with relevant environmental legislation and regulations and other requirements, such as industry association policies and best management practices to which the metal mine subscribes;
- maintain the environmental policy, communicate it to all employees, and communicate relevant components of the policy to on-site contractors; and
- make the environmental policy available to the public.

An environmental policy statement is a set of fundamental goals and principles that outline a company's environmental commitments. An environmental policy statement can provide a unifying vision of environmental principles and guide corporate activities, and it provides a public expression of those principles. An environmental policy statement provides a foundation and a focus for more comprehensive environmental plans and practices.

4.1.2 ENVIRONMENTAL ASSESSMENT

R 102: Mine proponents or current owners/operators should consult with federal and provincial/territorial regulatory and environmental assessment agencies early in the planning process to determine whether a proposed project will require an environmental assessment.

Environmental assessment principles should be followed by companies proposing new or significantly modified or expanded facilities. Proponents may consult the *Canadian Environmental Assessment Act* Reference Guide: Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects or relevant provincial/territorial documents.

Environmental assessment, also referred to as environmental impact assessment, is a planning and environmental management tool that is used to predict, analyze and interpret the effects of a project on the environment and to identify the measures that will be used to avoid or otherwise mitigate adverse effects. Most new mines, and some expansions of existing mining operations, are subject to environmental assessments under requirements of the *Canadian Environmental Assessment Act*, provincial/territorial legislation, or both. Early contact with regulatory agencies will assist in identifying information requirements and in facilitating an efficient and effective environmental assessment.

Environmental assessment, along with environmental follow-up and verification of environmental assessment predictions, makes it possible to systematically integrate a feedback loop, thus making it possible to draw on past experience to continually improve the process and inform future applications.

Baseline Studies

R 103: Water quality, aquatic ecosystems, air quality, soil quality, terrestrial ecosystems, groundwater and other environmental data collected as part of pre-operational baseline studies associated with environmental impact assessments should be collected so that it is comparable with monitoring data collected later in the mine life cycle. Data should be collected and analyzed so that it will be possible to identify long-term trends, periodic change and fluctuations in rates of change.

Baseline and historical data can be compared with monitoring data collected later in the mine life cycle to assess any changes in environmental conditions relative to the conditions that existed before mining.

4.1.3 ENVIRONMENTAL RISK MANAGEMENT

R 104: Site-specific environmental risk management procedures should be developed and implemented in a manner consistent with guidance provided in:

- CAN/CSA-Q634-M91 - Risk Analysis Requirements and Guidelines; and
- CAN/CSA-Z763-96 - Introduction to Environmental Risk Assessment Studies.

Risk management involves the identification of risk and the application of control measures to reduce or eliminate risks that are not acceptable. As part of a series entitled Best Practice Environmental Management in Mining produced by the Government of Australia, a booklet entitled Environmental Risk Management (1999) provides a good background on environmental risk management in the context of mining facilities. This document describes environmental risk management as an iterative process that encompasses:

- systematically applying policies, procedures and practices to the identification of hazards;
- identifying the consequences of those hazards;
- estimating risk levels, either quantitatively or qualitatively;
- assessing those levels of risk against relevant criteria and objectives; and
- making decisions about, and minimizing, the identified risks.

4.1.4 ENVIRONMENTAL MANAGEMENT SYSTEMS (EMS)

R 105: Site-specific environmental management systems (EMS) should be developed, implemented, maintained and updated in a manner that is consistent with a nationally recognized standard or system such as ISO 14001, developed by the International Organization for Standardization (ISO). Environmental management systems should be used to manage all environmental aspects of the activities and operations over which an operation has control or which it can reasonably influence.

Elements of an EMS should include:

- a clear definition of objectives and targets to meet the company's environmental policy;
- accountability for environmental action across the company;
- stated procedures to translate the environmental policy into day-to-day practices;
- monitoring, checking and auditing of the system; and
- implementation of actions to provide continual improvement.

Environmental management systems (EMS) may be used by mines to manage all environmental aspects throughout the mine life cycle in a manner that is fully integrated with all other management considerations. The EMS provides a structured approach to fulfilling the mine's environmental policy through a system of ongoing planning, implementation, checking, corrective action, and management review. This feedback process promotes continual improvement to achieve objectives and targets and fulfil the environmental policy over the life of the mine.

The development, implementation and ongoing maintenance of a comprehensive EMS, with regular reviews/audits and continual improvement, is ideally suited to mine operations, where the physical changes that are inherent in mining result in a very real need for reclamation plans and other management practices to be updated.

4.1.5 POLLUTION PREVENTION PLANS

R 106: Site-specific pollution prevention plans should be developed, implemented and updated in a manner consistent with the guidance provided in the Environment Canada (2001) Guidelines for the Implementation of the Pollution Prevention Planning Provisions of Part 4 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999).

Pollution prevention planning is a systematic, comprehensive method of identifying options to avoid or minimize the creation of pollutants or waste. Pollution prevention plans can focus on a single pollutant or on multiple pollutants, and they should be tailored to the needs of the mine, forming an integral part of its business and operational plans.

The pollution prevention planning process itself also has its own results and benefits. For example:

- a careful planning process ensures the selection and implementation of the most cost-effective pollution prevention options;
- systematic planning ensures that pollution prevention objectives and activities are consistent with the objectives and activities identified in the organization's broader planning processes;
- effective pollution prevention planning informs and assists broader business planning investment analysis and decision making;
- a documented pollution prevention plan may be a condition for receiving financing or insurance at improved rates; and
- pollution prevention planning assists in identifying risks, and it can be integrated with other planning activities, including environmental management systems and emergency planning.

4.1.6 ENVIRONMENTAL MANAGEMENT PLANS

R 107: Site-specific environmental management plans should be developed, implemented and updated throughout the mine life cycle. The plans should include, as a minimum, descriptions of the following:

- information about the owner/operator of the mine and information about the mine itself, including a description of the mining and ore processing methods used and the geographic setting of the site;
- the company's environmental policy statement;
- environmental performance requirements;
- air quality management programs;
- water quality management programs;
- management programs for tailings and waste rock;
- land management programs;
- pollution prevention planning;
- management of garbage and other waste materials;
- environmental objectives and targets along with schedules for achieving objectives and targets;
- environmental management programs and auditing;
- relationships with stakeholders, including local communities;
- procedures for communicating with regulatory agencies and stakeholders; and
- periodic review of the environmental management plan for effectiveness and continual improvement.

Building upon the EMS, the Environmental Management Plan (EMP) describes actions being taken or to be taken by a mine to:

- determine how the mine affects the environment;
- comply with regulations;
- keep track of environmental management activities; and
- meet environmental goals and targets.

An EMP also documents key elements of environmental management, including the environmental policy, responsibilities, applicable standard operating procedures and best management practices (BMP), record keeping, reporting, communications, training, monitoring, and corrective action.

4.1.7 ENVIRONMENTAL PERFORMANCE INDICATORS

R 108: Environmental performance indicators should be developed to facilitate tracking of the mining facility's overall environmental performance through readily understood measures of the facility's environmental performance and effects.

Environmental performance indicators (e.g., receiving water quality, wildlife populations) provide benchmarks against which environmental performance may be measured. Environmental performance indicators may be developed for the performance of environmental facilities, for environmental releases, and for environmental impacts. Indicators incorporate applicable environmental standards and environmental quality objectives. Indicators may also include economic measures that can help to link environmental and economic performance.

4.1.8 MONITORING AND INSPECTION OF ENVIRONMENTAL MANAGEMENT FACILITIES

R 109: Site-specific plans for the monitoring and inspection of on-site environmental facilities and infrastructure should be developed, implemented and updated. Plans should include:

- documentation of procedures for the monitoring and inspection of each on-site environmental facility, including air emission control equipment; water management and wastewater treatment facilities; transportation, handling, storage, and containment facilities for chemicals; waste handling and disposal facilities; and air quality and water quality monitoring and control instrumentation;
- a documented schedule for monitoring and inspections, including timing of monitoring and inspections and methods to be used;
- identification of those responsible for monitoring and inspections and for following up on the results of inspections;
- documentation of procedures for reporting the results of monitoring and inspection to both internal management and regulatory agencies;
- documentation of procedures for following up on monitoring and inspection reports;
- procedures for periodically reviewing and updating the monitoring and inspection plans; and
- procedures for quality assurance and quality control (QA/QC).

The ongoing monitoring and inspection of the performance and condition of environmental facilities is essential throughout the mine life cycle. Monitoring is used to determine whether facilities are operating as designed, and inspection is used to verify the condition of facilities and to provide early warning of any deterioration of the facilities.

4.1.9 ENVIRONMENTAL MONITORING

R 110: Environmental monitoring should include:
- monitoring of environmental releases, such as releases to air, water and land; and
- monitoring of environmental performance indicators, including air and water quality and aquatic and terrestrial species and ecosystems.

Site-specific environmental monitoring plans should be developed, implemented and updated throughout the mine life cycle that describe:
- all environmental monitoring and reporting required under regulations and permits;
- all environmental monitoring and reporting to be conducted which is beyond that required under regulations and permits;
- applicable environmental standards and environmental quality objectives, such as water or air quality standards or objectives;
- schedules for monitoring;
- sampling procedures, sample preservation requirements, and analytical methods employed;
- procedures for the comparison of monitoring results with applicable environmental standards and environmental quality objectives;
- actions to be undertaken when requirements set out in regulations or permits have not been met;
- procedures for reporting the results of monitoring to company management, regulatory agencies and the public;
- procedures for following up on monitoring reports;
- procedures for periodically reviewing and updating the environmental monitoring plans; and
- procedures for quality assurance and quality control (QA/QC).

R 111: Environmental monitoring should include specific plans to measure and verify all effects and endpoints that were predicted in the environmental assessment.

Environmental monitoring is the process of checking, observing, or tracking environmental releases from a mine and any environmental impacts potentially associated with the mine. Monitoring is essential to assessing environmental performance, and monitoring results may be used to help ensure continual improvement in environmental performance.

Some environmental monitoring is required by regulatory agencies. However, voluntary monitoring, beyond that required by regulatory agencies, may help to prevent pollution and will continually improve performance by identifying risks and avoiding potential problems before they occur. The CCME Canadian Environmental Quality Guidelines provide nationally endorsed science-based goals for the quality of atmospheric, aquatic, and terrestrial ecosystems.

Cumulative Effects Monitoring

R 112: Environmental monitoring plans should include measures to assess possible cumulative effects. The assessment of cumulative effects associated with mine development and operation should begin as early as possible in the mine life cycle, with consideration given to:
- applicable legislation related to the assessment of cumulative effects;
- potential activities in the vicinity of the mining facility, including infrastructure, that may contribute to cumulative effects; and
- existing monitoring activities, including any existing activities related to the assessment of cumulative effects.

Cumulative effects are those effects that are the result of an activity in combination with other past, present or reasonably foreseeable future activities. For example, cumulative effects may result from:
- a number of mining facilities operating in close proximity;
- a mining facility operating near another industrial facility, such as a pulp and paper mill; or
- a mining facility operating in an area of historical industrial activity.

For example, in the North, concerns have been raised about cumulative effects on caribou herds as a result of mining and exploration activity.

R 113: When environmental monitoring activities identify an effect or a change not predicted or not deemed acceptable in the environmental assessment, additional monitoring measures should be implemented to investigate the cause of the effect.

4.1.10 TRADITIONAL ECOLOGICAL KNOWLEDGE

R 114: Environmental assessment and monitoring should include, to the extent possible, a consideration of traditional ecological knowledge, and this knowledge should also be considered in relevant aspects of environmental planning and management.

In gathering and incorporating traditional ecological knowledge into environmental management, mine owners/operators should:

- respect the ownership, source and origins of the knowledge and the needs and sensitivities of its holders, and obtain their approval to use or disseminate that knowledge;
- establish trusting relationships with those who hold traditional ecological knowledge;
- work on projects of common interest and benefit;
- foster good communication between partners; and
- provide value-added knowledge back to the community in the form of useful products (such as reports) and services.

Traditional ecological knowledge is knowledge accumulated through time spent living on the land. In addition to an understanding of environmental systems as a whole and knowledge of appropriate techniques for harvesting, traditional ecological knowledge includes qualitative information on animals, plants and other natural phenomena.

Traditional ecological knowledge can be an important source of information that complements and supplements information gathered through environmental monitoring.

4.1.11 EMERGENCY PLANNING

R 115: Site-specific environmental emergency plans should be developed and implemented, then tested and updated on a regular basis. These plans must respect legislated requirements, such as those under the *Environmental Emergency Regulations* and the *Metal Mining Effluent Regulations*. In this regard, the plan should be consistent with the Implementation Guidelines for Part 8 of the *Canadian Environmental Protection Act, 1999* - Environmental Emergency Plans from Environment Canada.

However, the scope of environmental emergency plans should be broad and comprehensive in nature, and should go beyond the legislated requirements, particularly with respect to hazard identification, risk analysis and consequence as well as community involvement and communications. As such, the elements of emergency planning should also be consistent with recognized guidance documents such as APELL for Mining: Guidance for the Mining Industry in Raising Awareness and Preparedness for Emergencies at Local Level (United Nations Environment Programme, 2001).

A wide range of environmental emergencies may arise at mining facilities, including spills of fuels or other hazardous material, airborne releases of volatile substances, spills of mine tailings, and releases of untreated wastewater. Effective emergency planning, including training and testing, can help to prevent environmental emergencies and can help ensure prompt and effective response in an emergency. Emergency planning can also help ensure effective proactive communications with those potentially affected by emergencies, as well as timely and clear communications during an emergency.

In addition to relevant regulatory requirements, such as the requirements of the *Metal Mining Effluent Regulations* and the *Environmental Emergency Regulations*, standards such as ISO 14001 set out procedures for identifying and managing emergency situations. In addition, the United Nations Environment Programme (UNEP) Awareness and Preparedness for Emergencies on a Local Level (APELL) has prepared guidance, including the document cited in the above recommendation, that provides a framework for the preparation of an emergency response plan that can be used by mine management, emergency response agencies, government officials and local communities. The objectives of APELL are to:

- provide information to the concerned members of a community on the hazards involved in industrial operations in its neighbourhood and on the measures taken to reduce risks;
- review, update, or establish emergency response plans in the local area;
- increase local industry involvement in community awareness and emergency response planning;
- integrate industry emergency plans and local emergency response plans into one overall plan for the community to handle all types of emergencies; and
- involve members of the local community in the development, testing and implementation of the overall emergency response plan.

The objectives and scope of recommendations in the APELL document for mining are broader than what is required under current legislation, particularly in the area of community involvement and communications. Thus, this recommendation is intended to encourage mines to go beyond what they are required to do under current regulatory requirements.

4.1.12 ENVIRONMENTAL TRAINING AND AWARENESS

R 116: Site-specific procedures should be developed and implemented to identify environmental training needs and ensure that all personnel receive environmental training. As such, the procedures should encompass:

1. general awareness training for employees and service providers, including contractors, where the training includes but is not limited to:
   - the organization's environmental program, including the environmental policy and relevant environmental practices;
   - regulatory obligations; and
   - environmental emergencies procedures, including spill prevention, reporting, response and evacuation procedures;
2. an environmental training program that includes:
   - a list of all personnel that require environmental training and a categorization of groups of personnel with regards to the nature of the specific environmental training required; and
   - an outline of the environmental training required for each group of personnel, the training methods to be used, and the required frequency of refresher training; and
3. the identification of requisite competencies of contractors and environmental auditors.

Environmental training and awareness for all staff and on-site contractors of a company is important, since virtually all aspects of mine operations can have environmental implications. To help ensure continual improvement in environmental performance, it is important that all staff and on-site contractors play a role, not just those staff specifically responsible for environmental aspects of an operation. For example, those involved in explosives handling are key to helping to prevent pollution associated with ammonia.

As part of the Best Practice Environmental Management in Mining program, the Australian government has developed a booklet entitled Planning a Workforce Environmental Awareness Training Program (1995), which may be used as guidance in this area. This booklet identifies a number of potential benefits associated with environmental training and awareness programs, including:

- ownership of and commitment to environmental management at all levels of the workforce;
- a sustained, measurable improvement in environmental performance in both the individual and business unit level;
- an improved capacity to manage future environmental issues and to minimize environmental risk;
- improved understanding on the part of management and employees of how specific activities affect the environment;
- the development of management and employee skills resulting in cost-effective environmental solutions;
- management attention that is focused on the areas of greatest environmental impact and risk, and action on those areas;
- a responsible image presented to employees and the community; and
- reduced potential of an environmental incident.

4.1.13 CLOSURE PLANNING – DESIGNING FOR CLOSURE

R 117: The development of closure plans should begin during the planning phase for proposed mines and as early as possible in the mine life cycle for existing mines. Closure plans should be considered and incorporated into all aspects of mine planning, construction and operation so that key aspects of the closure are planned for throughout the mine life cycle. Plans should identify measures to be undertaken during the operations phase that are aimed at progressive reclamation of disturbed or developed areas of the mine site.

R 118: Mine closure should be carried out in a way that prevents or minimizes impacts and risks to the environment and human health after closure. Closure plans should identify site-specific objectives for mine closure and the intended post-closure land use for the site. Closure plans should detail the processes that will be used to decommission and reclaim all aspects of the mining facility, including:

- mining and ore processing facilities;
- site infrastructure; and
- water and waste management facilities, including waste rock piles and tailings management facilities.

Mine closure planning is a key tool in preventing or limiting environmental problems after a mine closes. The sooner in the mine life cycle that designing for mine closure begins, the greater the likelihood that closure measures will be effective and, in many cases, the less costly the mine closure process will be. In addition, the early development of closure plans can facilitate progressive reclamation activities during the mine operations phase, and this can help in preventing pollution during operations.

Designing a mine for closure should be an underlying theme in the design, implementation and management of all aspects of a mine throughout the mine life cycle.

Review of Closure Plans

R 119: Closure plans should be reviewed and revised as necessary throughout the mine life cycle. The plans may become more detailed, incorporating to a greater degree all activities related to the mine and taking into greater consideration site conditions and monitoring results. Closure plans may also be revised in response to:

- the results of progressive reclamation activities;
- the results of tests to assess specific aspects of the closure plan;
- public response to a proposed closure plan;
- changes in mine operations, such as production rate or ore type;
- changes in technology, such as improvement in technology for preventing or controlling acidic drainage;
- changes in economic conditions, such as input costs and other economics related to mine closure; and
- unexpected or adverse conditions encountered during the construction and operations phases of the mine life cycle.

4.1.14 ENVIRONMENTAL AUDITING

R 120: Periodic environmental audits should be conducted to determine (a) whether the site is operating in compliance with applicable regulatory requirements and appropriate non-regulatory and corporate requirements and (b) whether the EMS and other environmental plans have been properly implemented and maintained.

The recommendations in the Code of Practice should be included in the audit criteria, and each audit should take into consideration the results of previous environmental audits. Environmental auditors should be qualified by virtue of their relevant experience and training, and audit team members should be objectively selected.

ISO 19011, Guidelines for Quality and Environmental Management Systems Auditing, should be considered in the development and implementation of the audit program.

Environmental auditing is a process that may be used to assess all aspects of environmental management activities at a mine site. The scope of an environmental audit will vary depending upon the type and size of mine and the objectives of the audit. Generally, the objectives of environmental audits are to identify and assess potential liabilities, risks and hazards. The results of an audit may be used to identify areas for improvement in environmental management and to identify costs associated with reducing environmental risks and liability to acceptable levels. The International Organization for Standardization (ISO) has developed Guidelines for Quality and Environmental Management Systems Auditing (ISO 19011) as part of the ISO 14000 program.

4.1.15 PUBLIC INVOLVEMENT

R 121: Site-specific public involvement plans should be developed, implemented and updated throughout the mine life cycle. These plans should describe mechanisms by which public input will be sought and addressed. These plans should also:

- include a list of key community contacts;
- describe proposed mechanisms for informing the public that information is available and for distributing and receiving information;
- describe measures to be used to provide information in a form that is understandable to the public; and
- include plans for public reporting of monitoring activities.

The objective of public involvement is to ensure that decisions regarding environmental planning and management at mines are made as a result of informed, inclusive and fair consultation with the public. The "public" includes environmental non-governmental organizations, Aboriginal communities, community groups, commercial and/or sport fishers, and concerned individuals. There is a range of mechanisms by which the public may be involved, and the mechanisms used may evolve as relations with the public change. Dialogue with the public should be initiated in the early stages of the planning phase and continue throughout the mine life cycle.

Since mining activities often occur in more remote areas with significant Aboriginal populations, it is particularly important that Aboriginal communities be engaged as part of public involvement activities.

Further guidance on public involvement is provided in Chapter 10 of the Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring (2002), prepared by Environment Canada. The Sustainability Reporting Guidelines of the Global Reporting Initiative for the mining and metals sector may also be consulted.

4.1.16 PRODUCT STEWARDSHIP

R 122: Product stewardship programs should be developed and implemented, with the objective of minimizing the environmental impacts associated with the products used and produced by the mine. The programs should include consideration of:

- types of materials used;
- sources of supply of materials;
- sources and types of energy used;
- type and amount of packaging;
- management of manufacturing by-products and wastes;
- recycling or reuse of containers or the return of containers to the manufacturer;
- possible exchanges of waste materials with other local industries, such as the use of pulp mill waste as tailings cover material; and
- local purchasing of supplies to support community businesses and residents.

Under these programs, the mine takes full responsibility for the environmental impacts associated with the operational use and handling of the products used and produced at every stage of each product's life cycle that is under the direct control of the mine.

4.1.17 ADAPTIVE MANAGEMENT

R 123: Mine owners/operators should use adaptive management methods to revise and refine the environmental management strategy. Adaptive management should consider a wide range of factors, including:

- the results of environmental audits or other evaluation activities;
- the results of environmental monitoring;
- the results of monitoring of the performance or condition of environmental infrastructure, such as containment structures, water management systems or treatment facilities;
- technological developments; and
- changing environmental conditions.

Adaptive management is a systematic approach for improving environmental management by learning from management outcomes; it can be an important tool in achieving continual improvement in environmental performance.

Adaptive management involves exploring alternative ways to meet management objectives, predicting the outcomes of each alternative based on the current state of knowledge, implementing one or more of these alternatives, monitoring to learn which alternative best meets the management objectives (and testing predictions), and using these results to update knowledge and adjust management actions. Adaptive management can target areas of uncertainty and it provides a science-based learning process in which outcomes are used for evaluation and adjustment.[2]

4.2 ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE EXPLORATION AND FEASIBILITY PHASE

R 201: Environmental management plans should cover the full range of activities related to exploration, including land acquisition, surveys, access, camp and associated facilities, stripping, trenching, drilling and sampling. Environmental management practices should address water management and water quality, waste management, land disturbance, air quality, reclamation and closure.

The recommended practices identified in Table 4.1 should be followed during the exploration and feasibility phase. In addition, practices recommended for the planning, construction and mine operations phases apply during exploration and feasibility, albeit on a smaller scale.

2 Adaptive Management and Ecological Restoration. Murray and Marmorek. 2003.

❑ **TABLE 4.1:** RECOMMENDED ENVIRONMENTAL PRACTICES FOR THE EXPLORATION AND FEASIBILITY PHASE

Activity	Recommended Practices
Camps	
Site Selection	• Where possible, natural clearings should be used to avoid the necessity of clearing vegetation • Topsoil and organic matter should be stored for future rehabilitation needs • Nesting, breeding and migration areas and endangered species should be protected • Thawing of permafrost should be prevented to the extent practicable • Tree removal and compaction of soil should be minimized in areas of permafrost
Water Supply	• Withdrawal of water from streams should be done in a manner that protects fish populations • Withdrawal of water from streams should not exceed 10% of low flow of stream
Sewage and Domestic Washwater Disposal	• Pit toilets or sewage lagoons should be used for sewage disposal • Sewage disposal facilities should be a minimum of 100 m from any water body • Domestic washwater should not be discharged directly to any water body
Solid Waste Disposal	• Waste minimization practices should be implemented • Solid waste should be incinerated, hauled from site or buried on site • Landfills should be capped with a minimum of 1 m of soil • Drainage from landfills should not affect any watercourse • Waste should not be buried in permafrost
Infrastructure	
Access Roads	• Surface water control/diversion structures should be provided • Sedimentation and erosion control features should be installed • Except for crossings, roads should be located a minimum of 100 m from water bodies • Care should be taken in siting roads to avoid thin and sensitive vegetation covers
Aircraft Operations	Aircraft should: • remain 500 m above wildlife concentration areas; • remain 3000 m above special areas such as goose staging areas; • fly low only when required; • not make repeated low-level passes or circle over animals; • not overfly raptor colonies or colonies of nesting birds; and • stay clear of migration areas.
Docks	• Clearing of forested shores should be kept to a minimum • Rock-filled drums used for docks should be clean and readily removable • Wooden docks should be made of untreated lumber • Spill contingency supplies should be available for refuelling areas • Fuel hoses should be equipped with shut-off valves at both tank and nozzle ends
Fuel Storage and handling	• Fuel should be stored a minimum of 100 m from any water body • Spill containment dikes should be constructed of clay or hydrocarbon-resistant plastic • Fuel transfers should take place within the dike area • Fuel absorbent materials should be kept on site • Equipment should be repaired/serviced at least 100 m from any water body
Stream Crossings	• Stream crossings should be a minimum of 500 m from spawning areas • Gentle approaches should be selected with cut/fill at banks to a minimum • Fisheries and wildlife habitat should be protected and preserved • Stream bank erosion and sedimentation should be prevented • Intermittent stream channels should not be filled
Drilling and Trenching	• Drilling fluid should be biodegradable, and it should be contained and recycled • Trenches should be refilled and regraded after sampling
Off-road Vehicle Operation	• In northern areas, low-ground-pressure equipment should be used to mitigate the disturbance and erosion of permafrost active zones • Permafrost areas should be accessed via aircraft to the extent practicable

R 202: The guidelines of the Environmental Excellence in Exploration (e3) program developed by the Prospectors and Developers Association of Canada should be considered in the design and implementation of environmental management plans during the exploration and feasibility phase.

As described in Section 3.1, the potential for large-scale environmental impacts from exploration activities is lower than that associated with other phases of the mine life cycle. Nevertheless, environmental protection during exploration is essential. Exploration occurs at a large number of sites that will never become operational mines, and it often occurs in remote wilderness areas.

The purpose of the Environmental Excellence in Exploration (e3) program is to provide "cost-effective, technically sound and internationally acceptable practices for enhancing environmental and socio-economic performance in mineral exploration." The goal is to "foster the transfer of knowledge and technology to all stakeholders and therefore facilitate good practices and drive continuous improvement in environmental and socio-economic stewardship in the exploration and mining industry."

Environmental Excellence in Exploration consists of an online resource for environmentally and socially responsible exploration practices and issues. Emphasis is placed upon planning to avoid impacts wherever possible. The Environmental Excellence in Exploration manual includes information on measures and practices to minimize the environmental impacts of exploration activities, and it also contains guidelines for community engagement.

The manual consists of sections on community engagement and operating in areas of archaeological or cultural significance, as well as technical content laid out under six "activities":

- land acquisition;
- surveys;
- access;
- camp and associated facilities;
- stripping and trenching; and
- drilling.

Within each of these activities there is information on a range of issues, including:

- planning needs;
- land disturbance;
- site management;
- air management;
- fish and wildlife management;
- water use and conservation;
- spill management;
- hazardous materials management;
- waste management; and
- reclamation and closure.

Inclusion of Environmental Costs in Feasibility Studies

R 203: The anticipated costs of environmental management during mine operations, as well as the costs of mine closure and long-term post-closure liabilities, should be considered in the economic feasibility study for the mine and should be appropriately accounted for in the financial planning of the mine owner and operator.

Economic feasibility studies have traditionally considered ore grade and other characteristics of the ore body and economic conditions, including current and anticipated commodity prices, as well as the economics of the planned mining and ore processing methods. However, to consider fully the economic feasibility of a potential mine, the full costs of environmental management and protection throughout the mine life cycle, including closure and post-closure costs, also need to be considered.

Reclamation and Closure of Exploration Project

R 204: When exploration activities have ceased and further development of the site is not planned by the proponents:

- water intakes, culverts, docks and other waterway structures, as well as all machinery, equipment and building structures, should be removed;
- waste dumps, sewage/washwater pits and drill holes should be properly capped; and
- all areas that have been disturbed should be revegetated or rehabilitated to allow for natural revegetation.

The footprint of exploration activities should be minimized to the extent practicable.

4.3 ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE PLANNING AND CONSTRUCTION PHASE

Recommendations in this section apply to projects in the planning and construction phase. For new mines, this is a key phase in the mine life cycle from an environmental perspective, since much of the planning for environmental management practices takes place during this phase.

4.3.1 WATER MANAGEMENT

Water Management Planning

R 301: Site-specific surface water management plans should be developed and implemented. The plans should include:

- the identification of the mine property subwatersheds, including those for mine waste areas, drainage flow paths, and receiving water bodies;
- estimates of flow rates for each subwatershed under normal climatic conditions and extreme precipitation (i.e., design storm or low flow) events;
- analysis of the local groundwater regime, including flow direction and rates, recharge and discharge areas, and relationship with the local surface water regime;
- a water balance for the mine property that takes into account all significant water inputs, losses, and water recycling;
- descriptions of seasonal variations in surface water flow (e.g., due to melting of snow pack) and impacts on flow of any existing water level control structures;
- descriptions of measures to be implemented to manage water; and
- the identification and assessment of opportunities for diverting natural runoff away from the mine site to prevent pollution of this water.

Water management programs used at mines need to take into careful consideration the local hydrology and climate. Each program should include an assessment of the site's water balance and should incorporate structures, such as tailings water pond freeboard and overflow spillways, to control flows in the event of extreme precipitation events.

Some water management practices can also help to reduce the potential for soil erosion by using drainage and erosion control measures to stabilize the surface.

Water Use and Recycling

R 302: Ore processing facilities should be designed to:

- minimize the volume of fresh water that is used for ore processing by:
  - using ore processing methods that require less water; and
  - maximizing the recycling of water to reduce requirements for freshwater intake; and
- avoid or minimize the use of reagents that require treatment prior to effluent discharge.

Most ore processing methods, particularly the grinding of ore (which is usually done wet) and flotation separation and chemical separation processes such as cyanidation, use considerable amounts of water. Many ore processing facilities now recycle water for reuse in ore processing; this reduces the amount of freshwater that the facilities require and reduces the volume of water that must be treated prior to discharge to the environment.

Diversion of Clean Runoff and Consolidation of Wastewater Streams

R 303: In planning the site layout, consideration should be given to:

- consolidating to the degree practicable all facilities that are potential sources of wastewater with similar characteristics and treatment requirements;
- diverting all clean streams and drainage runoff away from areas of possible contamination by constructing ditches or dikes; and
- locating effluent discharge points away from environmentally sensitive areas.

Reducing the amount of water that becomes contaminated by mining activities is a key step in preventing pollution at mines. Water in natural streams or runoff channels on the mine site may become contaminated, even if that water is not used in the mining process. Thus, diversion of such streams and runoff away from mine sites can help to reduce the potential for water pollution.

Designing for Extreme Weather Events

R 304: Surface drainage facilities should be designed to handle peak conditions at least equivalent to a once in 100 year flood event. Consideration should be given to projections of increased extreme weather events resulting from global climate change, and facilities should be planned accordingly.

It is important that the water management infrastructure on a mine site be designed to handle extreme weather events, including high precipitation events, since the potential exists for high precipitation to overwhelm the water management infrastructure and result in releases of untreated effluent. In some instances, containment structures such as dams may also be weakened or fail.

Conventionally, such planning is based on historical weather records, and the maximum rainfall event predicted to happen once every 100 years is the basis for planning for facilities. However, projections of increases in extreme weather events as a result of global climate change should be considered.

4.3.2 PREDICTION OF WASTEWATER QUALITY

R 305: Site-specific programs for the prediction of wastewater quality should be developed and implemented. This work should begin as early as possible in the mine life cycle and continue throughout the planning and construction and mine operations phases.

Programs for the prediction of wastewater quality should include:

- the identification and description of all geological materials (including rock as well as overburden) to be excavated, exposed or otherwise disturbed by mining;
- the prediction of the metal leaching and acidic drainage potential of all geological materials, including the timing and conditions during which metal leaching and acidic drainage are expected to occur; and
- the prediction of other potentially harmful components in mine wastewater, including processing reagents, ammonia, algae-promoting substances, thiosalts, chlorides and elevated pH.

These steps are further detailed in recommendations R 306, R 307 and R 308.

The characterization of geologic materials is key to the prediction of wastewater quality, particularly for the rock that will be extracted from a mine. Waste rock and tailings, as well as the walls of the mine workings, are typically the main sources of acidic drainage and metal leaching.

The prediction of wastewater quality is a complex process, and there is no standard method for developing such a prediction. However, a number of prediction tools are available, and they may be applied on a site-specific basis to predict wastewater quality.

It is important to note that the prediction of wastewater quality should continue throughout the mine operations phase. The results of waste characterization and prediction work during mine operations can be used to verify predictions made during the planning and construction phase, and this information can help refine mine waste management plans to ensure that materials that may leach metals or generate acid are properly managed.

Identification and Description of Geologic Materials

R 306: Site-specific programs for the identification and description of rock and other geological materials that will be or have been moved or exposed as a result of mining activity should include, for each material:

- spatial distribution of the material, as well as the estimated mass of material present;
- geological characterization of the material, including its mineral and chemical composition;
- physical characterization of the material, including grain size, particle size and structural characteristics including fracturing, faulting and material strength;
- hydraulic conductivity of the material; and
- the degree of any oxidation of the material that has taken place.

The identification, description and mapping of all rock and other geologic materials that will be or have been moved or exposed as a result of mining activity are an essential first step in the prediction of wastewater quality from a mining facility. This characterization work is important to ensure that all possible sources of metal leaching and acidic drainage are evaluated, with the results being used to design and focus more detailed prediction work. Much of the information for this characterization can be derived from the results of work already done on site by geologists.

Prediction of Metal Leaching and Acidic Drainage Potential

R 307: All rock units and other geological materials that will be or have been moved or exposed as a result of mining activity should be tested for their metal leaching and acid generation potential. The testing program should be designed to meet site-specific needs, using a combination of static and kinetic test methods, as appropriate. The following documents should be consulted in designing, implementing and interpreting the results of the prediction program:

- William A. Price (1997). Draft Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia. British Columbia Ministry of Employment and Investment;
- MEND Manual, Volume 3 – Prediction (2000); and
- Bill Price (2005). List of Potential Information Requirements in Metal Leaching/Acid Rock Drainage Assessment and Mitigation Work. MEND Report 5.10E.

The objective of this phase of the prediction program is to determine the metal leaching and acidic drainage potential for each geological material identified and described. This prediction work forms the basis for plans for the management of waste rock and tailings and any other potential sources of metal leaching or acidic drainage.

Prediction of Other Potentially Harmful Components in Mine Wastewater

R 308: The presence of other components in mine wastewater that are potentially harmful to the environment should be predicted, in particular:

- the potential concentrations of ore processing reagents (e.g., cyanide) and their breakdown products in processing wastewater;
- the potential concentration of ammonia in wastewater;
- the potential pH of wastewater from ore processing, since processing is often carried out at a high pH; and
- the potential for the occurrence of thiosalts in wastewater from ore processing.

4.3.3 WASTE ROCK AND TAILINGS DISPOSAL PLANNING

R 309: The results of site-specific programs for the prediction of water quality should be considered in the planning of waste rock and tailings disposal management practices. In particular, where there is a potential for metal leaching or acidic drainage, the prevention and control of metal leaching and acidic drainage should be primary considerations in the design of waste rock piles, tailings management facilities, and associated water management facilities.

Due to their typically large volumes and the geologic characteristics of waste material, waste rock piles and tailings management facilities can have major design, operational and reclamation implications at many mines. Operations should be designed to minimize the cost of post-closure measures, such as collection and treatment of wastewater or re-handling of large volumes of material.

At sites where site-specific programs for the prediction of water quality have identified a potential for metal leaching or acidic drainage, the consideration of these results is essential, from the conceptual stage of planning onwards.

Prevention and Control of Metal Leaching and Acidic Drainage from Waste Rock and Tailings

R 310: Demonstrated practices should be planned and implemented to prevent or control acid generation and/or metal leaching from waste rock piles and tailings management facilities, where the potential exists. These practices may include:

- limiting the production of waste rock with acid generation or metal leaching potential;
- preventing or limiting the availability of oxygen to the acid-generating material by:
- disposing of potentially acid generating waste rock or tailings under a water cover; or
- using composite covers with a saturated layer to limit infiltration of oxygen;
- blending or layering potentially acid generating material with neutralizing materials;
- segregating potentially acid generating or metal leaching material from other material to facilitate efficient management of this material and to reduce the volume of material that needs to be managed in a way that prevents or controls acid generation and metal leaching; and,
- diverting surface water away from storage areas to minimize flushing and volumes of effluent.

In designing waste rock piles and tailings management facilities at sites where there is a risk of acid generation, there are several methods which may be used to prevent or control acidic drainage. While strategies to prevent and control acidic drainage may be implemented later in the mine life cycle, it is most cost effective to plan for them during the design phase.

In addition to concerns about acidic drainage, tailings from gold and some base metal ore processing facilities that use cyanide can have added concerns related to cyanide. Natural degradation of cyanide through exposure to sunlight during the summer months may be used as a treatment method for cyanide. This process can be optimized by ensuring, at the design phase, that the retention time of the liquid phase in tailings management facilities is adequate for natural degradation to occur.

Acidic Drainage in the North

R 311: In cases where freezing of waste rock or tailings in permafrost is to be used as a method to prevent or control acidic drainage, consideration should be given to the potential for a warmer climate to thaw the construction material in the future. An alternative method to prevent or control acidic drainage that does not depend on the use of frozen material should be developed if it is determined that there is a significant risk of future thawing.

Although sulphide oxidation of waste rock and mine tailings is generally slowed in northern, colder climates, its potential environmental impact remains a concern. There are a number of factors which contribute to the slowed formation of acidic drainage in colder regions:

- compacted snow and ice cover may help to reduce the rate of oxygen diffusion into the waste material, reducing the rate of oxidation;
- permafrost encapsulation reduces the rate of sulphide oxidation; and
- low temperature limits the rate of oxidation reactions that do occur in the active layer of permafrost during the summer months.

The potential of acidic drainage is not eliminated in the northern environment. Potentially acid generating materials are capable of generating acid within the seasonal thaw period. Precipitation and seasonal snow melts may flush accumulated acid into the environment, and oxygen is more soluble in cold water. Further, the oxidation of sulphide minerals is an exothermic reaction, meaning that heat energy is released during the reaction. This energy may prevent or slow the penetration of permafrost into the waste material.

If tailings are disposed of in a permafrost area and permafrost thaws in the future as a result of climate change, the rate of acid generation may begin to increase.

Selection of Locations for Waste Rock Piles and Tailings Management Facilities

R 312: The following factors should be considered in choosing the location for waste rock piles and tailings management facilities:

- local and regional surface water and groundwater flow and potential surface water and groundwater contamination;
- water management scheme and preliminary water balance;
- permafrost conditions in northern areas;
- topography;
- sites of existing (open or closed) waste rock piles;
- existing and possible future land and resource uses, including use of the receiving watershed and distance from habitation and areas of human activity;
- baseline environmental conditions, including natural flora and fauna;
- potential impacts on vegetation, wildlife, aquatic life and any downstream communities;
- condition of basin and dam foundations;
- deposition plane and storage volume/capacity;
- preliminary design of containment and water management structures;
- potential impact area;
- potential releases of airborne particulate matter;
- aesthetic considerations; and
- mine closure considerations.

The rationale for the selection of the site should be clearly documented, including discussion of alternate sites that were considered and rejected.

Tailings Management Facility Design

R 313: The following factors should be considered in the design of tailings management facilities:

- physical and chemical characteristics of the tailings material, including metal leaching and acidic drainage potential, as well as the potential for liquefaction;
- hydrology and hydrogeology, including local climatic conditions and extreme weather events (projections of increased extreme weather events as a result of global climate change should also be included);
- foundation geology and geotechnical considerations, as well as seismic data and earthquake risk;
- availability and characteristics of construction materials;
- topography of the tailings management facility and adjacent areas; and
- permafrost conditions in northern areas.

R 314: In designing tailings management facilities, the retention time for wastewater in the facilities should be maximized to allow for settling of suspended solids and the natural degradation of contaminants such as ammonia and cyanide.

At least 90% of the material that is sent for ore processing typically ends up as tailings. Tailings management facilities are key elements of the environmental management infrastructure at most mine sites. Tailings management facilities include all components and facilities functionally pertaining to tailings management, including dams, spillways, decant structures, tailings lines, as well as settling and polishing ponds. Frequently, effluents such as mine water and site runoff are directed to the tailings management facility for treatment prior to being released into the environment. Therefore, proper design of tailings management facilities is critical to ensuring effective environmental management.

The design of tailings management facilities requires the development of a comprehensive water balance for the mine site that takes into account all water inputs and losses.

Design of Containment Structures for Tailings Management Facilities

R 315: In designing and constructing containment structures for tailings management facilities, such as dams, stringent engineering standards should be employed.

R 316: The long-term monitoring and inspection of containment structures for tailings management facilities should be considered during the design and construction phase. In particular, appropriate instrumentation should be installed during construction to facilitate monitoring during the mine operations and closure phases. Specific design allowances should be made for and consideration should be given to location-specific conditions, such as the presence of permafrost, slopes, seismic activity and site drainage requirements, particularly during peak flow conditions.

The Mining Association of Canada Guide to the Management of Tailings Facilities is a useful reference document with respect to the design, construction, operation, and decommissioning of tailings management facilities. As well as the Canadian Dam Association Dam Safety Guidelines (2007) should be consulted.

In the North, materials and methods of construction used for tailings dams need to allow for the potential of permafrost thaw leading to soil instability and settling. Settling during a thaw may cause differential movement and cracking of dam structures, internal erosion, and the subsequent breaching of the dam. The deposition of fresh tailings may also melt permafrost, and the concentration of the process liquids may lower the freezing point of soil water exposed to the tailings.

4.3.4 LONG-TERM STABILITY OF WASTE ROCK PILES AND TAILINGS MANAGEMENT FACILITIES

Long-term Stability of Waste Rock Piles

R 317: Waste rock piles should be designed to remain structurally stable throughout the mine life cycle and post closure. Local seismic stability data and the risk of earthquakes should be considered in the design of waste rock piles.

The long-term physical stability of waste rock piles is an important consideration. The failure of a slope of waste rock piles can have impacts on aquatic and terrestrial habitat, and it can compromise any measures implemented to prevent or control acidic drainage from the waste rock piles.

Long-term Stability of Tailings Management Facilities

R 318: Tailings management facility risks should be assessed and managed in each phase of the life cycle to determine potential failure modes and probabilities and the consequences of failure. Measures should be planned to reduce these risks and to put in place contingency plans in the event of failure.

R 319: Tailings management facilities should be designed to remain structurally stable, as per the Dam Safety Guidelines of the Canadian Dam Association. Tailings management facilities should be designed to withstand a probable maximum flood (PMF) event. Further, containment structures should be designed to remain structurally stable in the event of a maximum credible earthquake (MCE).

The long-term stability of tailings management facilities and containment structures is a very important consideration. Failures of tailings management facilities can have severe impacts on aquatic and terrestrial ecosystems, and they can pose significant risks to human health and safety.

A probable maximum flood (PMF) is defined as "the flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the drainage basin under study."[3] The PMF is estimated using historical data and is re-estimated periodically as more data are collected. The PMF is often estimated to be the flood generated by the most severe precipitation possible at a site at a particular time of year, referred to as the probable maximum precipitation (PMP). The World Meteorological Organization has published the Manual for Estimation of Probable Maximum Precipitation (1986), which describes techniques for estimating the PMP. The Guidelines on Extreme Flood Analysis (Alberta Transportation, 2004) may also be consulted.

The Maximum Credible Earthquake (MCE) is defined as "the largest reasonably conceivable earthquake that appears possible along a recognized fault or within a

3 Federal Guidelines for Dam Safety: Glossary of Terms. U.S. Department of Homeland Security, Federal Emergency Management Agency. 2004.

geographically defined tectonic province, under the presently known or presumed tectonic framework."[4]

4.3.5 PLANNING AND CONSTRUCTION OF WASTEWATER TREATMENT SYSTEMS

R 320: Wastewater treatment systems should be planned taking into account:

- the water management plan;
- the results of prediction of wastewater quality;
- the waste rock and tailings disposal plans;
- relevant regulatory requirements for effluent quality; and
- relevant environmental performance indicators, including any water quality objectives.

Effective wastewater treatment is essential to ensuring that mine effluent does not affect aquatic ecosystems. Depending on the predicted wastewater quality, treatment may be required to adjust pH and reduce concentrations of metals, suspended solids, cyanide, ammonia, thiosalts and other contaminants.

4.3.6 CYANIDE MANAGEMENT PLANNING

R 321: For mines that will use cyanide for the processing of gold or base metals ores, cyanide management should be planned in a manner consistent with practices described in the International Cyanide Management Code (International Cyanide Management Institute, 2008). In particular, cyanide management planning should take into consideration:

- measures to minimize the amount of cyanide required, thereby reducing reagent use and limiting concentrations in tailings;
- design and implementation of measures to manage seepage from cyanide facilities to protect surface water and groundwater;
- design and operation of cyanide treatment systems to reduce cyanide concentrations in effluent discharged to the environment; and
- design and implementation of spill prevention and containment measures for process tanks and pipelines.

4 Selecting seismic parameters for large dams – Guidelines. International Commission on Large Dams. 1989.

R 322: If natural degradation of cyanide is to be used as a treatment method for cyanide, the tailings management facility should be designed to ensure that the retention time of the liquid phase is adequate for natural degradation to occur during high flow conditions, e.g., during spring runoff.

4.3.7 OTHER CONSIDERATIONS

Management of Chemicals

R 323: The design processes for new metal mines and modifications to existing metal mines should include procedures to:

- identify potential environmental concerns associated with proposed chemical processes and related environmental effects; and
- assess the use of alternative processes and chemicals, when they are available, with a view to mitigating or eliminating environmental effects.

R 324: Site-specific chemical management procedures should be developed and implemented for the safe transportation, storage, handling, use and disposal of chemicals, fuels and lubricants. These procedures should include appropriate emergency preparedness planning.

R 325: Each mine owner/operator should evaluate, on an ongoing basis, opportunities to reduce the quantities of potentially harmful chemicals used in the operation of the mine. This evaluation should include consideration of:

- selection of equipment and processes;
- potential modifications to existing equipment;
- new technologies, processes and procedures;
- the substitution of different materials;
- equipment maintenance; and
- employee training programs.

Based on this evaluation, measures to reduce the use of potentially harmful chemicals should be implemented, as appropriate.

R 326: The chemical storage and containment facilities used at each mine should be designed and constructed to meet the appropriate standards, regulations and guidelines of pertinent regulatory agencies and the owner/operator's environmental policy, objectives and targets. As a minimum, chemical storage and containment facilities should:

- be managed to minimize the potential for spills;
- provide containment in the event of spillage and be managed to minimize opportunities for spillage;
- comply with Workplace Hazardous Materials Information System (WHMIS) standards;
- ensure that incompatible materials are stored in ways to prevent accidental contact and chemical reactions with other materials; and
- minimize the probability that a spill could have a significant impact on the environment.

A wide range of chemicals are used at mining facilities. These can include fuels and lubricants, process reagents, and explosives, as well as a range of other chemicals, such as cleaning products, de-icing products and paints. Many of these chemicals could pose a risk to the environment or human health if they are released in sufficient concentrations. Further, some chemicals could react if they come in contact with or are exposed to other chemicals, and these reactions may pose a significant risk to human health and the environment. Therefore, the transportation, storage, usage and disposal of these products need to be carefully planned and implemented.

Sewage and Domestic Wastewater Disposal

R 327: Where sewage or domestic wastewater is to be disposed of on site, rather than sent to a municipal sewage treatment plant for disposal, an on-site sewage treatment facility should be constructed. The objective of these facilities is to prevent the contamination of surface water and groundwater, including drinking water supplies, and to meet all applicable regulatory standards.

R 328: Sludge from the treatment of sewage and domestic wastewater should be disposed of in an acceptable manner. Sludge may be disposed of on site or in a landfill, it may be used as cover material for tailings or waste rock, or it may be disposed of off site.

Management of Kitchen and Food Wastes

R 329: Wastes from on-site kitchen and dining facilities should be disposed of in a manner that does not attract wildlife. Measures should be put in place to ensure that all food wastes and food containers are properly disposed of, including those used away from kitchen and dining facilities. Training programs should be put in place to ensure that all employees and on-site contractors are aware of the importance of proper disposal of food wastes and the importance of not feeding wildlife on site.

Food and food wastes can attract animals to mine sites. This puts the animals at risk and, depending on the type of animals attracted, may also put staff at risk. Animals that are attracted to sites and become a risk to humans may have to be relocated or destroyed.

Avoidance of Environmentally Sensitive Areas

R 330: All mine facilities should be located and designed to avoid environmentally sensitive areas. The determination of environmentally sensitive areas should be undertaken in consultation with appropriate stakeholders, local Aboriginal communities and government officials.

On-Site Roads and Access Roads

R 331: Roads should be routed to avoid water bodies and wildlife habitat, where possible, and should be designed to avoid sharp turns to minimize the risk of spills and accidents. Route placement should consider the final use of roads with respect to either enhancing or limiting continued access to wilderness and developed areas by the public following closure.

Construction of roads is necessary on site, and, for mines in remote areas, the construction of access roads is frequently required. Access roads need to be able to handle the large trucks commonly used to transport goods to and from mine sites.

R 332: Measures should be designed and implemented to prevent and control erosion from roads associated with mining facilities. These measures should include:

- providing buffer zones of at least 100 m between roads and water bodies to the extent practicable; and
- designing road grades and ditches to limit the potential for erosion, including avoiding road grades exceeding 12% (5% near water bodies).

Since roads are not usually paved, these roads may be significant sources of sedimentation to adjacent water bodies unless appropriate measures are taken to control erosion from road surfaces.

R 333: Stream crossings for roads should be designed and constructed in a manner that protects fish and fish habitat. In particular, design and construction should prevent sedimentation of the streams and not obstruct movement of fish.

Where stream crossings have the potential to alter or destroy fish habitat, the Policy for the Management of Fish Habitat (1986), prepared by the Department of Fisheries and Oceans, should be consulted. In designing crossings, the Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta prepared by Alberta Transportation may be consulted.

Disposal of Snow

R 334: Locations for the disposal of snow should be identified. Snow should not be disposed of directly into lakes and streams or onto any ice-covered water body. Groundwater recharge areas, wetlands and areas with sensitive vegetation should be avoided. Measures should be taken to prevent contamination of water bodies by runoff from snow disposal areas, such as by directing runoff to settling ponds prior to discharge. Snow should be piled down from south to north. The south side will melt first and water will flow around or under the pile rather than over potential contaminants left upstream.

Pipelines

R 335: The routes of pipelines should be selected so as to limit risk of harm to aquatic and terrestrial ecosystems in the event of a failure. Pipelines should be designed to reduce the risk of failure, and measures should be in place to limit impacts in the event of a failure. Once operational, pipelines should be inspected on a regular basis to ensure they are in good condition, and monitoring systems should be in place to alert operators in the event of a potential problem.

Pipelines may be used on mine sites to carry fuel or tailings. A pipeline failure could have significant impacts on aquatic or terrestrial ecosystems unless the pipelines are properly located and appropriate measures are in place to limit impacts if a pipeline does fail. The failure of a pipeline could also pose an occupational health risk and could contaminate groundwater as well as surface water.

Conveyor Systems

R 336: The routes of conveyor systems should be selected so as to limit risks to the environment or human health from airborne particulate matter associated with the systems. To the extent feasible, conveyor systems should be enclosed to prevent or limit the release of airborne particulate matter. Loading and off-loading facilities for conveyor systems should be enclosed or other measures should be in place to prevent or limit the release of airborne particulate matter from loading and off-loading operations.

Conveyor systems are frequently used outside enclosed buildings to transport crushed or ground ore or other materials. Open conveyor systems can be a significant source of airborne particulate matter, which can pose risks to human health and the environment.

Clearing of Vegetation

R 337: Clearing of vegetation in preparation for construction should be carried out in such a way that:

- the area cleared is minimized;
- buffer zones of natural vegetative cover of at least 100 m are retained wherever possible between cleared areas and adjacent bodies of water; and
- the time between clearing of an area and subsequent development is minimized.

Note that the first two bullets also apply during the exploration and feasibility phase, particularly in the context of establishing camps and access roads and stripping outcrops.

Where feasible, vegetation from cleared areas may be replanted in nearby habitats for future relocation following mine closure.

The natural vegetation of a site is frequently the most effective and least costly protection against erosion. Vegetation along a shoreline is particularly important because it protects against erosion and reduces the potential for sediment generated on the construction site to enter a water body. Once an area is cleared, the potential for erosion increases with time until the area is suitably developed. A desire to minimize mobilization costs for clearing equipment and crews and a lack of thorough planning may result in areas being cleared unnecessarily or too early in the project.

Preservation and Stockpiling of Overburden

R 338: Site-specific procedures should be developed and implemented to ensure that overburden, particularly organic soils, excavated from the mine site during construction is preserved and stockpiled for future reuse in site reclamation. Facilities for stockpiling should be designed to prevent or limit erosion of the stockpiled material by rainfall or wind. Measures should be put in place to ensure that stockpiled material is not contaminated during mine operations.

Overburden from a mine site can provide ideal material for use in reclamation of the mine site, either as part of progressive reclamation during mine operations or during the mine closure phase.

Sedimentation Control

R 339: Site-specific plans for site erosion and sediment control should be developed and implemented. Measures that should be considered during the mine planning, construction, operations and closure phases include:

- determining site erosion potential and identifying water bodies at risk;
- establishing to the extent possible buffer zones of at least 100 m around water bodies that are at risk of sedimentation;
- recontouring to reduce the susceptibility of soil to erosion;
- revegetating and maintaining vegetated buffer zones adjacent to any water body for erosion control;
- diverting site drainage away from cleared, graded, or excavated areas;
- using and maintaining sediment barriers or sediment traps to prevent or control sedimentation;
- directing surface runoff from erodible areas to a settling pond prior to discharge to the environment; and
- monitoring and maintaining the measures once they are in place to ensure they are effective.

During the construction and mine operations phases, eroded sediment can become mobilized in the environment. Once in a watercourse, sediment can affect fish and fish habitat.

The mobilization of sediment to watercourses is influenced by weather, the season, the type of soil and the topography of the site. It is important to use appropriate control measures that will reduce erosion and prevent sediment from entering any water body on or adjacent to the site as a result of areas disrupted by the mine.

Northern Conditions and Permafrost Issues

R 340: The planning and construction of mines in the North should be undertaken in a manner that minimizes impacts to the environment, including surface water and groundwater quality, fish and wildlife, natural habitat and other unique northern features such as permafrost. Activities should be planned with consideration of:

- the project's requirements in terms of air landing strips, campsites or accommodation facilities, fuel and supply storage areas, survey lines and monuments, excavations, waste disposal and other infrastructure;
- the geography and vegetation of the area, including natural features such as eskers, rivers, streams, lakes and ponds, and pingos; and
- consideration of appropriate siting of mine components and monitoring of conditions that account for the presence of permafrost.

The sensitivity and uniqueness of conditions in Canada's North pose many specific considerations when planning mining activity. Characteristics which should be recognized and addressed include:

- an extreme climate of long, cold winters and short summers;
- a very thin and sensitive vegetation cover;
- relatively low precipitation levels resulting in generally arid conditions;
- occurrence of unstable bedrock conditions with thin or absent soil cover;
- permanently frozen ground; and
- the existence of extensive but impact-prone wildlife resources, such as caribou, muskox, polar bear and migratory birds.

4.3.8 CLIMATE CHANGE AND ADAPTATION

Sites in the Planning and Construction Phase

R 341: Strategies for reducing carbon releases to the atmosphere should be considered and implemented throughout all phases of the mine life cycle. Carbon reduction opportunities should include the use of heavy equipment and vehicles that are fuel efficient and/or use alternative fuel.

R 342: In planning all aspects of mine operations, particularly water management and mine waste management and disposal, the potential impacts of climate change should be considered. Regional long-term predictions of climate change should be consulted, and predicted changes with respect to temperature, precipitation and extreme weather events should be taken into account. In areas of permafrost, the potential impacts of climate change should also be considered with respect to other aspects of site infrastructure, such as roads, pipelines, and on-site structures, all of which could be affected by deterioration of the permafrost. Any aspects of site infrastructure that could be affected by climate change should be planned, constructed and operated in a manner that will reduce or eliminate the potential impacts associated with climate change.

Sites in the Mines Operations or Mine Closure Phases

R 343: Owners/operators of sites in the mine operations or mine closure phases should consult regional long-term predictions of climate change. A risk assessment should be carried out to identify any aspects of site infrastructure that could be affected by climate change, including predicted changes with respect to temperature, precipitation and extreme weather events. Measures to mitigate these risks should be planned and implemented in a manner that reduces or eliminates the potential impacts associated with climate change.

Future changes in climate could have significant impacts on many aspects of mining operations, and considering predicted changes due to climate change is important for all mining facilities.

The potential impacts are most evident in the North. In particular, mine waste disposal strategies that rely on permafrost encapsulation of waste to prevent acidic drainage or metal leaching could be at risk if permafrost deterioration occurs in the future as a result of climate change. Deterioration of permafrost could result in acidic drainage or metal leaching at such a site at some time in the future. Similarly, frozen core dams and other containment structures that are designed to remain frozen in order to remain structurally sound could be at risk of failure if these structures thaw. Other aspects of site infrastructure such as roads, runways or building foundations could also be at risk if permafrost deterioration occurs during the operational life of the infrastructure.

Climate change may have impacts on mining operations in all parts of Canada, not just those in areas of permafrost. In particular, water management infrastructure and associated waste management facilities may be a risk unless they are designed appropriately. For example, water management infrastructure is often designed to perform in a once in 100 year or once in 1000 year storm event, such as a severe rainfall event. However, if extreme precipitation events become more common and more extreme, water management infrastructure that is designed based on historical precipitation events rather than predicted future precipitation events may not be adequate.

Similarly, tailings management strategies that are dependant on keeping tailings under water cover could be at risk in an extreme drought event. Drought conditions could result in the loss of the water cover, at least on a temporary basis. This could lead to acidic drainage or metal leaching of the tailings.

4.4 ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE MINE OPERATIONS PHASE

4.4.1 WATER MANAGEMENT

R 401: Site-specific programs should be developed and implemented to monitor the quality of collected mine water and seepage from waste rock dumps and tailings management facilities. As a minimum, these programs should:

- describe the surficial and subsurface geology, including aquifers and aquitards;
- identify and characterize local groundwater resources and uses;
- indicate the locations of mine water and seepage sampling stations and mine waste areas;
- provide water sampling, handling and analyses protocols (where analyses are completed by outside laboratories, metal mines should have copies of the protocols used); and
- provide a groundwater database that is updated as sampling is undertaken.

During operations, the emphasis of water management shifts from planning to the implementation and ongoing review of water management practices. Water management plans need to be adapted as necessary to address changing conditions and new risks. Ongoing review and planning are facilitated by the collection of comprehensive monitoring data, which serve to validate the assumptions and predictions that were made during the planning and construction phase.

R 402: The hydrological models that were used in planning the water management system should be recalibrated. Data collected to complete this calibration should include:

- climatic variables, such as precipitation, temperature, solar radiation, relative humidity, and wind speed and direction;
- lake levels and snow pack thickness;
- stream flow and effluent discharge rates; and
- beaver activity and dam construction, where applicable.

R 403: Water management activities during the mine operations phase should include:

- monitoring to check and report on the performance, status and safety of water management facilities;
- inspection of pipelines for flow and hydraulic integrity;
- monitoring of water quality and level in retention facilities, such as tailings management facilities, sedimentation ponds and polishing ponds;
- inspection of drainage ditches and dikes for sediment accumulation and bank erosion and damage; and
- efforts to identify and implement ways to recycle water and reduce the use of fresh water as much as possible.

4.4.2 MANAGEMENT OF WASTE ROCK AND TAILINGS

Use of Tailings and Waste Rock as Mine Backfill

R 404: Where feasible, the owner/operator of a mine should use tailings and waste rock as mine backfill in order to reduce the quantities of these wastes that are placed in tailings management facilities and waste rock piles.

R 405: Tailings and waste rock being considered for use as mine backfill should be assessed to ensure that the material will be suitable for use as backfill, particularly if the material is to be used to provide structural support in underground mines. This should include an assessment of the physical as well as the chemical characteristics of the material to ensure that it has appropriate structural properties for use underground and to ensure that chemical alteration of the material will not compromise its structural properties or pose a risk to the environment.

R 406: Where potentially acid generating materials are used as mine backfill, monitoring measures should be implemented to assess impacts of the material on the quality of mine water and to predict potential impacts on the quality of mine water after mine closure. Potential impacts on regional groundwater quality should also be assessed.

Tailings and waste rock may be used in underground mines as backfill. This helps to provide structural support underground by filling mine voids. Tailings are thickened and may be mixed with cement prior to use as backfill. Similarly, waste rock used as backfill may also be mixed with cement. At some open pit operations, tailings and waste rock may also be disposed of in mined-out pits as an alternative to disposal on the surface.

Where tailings or waste rock are to be considered for use underground, a wide range of factors need to be considered in evaluating the suitability of the material. Using inappropriate material as backfill may increase the risks of injury or death for those working underground. Some of the properties that should be considered, particularly with respect to tailings, include:

- mineralogy
- specific gravity
- moisture content
- percent solids
- void ratio
- porosity
- rheology
- grain size distribution
- unconfined compressive strength
- shear strength.

Management of Tailings Management Facilities

R 407: Tailings management facilities should be controlled and monitored using a formalized procedure that is incorporated into the mine's EMS. Key control and monitoring subject areas should include:

- inspections of tailings management facilities with regard to performance monitoring, instability indicators, stability monitoring, tailings deposition, water management and control, and quality of effluent;
- construction controls, including the use of a construction management program;
- procedures for dust control; and
- quality assurance and quality control measures for all aspects of operations, monitoring and inspections.

As with water management, the emphasis for tailings management during the mine operations phase shifts from planning to the implementation and ongoing review of tailings management practices. Monitoring of all aspects of the performance of a tailings management facility is essential to ensuring that the facility is performing as designed.

R 408: All procedures related to the environmental management of tailings management facilities should be clearly documented, together with the roles and responsibilities of all relevant staff. This documentation should be revised as needed to ensure that it is up to date and accurate, and it should be maintained throughout the mine operations and mine closure phases.

The Mining Association of Canada has developed a document entitled Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities (2005), which provides useful guidance in documenting staff roles and management procedures, including:

- roles and responsibilities of personnel assigned to the tailings management facility;
- procedures and processes for managing change;
- the key components of the tailings management facility;
- procedures required to operate, monitor the performance of, and maintain the facility to ensure that it functions in accordance with its design, meets regulatory and corporate policy obligations, and links to emergency planning and response; and
- requirements for analysis and documentation of the performance of the facility.

4.4.3 MONITORING OF WASTE ROCK AND TAILINGS

R 409: Site-specific waste rock and tailings monitoring programs should be designed and implemented to:

- assess the potential of waste rock and tailings for metal leaching and acidic drainage;
- verify predictions made during the mine planning phase;
- collect data required for modelling;
- assess the level of acid generation when oxidizing reactions are occurring, and assess acidity and reaction products that are potentially available to migrate;
- evaluate the effectiveness of measures that have been implemented to prevent and control metal leaching and acidic drainage; and
- identify potential surface seeps and groundwater contamination.

Monitoring is used to evaluate the environmental performance of operations. On-site monitoring can include the safety of the equipment and the facility at waste rock piles and tailings management facilities, as well as hazardous substance storage and disposal facilities.

The primary focus of waste rock and tailings monitoring is surface and groundwater quality. Monitoring is often conducted on seepages and runoff from waste rock piles and tailings management facilities to detect changes in water quality and locate specific sources of concern prior to encountering problems with effluent quality at the final point of discharge. Tailings monitoring may also include analyses of groundwater, pore water, and tailings characteristics.

4.4.4 MANAGEMENT OF TREATMENT SLUDGE

R 410: Sludge that is a by-product of the treatment of mine effluent should be managed so that it will remain in a physically and chemically stable state. In this regard, a mine owner/operator should:

- characterize treatment sludge to determine whether there are potential leaching concerns;
- avoid disposal of treatment sludge with potentially acid generating wastes;
- dispose of sludge in a physically secure facility under conditions that will maintain the chemical stability of the sludge; and
- treat and monitor wastewater from the sludge management facility as necessary to ensure regulatory requirements are met.

In cases where a mine is predicted to produce large volumes of sludge over an extended period of time, the mine owner/operator should consider using a treatment process that produces a denser, lower volume sludge.

Treatment sludge that is a by-product of mine effluent treatment should be carefully managed to ensure long-term chemical stability and to prevent any releases of metals.

4.4.5 MANAGEMENT OF OTHER WATER QUALITY CONCERNS

Ammonia Management

R 411: Mines using ammonium-based explosives should adopt best management practices for blasting and the handling of these explosives to avoid spillage and minimize ammonium residue remaining after blasting, thereby lowering the potential for ammonium contamination.

R 412: Site-specific ammonia monitoring and management plans should be developed and implemented to assist in ensuring that final effluent is not acutely lethal and does not have an adverse impact on the receiving aquatic environment. As a minimum, the plans should:

- identify potential sources of ammonia, including explosives and cyanate hydrolysis;
- estimate ammonia loading and identify the need for additional controls if warranted; and
- include procedures to assist in mitigating ammonia contributions from blasting agent spillage or other losses.

Cyanide Management

R 413: Building on recommendation R 321, cyanide and cyanide related materials should be transported, stored, used and disposed of in a manner consistent with the practices described in the International Cyanide Management Code (International Cyanide Management Institute, 2002). In particular, mines using cyanide should:

- implement preventative and mitigative measures to protect fish and wildlife from direct and indirect discharges of cyanide process solutions to surface water and groundwater;
- implement routine monitoring programs to evaluate the effects of cyanide exposure on wildlife, surface water and groundwater quality; and
- plan and implement procedures for effective decommissioning of cyanide facilities to protect surface water and groundwater.

Thiosalts Management

R 414: At sites where there is a risk of thiosalts occurring in wastewater from ore processing:

- measures should be taken to minimize the discharge of thiosalt-bearing wastes to the environment either by recycling the water back to the ore processing facility or by implementing measures to ensure thiosalt degradation on site;
- programs should be designed and implemented to monitor concentrations of thiosalts in wastewater as well as to check for pH depression downstream; and
- treatment systems or mitigation measures should be put in place to minimize the concentration of thiosalts in effluent before it is discharged to the environment.

4.4.6 MANAGEMENT OF AIR QUALITY ISSUES

Measures to Control Greenhouse Gas Emissions

R 415: Site-specific plans should be developed and implemented to minimize releases of greenhouse gases. Plans should describe:

- potential sources of releases of greenhouse gases;
- factors that may influence releases of greenhouse gases;
- measures to minimize releases of greenhouse gases;
- monitoring and reporting programs for releases of greenhouse gases;
- mechanisms to incorporate the results of monitoring programs into further improvements to measures to minimize releases; and
- mechanisms to periodically update the plans.

Measures to Control Releases of Airborne Particulate Matter

R 416: Site-specific plans should be developed and implemented to minimize releases of airborne particulate matter. These plans should describe:

- potential sources of releases of airborne particulate matter, including specific activities and specific components of mine infrastructure;
- factors that may influence releases of airborne particulate matter, including climate and wind;
- potential risks to the environment and human health from releases of airborne particulate matter;
- measures to minimize releases of airborne particulate matter from the sources identified;
- monitoring programs for local weather, for consideration in the ongoing management of releases of airborne particulate matter;
- monitoring and reporting programs for releases of airborne particulate matter and for environmental impacts of releases;
- mechanisms to incorporate the results of monitoring programs into further improvements to measures to minimize releases; and
- mechanisms to periodically update the plans.

R 417: Consistent with the Canada Wide Standard for particulate matter (PM), the concentration of particulate matter less than 2.5 microns in size ($PM_{2.5}$) should not exceed 15 $\mu g/m^3$ (24-hour averaging time) outside the boundary of a mining facility.

Particulate matter, especially particles less than 10 microns (μm) in size, can affect human health and the environment. Particulate matter can also be potentially harmful in cases where it contains metals or other contaminants. The release of airborne particulate matter can be a concern throughout the mine life cycle. This discussion and related recommendations should also be considered in other phases of the mine life cycle, particularly during construction and mine closure.

Releases of airborne particulate matter may result from many mining related activities, including blasting, crushing, loading, hauling, and transfer by conveyor. Open pits, waste rock piles, tailings management facilities, and stockpiles are potential sources of wind-blown particulate matter. Wind can carry particulate matter for some distance off site before deposition occurs.

4.4.7 MANAGEMENT OF NOISE AND VIBRATION

Measures to Control Noise

R 418: Site-specific assessments should be conducted to identify sources, or potential sources, of noise, and measures should be implemented to reduce noise levels from these sources. Such measures should include consideration of:

- elimination of noise sources;
- the purchase of equipment with improved noise characteristics;
- proper maintenance of equipment;
- enclosure or shielding of sources of noise;
- suppression of the noise at source;
- locating noise sources to allow natural attenuation to reduce levels to potential recipients; and
- the operation of noise sources only during hours agreed to in consultation with local communities.

Monitoring should be conducted to assess the effectiveness of these measures and to plan further improvements in noise reduction.

Ambient Noise from Mining Operations

R 419: In residential areas adjacent to mine sites, the equilibrium sound pressure level (L_{eq}) from mining activities should not exceed 55 dBA during the day and 45 dBA at night. Ambient noise can also affect wildlife, so sites in remote locations should also work to meet these objectives for off-site ambient noise levels.

Control of Noise and Vibration from Blasting

R 420: Mines in areas where ground vibration and noise from blasting are not regulated should design their blasts so that the following criteria are not exceeded at or beyond the boundaries of the mine property:

- ground vibration of 12.5 mm/sec peak particle velocity measured below grade or less than 1 metre above grade; and
- concussion noise of a maximum of 128 dB.

Blasting in or Adjacent to Fish-Bearing Water Bodies

R 421: Blasting conducted in or adjacent to any fish-bearing water body should be done in accordance with the Guidelines for the Use of Explosives in or near Canadian Fisheries Waters, prepared by the Department of Fisheries and Oceans (1998).

In addition to potential effects on nearby communities and structures from vibration and noise caused by blasting, blasting in or adjacent to fish habitat can disturb, injure or kill fish and it can cause the harmful alteration, disruption or destruction of their habitats. The Guidelines for the Use of Explosives in or near Canadian Fisheries Waters provides information on the conservation and protection of fish and their habitat from impacts arising from the use of confined or unconfined explosives in or near Canadian fisheries waters.

4.4.8 ENGINE OPERATION AND MAINTENANCE

R 422: Engines in vehicles and stationary equipment should be maintained and operated in a manner that minimizes emissions of criteria air contaminants, particularly:
- total particulate matter (TPM);
- particulate matter less than or equal to 10 microns (PM_{10});
- particulate matter less than or equal to 2.5 microns ($PM_{2.5}$);
- sulphur oxides (SO_x);
- nitrogen oxides (NO_x);
- volatile organic compounds (VOCs); and
- carbon monoxide (CO).

R 423: Maintenance shops should be operated to ensure that potential contaminants, such as used lubricants, batteries and other wastes, are properly managed. Appropriate disposal mechanisms should also be in place for these materials. Stores should be managed such that potentially hazardous materials are handled in accordance with procedures detailed in the environmental management system for the mine.

The operation and maintenance of engines at mining facilities, both those in vehicles and those in stationary equipment such as generators, should be properly managed to minimize air emissions and to minimize or prevent releases associated with vehicle maintenance.

4.4.9 PROGRESSIVE RECLAMATION

R 424: Progressive reclamation should be undertaken over the mine life cycle to reduce environmental impacts and the amount of work to be done during the mine closure phase. The owner/operator of each metal mine should develop a site-specific progressive reclamation schedule as part of the closure plan. The schedule should be used by mine staff to monitor the status of progressive reclamation activities, and the schedule should be updated on a regular basis. Progressive reclamation activities should be consistent with the site-specific objectives for mine closure and the intended post-closure land use for the site.

Progressive reclamation is the reclamation of certain areas of a mine site before the mine ceases operations and enters the final mine closure phase. The implementation of progressive reclamation measures can have many benefits:
- releases of airborne particulate matter, erosion and sedimentation from exposed materials can all be reduced;
- liabilities may be reduced on an ongoing basis if optimizing reclamation work is undertaken during the mine operations phase rather than deferring all closure costs to the mine closure phase;
- aspects of mine closure plans can be tested and the results can be used to improve the mine closure plan; and
- priority areas for ongoing research and/or remediation can be identified.

Progressive Reclamation of Waste Rock Piles and Tailings Management Facilities

R 425: Progressive reclamation of waste rock piles and tailings management facilities should be carried out during the mine operations phase, to the extent feasible. Progressive reclamation activities should be carried out in a manner consistent with the site-specific objectives for mine closure and the intended post-closure land use for the site, as identified in the closure plan.

The planning and implementation of progressive reclamation measures should include consideration of:
- the final contouring of waste rock piles;
- the establishment of a final drainage system;
- the establishment of wet covers or dry covers, where these cover systems are to be used to prevent or control acidic drainage; and
- the revegetation of exposed areas.

Progressive Reclamation of Mine Site Infrastructure

R 426: Progressive reclamation of mine site infrastructure should be carried out during the mine operations phase, to the extent feasible. This may include roads which are no longer used and areas affected during earlier activities, such as drill pads or campsites established during the exploration or construction phases.

4.5 ENVIRONMENTAL MANAGEMENT PRACTICES FOR THE MINE CLOSURE PHASE

4.5.1 EVALUATION OF REVISION OF EXISTING ENVIRONMENTAL PLANS

R 501: At the end of the mine operations phase and throughout the mine closure phase, plans to manage various environmental aspects of the mine that were established and implemented earlier in the mine life cycle should be evaluated and revised to ensure that they remain appropriate for the changing conditions of mine closure. In particular, consideration should be given to the evaluation and revision of the following:

- pollution prevention plans;
- environmental management plans;
- plans for the monitoring and inspection of environmental facilities;
- plans for environmental monitoring; and
- emergency plans.

It is also important that these plans be appropriate to the site conditions and needs after all aspects of the mine closure plan have been implemented, particularly in cases where such plans will still be required after completion of the closure plan in the post-closure period.

The ideal condition for post-closure is a site with no ongoing needs for effluent treatment. However, even at sites where such a "walk away" condition can be achieved, there may still be a requirement, after the completion of the closure plan, for periodic monitoring and inspection to ensure that structures such as dams or covers for tailings or waste rock are still in good condition and are functioning as designed.

4.5.2 FINANCING OF MINE CLOSURE AND LONG-TERM MONITORING, MAINTENANCE OR TREATMENT

Mine Closure Costs

R 502: The anticipated costs of mine closure should be re-evaluated regularly throughout the mine life cycle. The mine owner/operator should ensure that adequate funds are available to cover all closure costs, and the amounts of any security deposits should be adjusted accordingly.

Financing Long-Term Monitoring, Maintenance or Treatment

R 503: At sites where it is determined that long-term monitoring, maintenance or effluent treatment will be necessary post closure, mechanisms should be identified and implemented that will ensure that adequate and stable long-term funding is available for these activities. In determining funding levels required, consideration should be given to contingency requirements in the event of changes in economic conditions, system failures, or major repair work post closure.

All jurisdictions in Canada require mining companies to provide financial sureties to guarantee the costs of repairing environmental damage. It is essential to ensure that all factors are considered to ensure that these sureties are sufficient.

4.5.3 SUSPENDED OPERATIONS AND INACTIVE MINES

R 504: Each mine should develop a plan for the care and maintenance of the mine site in the event that mine operations are suspended or the mine otherwise becomes inactive. The plan should include continued monitoring and assessment of the environmental performance of the site, as well as the maintenance of all environmental controls necessary to ensure continued compliance with relevant regulatory requirements.

At some mine sites operations may be suspended. Since the intent is to re-open the mine at some time in the future, the mine owners/operators do not proceed with the implementation of the final mine closure plan.

However, mines at which operations are suspended may still be sources of environmental releases, and measures should be put in place to ensure ongoing environmental protection during the time that operations are suspended.

4.5.4 ASPECTS TO BE CONSIDERED IN MINE CLOSURE

R 505: Mine closure activities should address the following environmental aspects:

- underground and open pit mine workings;
- ore processing facilities and site infrastructure;
- waste rock piles and tailings management facilities;
- sludge disposal areas as well as ongoing sludge disposal requirements, post closure;
- water management facilities;
- landfill and waste disposal facilities; and
- exploration areas.

Many of the environmental considerations during the mine closure phase are common to all types of metal mines, although there are additional concerns unique to some sites, such as the reclamation of radioactive wastes at uranium mines.

4.5.5 DECOMMISSIONING OF UNDERGROUND AND OPEN PIT MINE WORKINGS

R 506: If it is technically and economically feasible to do so, underground or in-pit infrastructure (e.g., crushers, rails, metal structures, water and air pipes) and equipment (e.g., fans and pumps) should be removed from the site. Any equipment to be left underground or in the pit should be inspected and remediated as appropriate to ensure that there is no risk of leakage of any contaminants.

R 507: During the decommissioning of underground and open pit mines, any contamination associated with vehicle and equipment operations and maintenance should be identified and remediated, as appropriate.

R 508: Underground mine workings should be secured and signs should be posted warning the public of potential dangers associated with the facility. In the event that underground openings are utilized by bats, gates should be installed that allow for continued access by them, while protecting the public.

R 509: The risk of subsidence in underground mines should be assessed. Appropriate measures should be taken to prevent subsidence in cases where the risk of subsidence is determined to be significant. The primary measure used to prevent subsidence is the backfilling of underground voids.

R 510: Open pits should be backfilled or flooded to the extent practicable to prevent unauthorized access and to protect public safety. In cases where backfilling or flooding is not practically feasible, fencing should be installed to protect the public. In all cases, signs should be posted warning the public of potential dangers associated with the site.

A key concern in the decommissioning of mine workings is public safety. All openings to underground mines must be secured to prevent unauthorized access. Backfilling or flooding of the mine to the extent feasible is preferred, since fencing requires perpetual inspection and maintenance. An additional concern with the decommissioning of underground mines is subsidence, which may occur if there are any collapses in the underground workings. This could lead to unstable conditions at the surface and in some cases lead to the collapse of the material into the workings. This can be particularly hazardous in populated areas or in cases where the collapse affects roads or railways.

From an environmental perspective, the primary concern is the potential for discharges of mine water from mine workings and the associated risks of surface water contamination.

R 511: The potential for mine water discharges should be assessed. For underground mines, this should be done using a hydrogeological assessment. For open pit mines, this may be done using water balance calculations and, in some cases, hydrogeological assessment. Where mine water discharge is predicted, the flow rate should be estimated.

R 512: Where there is the potential of mine water discharge after mine closure, the quality of the discharge should be predicted. Mine water quality should be assessed once closure has been completed to verify the accuracy of the predictions.

R 513: Where there is the potential of mine water discharge of poor quality, measures should be implemented to prevent or control that discharge and to collect the mine water for treatment. Prevention methods may include capping of mine openings to prevent mine water discharge.

4.5.6 DECOMMISSIONING OF ORE PROCESSING FACILITIES AND SITE INFRASTRUCTURE

R 514: On-site facilities and equipment that are no longer needed should be removed and disposed of in a safe manner, unless facilities or equipment are to be preserved for post-closure land use. Efforts should be made to sell equipment for reuse elsewhere or to send equipment for recycling, rather than disposing of it in landfill facilities.

The decommissioning of ore processing facilities and other on-site structures is carried out in a manner consistent with the intended post-closure land use. Normally, on-site equipment is removed and sold for use at other sites or as scrap.

Buildings and Foundations

R 515: The walls of on-site buildings should be razed to the ground, except in cases where they are to be preserved for post-closure land use. Foundations should be removed or covered with a sufficiently thick layer of soil to support revegetation.

R 516: If buildings are to be preserved, either as a heritage resource or for some other post-closure land use, structures and foundations should be inspected to ensure that no contamination is present. If the structures or foundations are contaminated, they should be remediated as necessary to ensure public health and safety for post-closure land use.

Support Infrastructure

R 517: Support infrastructure, such as fuel storage tanks, pipelines, conveyors and underground services, should be removed, except in cases where it is to be preserved for post-closure land use.

Roads

R 518: The main access road to the site (or runway in the case of remote sites) and other on-site roads, as appropriate, should be preserved in a sufficient condition to allow post-closure access for monitoring, inspection and maintenance activities.

R 519: Roads, runways or railways that will not be preserved for post-closure use should be reclaimed:

- bridges, culverts and pipes should be removed, natural stream flow should be restored, and stream banks should be stabilized by revegetating or by using rip-rap;
- surfaces, shoulders, escarpments, steep slopes, regular and irregular benches, etc., should be rehabilitated to prevent erosion; and
- surfaces and shoulders should be scarified, blended into natural contours, and revegetated.

Electrical Infrastructure

R 520: Electrical infrastructure, including pylons, electrical cables and transformers, should be dismantled and removed, except in cases where this infrastructure is to be preserved for post-closure land use or will be needed for post-closure monitoring, inspection and maintenance. This includes infrastructure on site, as well as any off-site infrastructure owned by the mining company.

R 521: If polychlorinated biphenyls (PCBs) were used on site, any equipment contaminated with PCBs should be disposed of in accordance with relevant regulatory requirements. Soils and subsoils near electrical stations should be assessed to determine whether there is any contamination due to PCBs. If soils are contaminated with PCBs, this contamination should be mitigated in an appropriate manner.

Waste Disposal and Contamination

R 522: Waste from the decommissioning of ore processing facilities and site infrastructure, such as waste from the demolition of buildings and the removal of equipment, should be removed from the site and stored in an appropriate waste disposal site or disposed of on site in an appropriate manner in accordance with relevant regulatory requirements. If material is disposed of on site, the location and contents of the disposal site should be documented.

R 523: Sampling and analysis of soils and other materials should be conducted to ensure that none of the material is contaminated, e.g., with asbestos and mercury from buildings. If contaminated materials are identified, they should be handled and disposed of in an appropriate manner in accordance with all applicable regulatory requirements.

4.5.7 DECOMMISSIONING OF WASTE ROCK PILES AND TAILINGS MANAGEMENT FACILITIES

There are a wide range of factors to be considered in the decommissioning of waste rock piles and tailings management facilities. The primary concerns relate to the long-term physical stability of these facilities and the risks associated with long-term metal leaching and acidic drainage. Access to these facilities may need to be restricted in the interests of safety, for example, in the context of protecting the facilities from damage resulting from post-closure activities such as vehicle operations.

Long-term Physical Stability of Waste Rock Piles and Tailings Management Facilities

R 524: At the end of the mine operations phase, detailed inspections and assessments of waste rock piles and tailings management facilities, particularly dams and other containment structures, should be carried out. The objective of these inspections and assessments is to evaluate the actual performance against design projections related to anticipated post-closure conditions. Factors that should be considered include:

- the extent of deformation;
- the rate and quality of seepage;
- the condition of foundations and sidewalls; and
- design loads, which may be different after mine closure.

R 525: At the end of the mine operations phase, comprehensive risk assessment should be conducted for mine closure to:

- evaluate the long-term risks associated with possible failure modes for waste rock piles and tailings management facilities;
- identify possible impacts on the environment and human health and safety in the event of a failure;
- determine parameters critical to these failure modes and possible impacts; and
- develop and implement long-term control strategies to manage the identified risks.

As described in sections 4.3.3 and 4.3.4, the long-term physical stability of waste rock piles and tailings management facilities is a very important consideration. In particular, the stability of dams or other containment structures for tailings management facilities is vital, since the consequences of a failure after a mine has closed can be just as serious as the consequences of a failure during the mine operations phase.

R 526: At sites where long-term risks are identified under recommendation R 525, a long-term monitoring and maintenance plan for waste rock piles and tailings management facilities should be developed and implemented, as appropriate, to ensure post-closure monitoring and maintenance of these facilities. This plan should include the following elements:

- identification of roles and responsibilities of persons to be involved in monitoring and maintenance;

- identification of aspects to be monitored and the frequency;
- identification of routine maintenance activities to be conducted and the frequency;
- description of contingency plans to address any problems identified during routine maintenance and monitoring.

Prevention, Control and Treatment of Metal Leaching and Acidic Drainage

R 527: At the end of the mine operations phase, plans for management of waste rock and tailings to prevent, control and treat metal leaching and acidic drainage should be re-evaluated and revised as necessary, to ensure that they are consistent with the objectives and plans for mine closure and post closure. This evaluation should consider:

- the results of the re-evaluation of the performance of these facilities;
- the performance of progressive reclamation to date; and
- possible alternative technologies for closure.

R 528: At sites where there is an identified long-term risk of metal leaching or acidic drainage, the site-specific monitoring programs for waste rock and tailings developed under recommendation R 409 should be revised and updated to ensure that monitoring programs are consistent with objectives and plans of mine closure and post closure. The revised plans should include the following elements:

- identification of roles and responsibilities of persons to be involved in monitoring;
- identification of parameters to be monitored and the frequency; and
- description of contingency plans to address any problems identified during routine monitoring.

Practices for the prevention, control and treatment of metal leaching and acidic drainage during the mine closure phase and post closure are largely an extension of those practices planned and implemented earlier in the mine life cycle.

There may be a risk of metal leaching or acidic drainage post closure even at sites that do not experience any problems during the mine operations phase. Prediction work conducted earlier in the mine life cycle should identify such long-term risks. At sites where there is long-term risk, monitoring of waste rock and tailings remains important through mine closure and post closure.

Closure in Permafrost Conditions

R 529: At all mines that exist in permafrost conditions, downstream slopes of tailings containment structures should be revegetated.

Closure in areas where permafrost exists requires special consideration. The tailings management facility may also be capped and revegetated. Capping and revegetating help to establish permafrost in the tailings by ensuring that the overlying materials rather than the tailings are in the active permafrost layer. Where capping is not possible, substantial runoff in excess of evaporation may collect behind the pond, and a permanent spillway may be required.

Decommissioning of Tailings from Uranium Mining Facilities

R 530: At uranium mines, measures should be taken in decommissioning tailings management facilities to prevent or control the release of radon gas. Such measures may include single or multiple soil layers involving waste rock and low-grade tailings or water covers.

Decommissioning of uranium mill tailings management facilities requires special attention to prevent or control the release of radon gas.

4.5.8 WATER MANAGEMENT AND TREATMENT

Water Management

R 531: At the end of the mine operations phase, water management plans should be evaluated and revised as necessary to ensure that they are consistent with the objectives and plans for mine closure and post closure. This evaluation should consider:

- the results of an evaluation of the performance of the existing water management plan;
- expected changes in water flow and water balance on site; and

- expected changes in wastewater volume and composition.

Based on this evaluation, the following should be identified:
- water management structures, such as dams and diversion ditches, that will no longer be needed, methods to be used for decommissioning these structures, and the timing of decommissioning;
- water management structures that will continue to be needed and any long-term maintenance or replacement requirements associated with these structures;
- water management structures that will need to be modified, methods to be used to modify these structures, the timing of modification, and any long-term maintenance requirements associated with these structures; and
- long-term monitoring requirements to ensure that the water management system continues to function as designed.

During the mine closure phase there may be significant changes in water management as a result of reductions in water use on site, reductions in activities, and the reclamation of the site. As a result, the water management plans in place during the mine operations phase may no longer be appropriate, and some components of those plans may no longer be necessary. Further, new needs for water management may arise as a result of studies and evaluation.

Long-term Treatment of Wastewater

R 532: At sites where it is determined that long-term treatment of wastewater will be necessary during post closure, a long-term wastewater treatment plan should be developed and implemented. This plan should include the following elements:
- identification of roles and responsibilities of persons to be involved in operation and maintenance of the treatment system;
- identification of the type of treatment system to be used;
- identification of any by-products from the treatment system, such as treatment sludge, and management plans for the disposal of those by-products;
- identification of routine maintenance activities to be conducted on the treatment system and the frequency;
- identification of monitoring to assess ongoing performance of the treatment system and the frequency;
- identification of reporting requirements for internal management and regulatory agencies; and
- description of contingency plans to address any problems associated with the treatment system.

Consideration should be given to the implementation of a passive treatment system. In some cases, these systems may have lower maintenance requirements than traditional treatment systems, although all systems do require some degree of ongoing maintenance.

Where there is a need for long-term treatment of wastewater from mines during mine closure and post closure, a long-term treatment plan should be developed. Due to changes in wastewater volume and possible changes in the chemical composition of wastewater after the end of the mine operations phase, treatment systems in place during mine operations may not be appropriate during mine closure and post closure.

4.5.9 MINE SITE REHABILITATION AND REVEGETATION

R 533: Post-closure landscapes should be designed in a manner consistent with the objectives of mine closure and the intended post-closure use of the site.

R 534: In re-establishing soil cover on the site, consideration should be given to the characteristics of the soil that will be used as well as the soil requirements of the vegetation to be established on the site. Where possible, overburden that was stripped and stockpiled earlier in the mine life cycle should be used in the development of the reclamation surface. If this is not possible, or if there is insufficient stockpiled overburden, soil from a local source should be used to ensure similar soil conditions and avoid the importing of non-native seeds.

R 535: Species used in revegetation and the resulting plant community should be consistent with the goals of mine closure and the intended post-closure use of the site. Species native to the area around the mine site should be used for this purpose, and invasive species should never be used.

Rehabilitation and revegetation efforts should ensure that the mine site returns to a productive and self-sustaining ecosystem. The resulting ecosystem could resemble the pre-mining land use or an alternative but equally beneficial land use.

4.5.10 MONITORING

R 536: Monitoring programs should be designed and implemented during mine closure to ensure that closure activities and any associated environmental effects are consistent with those predicted in the closure plan and to ensure that the objectives of mine closure are being met. Monitoring activities should include many of the monitoring activities conducted during the mine operations phase. Monitoring of aquatic and terrestrial ecosystems should continue until all work associated with mine closure is complete. Monitoring should also be conducted post closure to ensure that closure and rehabilitation measures are functioning as designed in accordance with applicable regulatory requirements.

Monitoring during the mine closure phase is essential to demonstrate compliance with the targeted end land use and to determine whether the use is self-sustaining.

GLOSSARY OF TERMS

A

Acid: A substance containing hydrogen; when this substance is dissolved in water, it tends to provide hydrogen ions (protons). Or a substance having a tendency to lose protons.

Acidic drainage: Acidic water (and possibly water that contains metal(s)) resulting from the chemical weathering of rock or soil material primarily caused by the oxidation of sulphide minerals. Also referred to as acid mine drainage (AMD) or acid rock drainage (ARD).

B

Base metals: Industrial non-ferrous (non-iron) metals excluding precious metals.

Bulk sampling: A method whereby a sample (also called a gross sample) is taken from a *deposit* lot for analysis. The bulk sample is intended to be representative of the deposit.

C

Concentrate: The clean or final *ore* product recovered in the concentration or separation stage of the milling process.

Contaminant: Any physical, chemical or biological substance that is introduced into the environment. Does not imply an effect. Usually refers to substances of anthropogenic origin.

Cyanidation: A method of extracting exposed gold or silver grains from crushed or ground *ore* by dissolving it in a weak *cyanide* solution. May be carried out in tanks inside a *mill* or in heaps of ore out of doors.

Cyanide: A chemical inorganic salt of hydrocyanic acid (HCN) used in the milling process to dissolve precious metals such as gold and silver.

D

Deposit: *Mineral* deposit or *ore* deposit used to designate a natural occurrence of a useful mineral, or an ore, in sufficient extent and degree of concentration to invite exploitation.

Dissolution: The process of dissolving a solid substance into a solvent to yield a solution (a stage in *leaching*).

E

Ecosystem: A dynamic complex of plant, animals and microorganism communities and their non-living environment interacting as a functional unit.

Effluent: A complex waste material that is a by-product of human activity (i.e., liquid industrial discharge or sewage) and is discharged to the environment.

Exploration: Prospecting, sampling, mapping, diamond drilling and other work involved in searching for *ore*. In some cases exploratory mining is conducted in which small-scale mining activities are carried out to study potential ore *deposits*.

F

Flotation: A *milling* process in which valuable *mineral* particles are induced to become attached to bubbles and float as others sink.

G

Geochemistry: The study of the chemical properties of rocks.

Geology: The science concerned with the study of the rocks that compose the Earth.

Gypsum: A hydrated calcium sulphate mineral ($CaSO_4 \cdot 2H_2O$).

H

Habitat: A geographic area that can provide for the key activities of life.

Heavy metal: Metallic elements with relatively high atomic weights (> 5.0 specific gravity) such as lead, cadmium, arsenic and mercury. Generally toxic in relatively low concentrations to plant and animal life.

Hydrometallurgy: A branch of extractive metallurgy that involves the use of aqueous chemistry for the recovery of metals from *ores*, concentrates, and recycled or residual materials (*leaching* is a sub-process.)

L

Leaching: A chemical process for the extraction of valuable *minerals* from *ore*. Also, a natural process by which groundwaters dissolve minerals, thus leaving the rock with a smaller proportion of some of the minerals than it contained originally.

Liquefaction: The behaviour of sediments that, when loaded, suddenly go from a solid state to a liquefied state. Or having the consistency of a heavy liquid.

M

Mill: A facility in which *ore* is treated and metals are recovered or prepared for *smelting*. Also, a revolving drum used for the grinding of ores in preparation for treatment.

Milling: The part of the mining process by which *minerals* of economic value are recovered by crushing and grinding *ore*, by ore separation or concentration, and by dewatering the ore. The objective of milling is to separate minerals of economic value from the rock in which they occur.

Mineral: A naturally occurring homogeneous substance having definite physical properties and chemical composition and, if formed under favourable conditions, a definite crystal form.

Mining: Excavation for the purpose of extracting valuable *minerals* from an economic *ore deposit*. Can be a surface or *open pit mine* or an underground mine.

N

Nutrient: A substance, element or compound necessary for the growth and development of plants and animals.

O

Open pit mining: Term used to differentiate this form of mining from extractive methods that require tunnelling into the earth. Open pit mines are used when deposits are found near the surface, where the *overburden* is relatively thin or the material of interest is structurally unsuitable for tunnelling. Also commonly referred to as strip mining.

Ore: A natural *mineral deposit* in which at least one mineral occurs in sufficient concentrations to make mining the mineral economically feasible.

Overburden: Generally means the material overlying the *ore deposit*, including rock as well as soil and other unconsolidated (loose) materials. For this document, the term overburden is restricted to unconsolidated materials, including soil, glacial deposits, sand, and sediment.

Oxidation: A chemical reaction in which electrons are lost from an atom and the charge of the atom becomes more positive. Normally, oxidation involves the addition of atmospheric oxygen or water. Oxidation occurs concurrently with *reduction*.

Oxide minerals: A group of minerals whose fundamental unit is oxygen, O^{-2}. The common cations in oxides include Cu^{+2}, Mg^{+2}, Al^{+3}, Fe^{+2}, Mn^{+2}, Ti^{+2}, Cr^{+2} and Sn^{+2}.

Oxides: See *Oxide minerals*.

P

pH: A measure of the acidity or alkalinity of water, *sediment* or soil. The measure is based on the concentration of hydrogen ions and gives the negative logarithm of the hydrogen (H^+) ion, corresponding to 10^{-7}. A pH value of 7 is neutral. All values higher are considered alkaline, and all values lower are considered acidic.

Permafrost: Soil at or below 0°C for two or more years. Here there is not sufficient heat during the warming months to thaw the frozen soil completely. Ice may or may not be present. The **active layer** is the top layer of soil that thaws during the summer and freezes again during the autumn. Liquid water cannot flow below the active layer, with the result that permafrost environments tend to be very poorly drained and boggy.

Precipitation: The condensation of a solid from a solution (a stage in the *leaching* process).

Pyrometallurgy: A branch of extractive metallurgy consisting of the thermal treatment of *minerals* and metallurgical *ores* and *concentrates* to bring about physical and chemical transformations in the materials to enable the valuable metals to be recovered (*smelting* is a sub-process).

R

Reclamation: The process by which lands disturbed as a result of mining activity are returned to a beneficial land use. Reclamation activity may include the removal of buildings, equipment, machinery, other physical remnants of mining, closure of *tailings* impoundments, leach pads and other mine features, and contouring, covering and revegetating waste rock piles and other disturbed areas.

Reduction: A chemical reaction in which electrons are gained by an atom and its charge becomes more negative. Reduction occurs concurrently with *oxidation*.

S

Sediment: Solid fragmental material that originates from weathering of rocks and is transported or deposited by air, water or ice, or that accumulated by other processes, such as chemical *precipitation* from solution or secretion by organisms. The term is usually applied to material held in suspension in water or recently deposited from suspension and to all kinds of deposits, essentially of unconsolidated materials.

Slurry: A fluid mixture of liquids and solids.

Smelting: A sub-process of *pyrometallurgy*; its main use is to produce a metal from its *ore*. This includes the extraction of iron from iron ore (for the production of steel) and the extraction of copper and other base metals from their ores. Smelting uses heat and a chemical reducing agent, commonly a fuel that is a source of carbon such as coke, to change the *oxidation* state of the metal ore. The carbon or carbon monoxide derived from it removes oxygen from the ore, leaving just the metal.

Species: A group of plants, animals or microorganisms that have a high degree of similarity and generally can interbreed only among themselves.

Sulphate mineral: A mineral characterized by the bonding of a sulphate anion with a metal such as barium, calcium, lead or copper. Sulphates may or may not include water in their structure. Common examples include barite ($BaSO_4$) and *gypsum* ($CaSO_4 \cdot 2H_2O$).

Sulphates: See *Sulphate mineral*.

Sulphide mineral: A metallic *mineral* characterized by the covalent bonding of sulphur with a metal or semi-metal, such as iron, copper, lead, zinc, nickel or molybdenum. An example of a common sulphide mineral is pyrite, which has the chemical formula FeS_2. Sulphide minerals occur in a wide range of geological environments. When occurring in sufficient concentrations, sulphide minerals can be important *ore* minerals for a range of *base metals*, including copper, lead, zinc and nickel.

Sulphides: See *Sulphide mineral*.

Suspended solids: A solid substance present in water in an undissolved state, usually contributing directly to turbidity.

T

Tailings: The waste material and water mixture that is left over after the *mill* removes the valuable rocks. The rock material in tailings is usually the size of sand grains or smaller.

Tailings Management Facility: All components and facilities functionally pertaining to tailings management, including dams, spillways, decant structures, tailings lines, as well as settling and polishing ponds.

Toxicity: The inherent potential or capacity of a material to act on a group of selected organisms, under defined conditions. An aquatic *toxicity test* usually measures the proportion of organisms affected by their exposure to specific concentrations of chemical, effluent, elutriate, leachate, or receiving water.

Toxicity test: The means by which the *toxicity* of a chemical or other test material is determined. A toxicity test is used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical).

Trench: A long, narrow excavation dug through *overburden*, or blasted out of rock, to expose a vein or *ore* structure.

W

Waste rock: Rock which does not contain any *minerals* in sufficient concentration to be considered *ore*, but which must be removed in the mining process to provide access to the ore.

Wastewater: Any water that has been adversely affected in quality by anthropogenic influence. In the case of operations at a mine or *mill* site, wastewater includes all water generated as part of a process prior to discharge as an *effluent*, including any mine and site runoff water. **Domestic wastewater** refers specifically to wastewater from non-industrial sources such as laundry and other wash water and sewage.

Water body: Any significant accumulation of water, including oceans, seas, lakes, ponds, *wetlands*, rivers, streams, canals, and other geographical features where water moves from one place to another.

Wetlands: *Habitats* where the influence of surface or groundwater has resulted in the development of plant or animal communities adapted to such aquatic or intermittently wet conditions. Wetlands include tidal flats, shallow subtidal areas, swamps, marshes, wet meadows, bogs, muskeg, and similar areas.

ADDITIONAL RESOURCES

Note: When available, Internet links to the resources below have been provided. These links were active as of the date of publication of the Code.

GOVERNMENT OF CANADA

ENVIRONMENT CANADA

An Approach to Assessing Risk to Terrestrial Biodiversity in Canada. Environment Canada. 1999.
http://www.ec.gc.ca/soer-ree/English/SOER/biodiversity.pdf

Best Practices for the Use and Storage of Chloride-Based Dust Suppressants. Environment Canada. 2007.
http://www.ec.gc.ca/nopp/roadsalt/reports/chlorideBP/en/ChlorideBPe.pdf

Environmental Code of Practice for Base Metals Smelters and Refineries: Code of Practice, Canadian Environmental Protection Act, 1999. Environment Canada. 2006.
http://www.ec.gc.ca/CEPARegistry/documents/code/smelters/BMS_CP_E.pdf

Federal Policy Discussion Paper: Critical Habitat. Environment Canada. 2004.
http://www.sararegistry.gc.ca/virtual_sara/files/policies/Critical%20Habitat%20Discussion%20Paper%5Fe%2Epdf

Federal Policy Discussion Paper: Residence. Environment Canada. 2004.
http://www.sararegistry.gc.ca/virtual_sara/files/policies/residence%5Fpolicy%5Fe%2Epdf

Final Report of the Assessment of the Aquatic Effects of Mining in Canada (AQUAMIN). AQUAMIN Steering Committee. 1996.
http://www.ec.gc.ca/esee-eem/Default.asp?lang=En&n=70B3C237-1

Guidance Document for Flow Measurement of Metal Mining Effluents. Environment Canada. 2002.
http://www.ec.gc.ca/nopp/docs/regs/mmer/download/MMER_Flow_En.pdf

Guidance Document for the Sampling and Analysis of Metal Mining Effluents. Environment Canada. 2002.
http://www.ec.gc.ca/nopp/docs/regs/mmer/download/MMER_Sampling_En.pdf

Guidance Document: Off-Road Compression-Ignition Engine Emission Regulations under the Canadian Environmental Protection Act, 1999. Environment Canada. 2006.
http://www.ec.gc.ca/CEPARegistry/documents/regs/orcieeg_GD/orcieeg_GD_e.pdf

Guidelines for the Implementation of the Pollution Prevention Planning Provisions of Part 4 of the Canadian Environmental Protection Act, 1999 (CEPA 1999). Environment Canada. 2002.
http://www.ec.gc.ca/planp2-p2plan/default.asp?lang=En&n=47D71451-1

Implementation Guidelines for Part 8 of the Canadian Environmental Protection Act, 1999 – Environmental Emergency Plans. Environment Canada. 2004.
http://www.ec.gc.ca/CEPARegistry/guidelines/impl_guid/toc.cfm

Metal Mining Guidance document for Aquatic Environmental Effects Monitoring. 2002.
http://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=D450E00E-1

Canadian Environmental Assessment Agency

Reference Guide: Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects. Canadian Environmental Assessment Agency. 2003.
http://www.acee.gc.ca/013/0001/0008/guide3_e.htm

Fisheries and Oceans Canada

Guidelines for the Use of Explosives in or near Canadian Fisheries Waters. Department of Fisheries and Oceans. 1998.
http://www.dfo-mpo.gc.ca/oceans-habitat/habitat/water-eau/explosives-explosifs/index_e.asp

Operational Statements. Fisheries and Oceans Canada. 2007.
http://www.dfo-mpo.gc.ca/oceans-habitat/habitat/modernizing-moderniser/epmp-pmpe/index_e.asp?#intro

Policy for the Management of Fish Habitat. Department of Fisheries and Oceans. 1986.
http://www.dfo-mpo.gc.ca/oceans-habitat/habitat/policies-politique/management-gestion_e.asp

Indian and Northern Affairs Canada

Mine Site Reclamation Guidelines for the Northwest Territories. Indian and Northern Affairs Canada. 2006.
http://www.mveirb.nt.ca/upload/project_document/1171399596_Reclamation_Guidelines_2006_revised.pdf

Mine Site Reclamation Policy for the Northwest Territories. Indian and Northern Affairs Canada. 2002.
http://www.ainc-inac.gc.ca/nth/mm/pubs/recpolnwt/recpolnwt-eng.pdf

Mine Site Reclamation Policy for Nunavut. Indian and Northern Affairs Canada. 2002.
http://www.ainc-inac.gc.ca/nth/mm/pubs/recpolnuna/recpolnuna-eng.pdf

Natural Resources Canada

NOTE: See also the separate listing below for publications of the Mine Environmental Neutral Drainage (MEND) Program

Climate Change Impacts and Adaptation: A Canadian Perspective. Natural Resources Canada. 2004.
http://adaptation.nrcan.gc.ca/perspective/pdf/report_e.pdf

Mining Information Kit for Aboriginal Communities. Natural Resources Canada. 2006.
http://www.pdac.ca/pdac/advocacy/aboriginal-affairs/2006-mining-toolkit-eng.pdf

Health Canada

The Canadian Handbook on Health Impact Assessment, Volume 4: Health Impacts by Industry Sector. Health Canada. 2004.
http://www.hc-sc.gc.ca/ewh-semt/pubs/eval/handbook-guide/vol_4/index_e.html

Laws and Regulations

Canadian Environmental Assessment Act. Statutes of Canada 1992, chapter 37.
http://laws.justice.gc.ca/en/C-15.2/

Canadian Environmental Protection Act, *1999*. *Statutes of Canada* 1999, chapter 33.
http://www.ec.gc.ca/CEPARegistry/the_act/

Environmental Emergency Regulations. *Statutory Orders and Regulations* 2003-307.
http://laws.justice.gc.ca/en/showdoc/cr/SOR-2003-307//20090223/en?command=home&caller=SI&search_type=all&shorttitle=environmental&day=23&month=2&year=2009&search_domain=cr&showall=L&statuteyear=all&lengthannual=50&length=50

Fisheries Act. *Revised Statutes of Canada* 1985, chapter F-14.
http://laws.justice.gc.ca/en/F-14/index.html

Metal Mining Effluent Regulations. *Statutory Orders and Regulations* 2002-222.
http://laws.justice.gc.ca/en/F-14/SOR-2002-222/

Species at Risk Act. *Statutes of Canada* 2002, chapter 29.
http://laws.justice.gc.ca/en/S-15.3/index.html

PROVINCIAL, TERRITORIAL AND MUNICIPAL GOVERNMENTS

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Detailed documentation is available at
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ISO 19011: Guidelines for Quality and/or Environmental Management Systems Auditing. International Organization for Standardization. Detailed documentation is available for purchase from
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Canadian Dam Association

NOTE: The following document outlines the principles of the Dam Safety Guidelines. Detailed documentation is available for purchase from the Canadian Dam Association
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Detailed documentation on environmental standards, including standards for environmental management and environmental technology, is available for purchase from
http://www.csa-intl.org/onlinestore/GetCatalogDrillDown.asp?Parent=6

International Commission on Large Dams (ICOLD)

NOTE: The International Commission on Large Dams has a large number of technical publications related to all aspects of dam design, construction, operation, monitoring and maintenance, including those listed below. These documents are available for purchase at
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http://www.goodpracticemining.org/

PUBLICATIONS OF THE MINE ENVIRONMENT NEUTRAL DRAINAGE (MEND) PROGRAM

A complete list of all publications of the MEND Program is provided in Appendix 1. With the exception of the document listed below, MEND publications are available for purchase from the MEND website at
http://www.nrcan-rncan.gc.ca/com/resoress/pubpub-eng.php

List of Potential Information Requirements in Metal Leaching and Acid Rock Drainage Assessment and Mitigation. 2005. MEND.

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* available on MEND 7.3 CD-1 ** available on MEND 7.4 CD-2 *** available on MEND 7.5 CD-3

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IW.06 — Bonding and Security***

IW.07 — Waste Rock and Tailings Disposal Technologies

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